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# PRODUCTIVITY GROWTH OF THE NON-TRADABLE SECTORS IN CHINA

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## Abstract

Little is known about the total factor productivity of the non-tradable sectors in China. In this paper we estimate productivity growth of the non-tradable sectors by studying the relative price movements of the non-tradable sectors vis-à-vis the tradable sectors, i.e. changes in the internal real exchange rate. We find that prices of the non-tradable sectors have risen significantly faster than those of the tradable sectors, and China's internal real exchange rate has appreciated at a faster pace than the renminbi real effective exchange rate. We also find the non-tradable sectors have seen much lower productivity growth than the tradable sectors, and such productivity differentials are large when compared to other economies. We argue that if productivity growth in the non-tradable sectors remains slow, China will likely see more difficulty in rebalancing its growth pattern and higher inflationary pressures in the medium term. As such, it is important for the authorities to take policy actions to raise productivity growth in the non-tradable sectors.

Keywords: Tradable and Non-Tradable Sectors, Internal Real Exchange Rate, Total Factor Productivity
JEL Classification: E31, F31, F43

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# 1. Introduction

Productivity matters a great deal for an economy's growth, inflation and hence household welfare. While productivity of manufacturing has been studied for about two hundred years, that of the non-tradable sectors, which mainly consist of services, did not receive much attention until the middle of the 1990s. It is widely known that productivity of the service sector cannot be estimated with the methodologies for the manufacturing sector. First of all, it is difficult to quantify inputs and outputs in the service sector. Intangible elements, including information technologies and even customers' participation and service culture, are critical for the productivity of the service sector, whereas tangible elements such as materials and machines appear to be less important. Second, inputs and outputs in the service sector are highly heterogeneous and may not be measured with one common methodology. As pointed out by Triplett and Bosworth (2000), each individual service industry has specific measurement problems unique to the characteristics of its inputs and outputs. For example, the measures of inputs and outputs for healthcare could differ a lot from those of banking services.

Little is known about productivity of the non-tradable sectors in Mainland China (henceforth China), not only because of the above-mentioned general difficulties, but also due to the availability of data on output and employment for the service sector. It is generally understood that China's service output has likely been underestimated (Wang et al. 2010), while employment data is problematic, particularly for those years of deep structural reforms. Against this background, we estimate productivity (total factor productivity, TFP) growth of the non-tradable sectors indirectly. We derive TFP growth in the non-tradable sectors using the relationship between the internal real exchange rate (IRER, price of non-tradable goods relative to tradable goods) and productivity differentials between the tradable and non-tradable sectors (Rogoff and Obstfeld, 1996). The real exchange rate behaviour and its relationship with productivity growth have long been a research interest in international economics, as real exchange rate movement could result in changes in inflation and international trade, and trigger policy reactions both domestically and internationally. To name a few, Canzoneri et al. (1997) show that the productivity differentials are co-integrated one-for-one with the relative price of non-tradable goods to tradable goods, and Strauss (1999) uses various econometric techniques and demonstrates that the increases in the domestic relative prices of non-tradable goods are associated with the appreciation of real and nominal exchange rates, and hence may explain persistent deviations in the Purchasing Power Parity (PPP).

Productivity growth in the non-tradable sectors has important implications for growth and inflation in the medium term. As laid out in the 12$^{th}$ five-year plan, the Chinese government has pledged to rebalance the growth pattern by promoting domestic final demand and developing the service sector. This is because the on-going growth model, which depends greatly on investment and exports, is likely to be unsustainable. For instance, the savings rate is set to decline with population ageing, while exports will face some headwinds given the subdued growth in the advanced economies. Whether household consumption will grow more quickly depends largely upon the degree to which consumption of services rises. Private consumption of manufacturing products in China has been largely commensurate with the level of its per capita income, while the penetration of services has been much lower (Ma and Lu, 2010). On the other hand, in order to boost household consumption, it is necessary to increase the share of labour income in total output. Developing the service sector is undoubtedly an important channel to achieve this target since services are, on the whole, more labour-intensive than manufacturing. Whether China can successfully rebalance its growth pattern hinges not only on the government's efforts to expand the investment in services, but also on the productivity of this sector since productivity growth is the basis for improvements in real income.

Productivity growth in the non-tradable sectors also matters for China's medium-term inflation. Numerous factors point to higher inflation going forward (Zhang 2011, for instance). In particular, the declining trend of labour forces growth and a slowdown in labour transfer from rural areas to urban areas could lead to persistent wage pressures. For instance, using survey data from the China Household Income Project, Knight et al. (2010) project that the pool of migrant workers from rural areas will keep shrinking at a rapid pace until 2020.[1] Indeed, increasing wage pressures have been observed and will likely prevail in the medium term. Using data from the Urban Household Surveys conducted by the National Bureau of Statistics, Ge and Yang (2010) find that over one-third of urban wage increases come from a growing base wage, although schooling and skill premium have also contributed to more than one-third of overall wage increase. However, the extent to which wage increases will add to inflationary pressures depends largely on the future growth of labour productivity, particularly in the service sector. If growth of labour productivity in the service sector is high enough to absorb the increase in unit labour costs, wage pressures should not generate much impact on inflation. As TFP growth is a component of labour productivity growth (the other component is capital deepening), higher TFP growth in the service sector points to lower inflationary pressures accordingly.

Our research shows that prices in China's non-tradable sectors have increased at a much faster pace than the tradable goods prices in the past decade, indicating a significant appreciation in the IRER. The external competitiveness measured with the PPP-based real exchange rate has worsened less than suggested by the IRER, partly because the nominal effective exchange rate of the renminbi depreciated before 2005 and only appreciated at a gradual pace afterwards. Our analysis further shows that productivity growth in the tradable sectors was higher in the first half than the second half of the past decade, partly reflecting the gradual fading of the positive impact from entry into the World Trade Organization (WTO). Productivity growth in the non-tradable sectors also declined in the second half of the decade, to an even greater extent than in the tradable sectors. Overall, productivity growth in the non-tradable sectors has been notably lower than that in the tradable sector. This could be due to a number of factors, including the lack of sufficient competition in the service sector, particularly in those areas where large state-owned firms dominate the market.

[1] Their result is in line with other projections such as Cai (2008) and Park et al. (2008).

The rest of the paper is organized as follows. Section two introduces the model we use to estimate TFP growth in the non-tradable sectors. Section three compiles tradable and non-tradable sector price indexes, and estimates the changes in the internal real exchange rate. Section four estimates productivity growth in the tradable sectors using two approaches that complement each other, and derives productivity growth in the non-tradable sectors accordingly. Section five discusses policy implications, and Section six concludes the paper.

## 2. The Model to Estimate Productivity Growth in the Non-Tradable Sector

We estimate productivity growth in the non-tradable sectors indirectly based on the relationship between the IRER and productivity differentials of the tradable and non-tradable sectors. Suppose the economy can be split as a tradable and a non-tradable sector with a homogeneous production function of $f(.)$ and $g(.)$ respectively using capital and labour as inputs. Let $k_T$ ($k_N$) be the capital labour ratio, $w_T$ ($w_N$) the nominal wage of the tradable (non-tradable) sector, and $r$ the world interest rate in terms of tradable goods, then under perfect foresight and perfect capital mobility, the first order conditions, combined with the zero profit condition, yield

$$A_T f(k_T) = rk_T + w_T \quad (1)$$

$$\tilde{q}\, A_N g(k_N) = rk_N + w_N \quad (2)$$

where $\tilde{q}$ is the relative price of domestic non-tradable goods to domestic tradable goods (IRER), and $A_T$ and $A_N$ are TFP in the tradable and non-tradable sectors, respectively. Static analysis with respect to $A$, $k$ and $w$ after taking log-difference of these two equations yields ($f'(k) = rk$, with $r$ being internationally given)

$$\hat{A}_T + \frac{rk_T}{A_T f(k_T)}\hat{k}_T = \frac{rk_T}{A_T f(k_T)}\hat{k}_T + \frac{w_T}{A_T f(k_T)}\hat{w}_T \quad (3)$$

$$\hat{\tilde{q}} + \hat{A}_N + \frac{rk_N}{A_N g(k_N)}\hat{k}_N = \frac{rk_N}{A_N g(k_N)}\hat{k}_N + \frac{w_N}{A_N g(k_N)}\hat{w}_N \quad (4)$$

Let $s_T = \dfrac{w_T}{A_T f(k_T)}$, $s_N = \dfrac{w_N}{A_N g(k_N)}$ be the respective share of labour income in the total output of the tradable and non-tradable sectors, and $m = \dfrac{\hat{w}_N}{\hat{w}_T}$ the relative wage growth of the non-tradable sector, then the change in the IRER reads[2]

$$\hat{\hat{q}} = m \frac{s_N}{s_T} \hat{A}_T - \hat{A}_N \quad (5)$$

Obviously, once other variables in equation (5) are known, the TFP growth of the non-tradable sector ($\hat{A}_N$) can be estimated accordingly. As pointed out by Anderson (2008), although the state share is still sizeable in China's economy, it has become a much more fundamentally market-oriented economy in the past decade. This suggests it is reasonable to apply the above equation to the Mainland economy.[3]

# 3. Price Indexes of the Tradable and Non-Tradable Sectors and Internal Real Exchange Rate

We use two criteria to identify tradable goods and non-tradable goods following the literature. The first criterion follows De Gregorio (1994) and Engel (1999), with tradability of a sector being measured as the share of exports of each sector to its gross output. A sector is specified as tradable when the ratio of exports to gross output is higher than 10%. The second criterion follows Bems (2008) who defines the tradability of a sector as the ratio of total trade (imports plus exports) to its gross output. A sector is defined as tradable if its tradability is higher than that of the retail and wholesale sector (a benchmark non-tradable sector in the literature). We calculate each sector's tradability by using the input-output (IO) tables of 2002 and 2007. We find that for most sectors, the two methodologies have the same results, with no changes in 2007 from 2002, see Table A1 in the appendix for details. There are two points meriting attention, however. First, the sectors for which no price data is available (finance and insurance, for instance) are excluded in our estimation. Second, those sectors, which are closely related to natural endowments, including oil exploration, mineral or non-mineral exploration,

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2 $\hat{\hat{q}} = \pi_N - \pi_T$, with $\pi_N$ and $\pi_T$ being the year-on-year price changes of tradable and non-tradable goods respectively.

3 Note that this framework already implies labour market friction in the presence of the wage differential *m*. Equation (5) is still valid under imperfect international capital mobility, as long as the spread between the international and domestic interest rates remains stable. A closed form solution is available under imperfect inter-sectoral capital mobility, as long as we assume that there exist two distinct goods in the tradable sector. The relationship between the internal real exchange rate and productivity differentials then becomes $\hat{\hat{q}} = [n + (m - n)u_{LN}]\hat{A}_T - \hat{A}_N$, where *n* is the growth rate of the interest rate in the non-tradable sector relative to that in the tradable sector. This solution implies that both factor prices rise at the rate of the tradable productivity growth, $\hat{A}_T$. However, to gauge *n* requires estimating non-tradable stock $k_N$, which is what we would like to bypass here. Therefore we will not discuss this scenario further and stick to Equation (5) for productivity estimation in the following section.

are also excluded because their output is mainly determined by natural endowments and has little to do with productivity. The consolidated tradable and non-tradable sectors are listed in Table 1.

We compile the price indexes for the two sectors using the production-based approach because it has a much broader coverage than the consumption-based approach. There are different methodologies to compile tradable and non-tradable goods price indexes in the literature. Strauss (1999), for instance, takes the manufacturing goods component in the CPI as the tradable goods price index, while the rest of the CPI basket is taken as the non-tradable goods price index. Engel (1999) uses various methodologies to compile tradable and non-tradable goods price indexes. In one case he uses aggregate PPI inflation as tradable goods price inflation, and defines the non-tradable goods price inflation as the differential between CPI inflation and PPI inflation. De Gregorio et al. (1994) use the OECD's international sectoral database for 20 sectors to compile tradable and non-tradable goods price indexes. As no data is available for sectoral price indexes on the production base for China, we compile the price indexes for tradable and non-tradable goods price indexes ourselves.

The methodology to compile the tradable and non-tradable sector price indexes is similar to that used by the National Bureau of Statistics (NBS) in compiling the CPI. We first compile a month-on-month price index (i.e., the gross month-on-month price change) for each product, and then aggregate those price indexes into price indexes of corresponding categories with the geometric mean.[4] The price indexes of these categories are further aggregated into price indexes of relevant sectors by using the geometric mean. For example, the sector "Metal smelting and pressing" includes five categories, namely, "Steel", "Copper", "Aluminium", "Zinc", and "Nickel". The category "Steel" includes nine goods (i.e., product items), "Zinc" and "Nickel" categories each include two goods, and the categories of "Copper" and "Aluminium" each include only one good. The price index for the sector "Metal smelting and pressing" is the geometric mean of the price indexes of the five categories. The month-on-month price indexes for tradable and non-tradable goods, $\hat{p}_T$ and $\hat{p}_N$, are then measured by the weighted arithmetic mean of relevant sub-sector price indexes, i.e.,

$$\hat{p}_T = w_{T1}\hat{p}_1^T + w_{T2}\hat{p}_2^T + \ldots + w_{TJ}\hat{p}_J^T \tag{6}$$

$$\hat{p}_N = w_{N1}\hat{p}_1^N + w_{N2}\hat{p}_2^N + \ldots + w_{NK}\hat{p}_K^N \tag{7}$$

where $\hat{p}_j^T$ *(j=1,2,…, J)* and $\hat{p}_k^N$ *(k=1,2,…, K)* are sub-sector price indexes for tradable and non-tradable sectors respectively, with $w_{Tj}$ *(j=1,2,…, J)* and $w_{Nk}$ *(k=1,2,…,K)* as their weights. Here the shares of each sub-sector's value added in the relevant sector's total value added based on 2002 and 2007 IO tables are used as the corresponding weights for periods 2001-2005 and 2006-1010 respectively. The year-on-year price changes of the tradable and non-tradable sectors ($\pi_N$ and $\pi_T$) can be derived from the month-on-month price indexes.

4 If a category has only one good in the sample, then the category price index is the same as the good price index.

Monthly data for tradable and non-tradable goods prices are mainly from the CEIC database and cover the period of 2000-2010. These data are originally in levels and are converted into month-on-month and year-on-year price changes. Data for sectors including textile, computer and communication equipment, generalized and specialized equipment, and electronic machinery and equipment are from the WIND database. The original data is in year-on-year growth rates. We convert the data into month-on-month price indexes by assuming the monthly prices in the base year are all equal to 100. One hundred and seventy-eight data series are used to compile the price indexes, out of which 74 series are tradable goods and 104 for non-tradable goods.

Our research shows that the non-tradable goods prices have risen faster than the tradable goods prices on a cumulative basis, but the latter was more volatile than the former (Figures 1-2). During 2001-2010 non-tradable goods prices rose by 82.2%, compared with an increase of 35.2% in the tradable goods prices. In other words, the annual inflation rate of non-tradable goods prices was around 8.2% on average in the past decade, while that of tradable goods prices was about 3.5%. The non-tradable sectors experienced inflation during the whole sample period, while the tradable sector saw deflation in some years, especially right after the eruption of the global financial crisis of 2008-2009. In some years, the non-tradable goods price inflation was lower than the tradable goods price inflation. For instance, in 2004-2005, the non-tradable goods price inflation was lower because it had been more affected by the SARS epidemics than tradable goods prices. The tradable goods prices dropped notably after the global crisis broke out, while the non-tradable goods prices remained stable. Tradable goods prices recovered pretty fast from the crisis, with the gap between tradable inflation and non-tradable price inflation having nearly closed.

The IRER appreciated at a faster pace than the real effective exchange rate (REER) of the renminbi during the past decade. As shown in Figure 3, the IRER appreciated by about 35% on a cumulative basis, compared with the appreciation of 5% in the REER compiled by the Bank for International Settlements (BIS). In particular, the IRER appreciated by 14.3% during 2008-2009, while the REER appreciated by 7.2% over the same period. The two real exchange rates were loosely correlated before 2005 – the IRER followed an appreciation trend while the REER depreciated – but broadly moved in the same direction afterwards.[5]

These findings have important implications as to China's external competitiveness. As discussed in Edwards (1989), the IRER summarises incentives that guide resource allocation across the tradable and non-tradable sectors. An appreciation in the IRER makes the production of non-tradable sector relatively more profitable and induces resources to move out of the tradable sector into the non-tradable sector. This appears to be consistent with what has been observed in China. For example, property prices have increased multi-fold in the past decade and anecdotal evidence suggests that a large part of resources have been used in the real estate sector, with the property sector FAI now accounting for about 20% of total FAI. An appreciation in the IRER indicates a rise in the domestic

[5] The PPP-based REER was compiled based on CPI inflation in China and its trading partners, while the IRER was constructed using the production-based approach. This can also be a reason for differences between the two series.

cost of producing tradable goods and implies a weakening in the economy's international competitiveness if there are no changes in relative prices in the rest of world.

The impact of the changes in the IRER on China's external competitiveness should be clearer by looking at the relationship between the IRER and the REER. By definition, the PPP-based REER can be decomposed into three parts: the law-of-one-price condition for tradable goods, the IRER, and the foreign economy's IRER:

$$q_{REER} = \alpha(p_N - p_T) - (p_T^* - p_T - e) - \alpha^*(p_N^* - p_T^*) \quad (8)$$

where $q_{REER}$ denotes the log of the REER, $p_N$ denotes the log of domestic non-tradable goods price, $p_T$ denotes the log of domestic tradable goods price, $e$ denotes the log of the nominal effective exchange rate (NEER), and $\alpha$ is the share of non-tradable goods price in the aggregate price of the economy. The "*" represents the foreign economy. The above equation indicates that an economy's external competitiveness is not only affected by its own IRER but also by the price of domestic tradable goods relative to foreign tradable goods, nominal exchange rate, as well as the foreign economy's IRER. In particular, if the law-of-one-price condition holds for tradable goods, and the IRER in the foreign economy remains stable, then the REER changes should be fully explained by the changes in the IRER.

The impact of the IRER on China's external competitiveness has been partly mitigated by the slower appreciation in the renminbi nominal exchange rate. As shown in Figure 3, the NEER of the renminbi depreciated before 2005 alongside the weakening of the US dollar against major currencies and has only appreciated at a gradual pace afterwards. In addition, China's tradable goods prices have remained competitive relative to its major trading partners, which helped it to maintain its external competitiveness.[6] While low costs of materials, energies, land and taxation for tradable goods helped China maintain its price competitiveness in tradable goods, lower entry barriers to the manufacturing sector and hence sufficient supply (even over supply) have also played an important role.

Looking ahead, continued increases in non-tradable prices could noticeably worsen China's external competitiveness. As the renminbi exchange rate becomes more flexible, the weak US dollar may not necessarily help to offset the impact of an increase in non-tradable goods prices on the REER of the renminbi. Indeed, as shown in Figure 4, the correlation between the two data series using three-year moving windows trended up from negative values in early 2003 to around 0.6 in recent years. The periods with positive and increasing correlation between the two exchange rates coincide with the latest round of renminbi exchange rate reform that first took place between mid-2005 and mid-2008, and resumed in mid-2010. In addition, the adverse impact of rising non-tradable goods prices on

6 See Cui (2011) for example.

China's external competitiveness could be more obvious going forward given that the degree of domestic contents (including domestic services) in China's exports has been increasing with the steady rise of the importance of ordinary exports in China's total exports.[7]

# 4. Estimates of Productivity Growth in the Tradable and Non-Tradable Sectors

We use two methodologies and two data sets to estimate TFP growth in the tradable sectors to form a comprehensive picture of productivity growth in China. The first one is a non-parametric approach (the DEA approach with the Malmquist index) using the sector-level data of value added, capital stock and employment. As is known, conventional methods, which specify a certain production function and assume production is conducted on the frontier, could overestimate the TFP growth as the so-called technical inefficiency is assumed away. In contrast, the DEA approach does not pre-set any production function and instead estimates the frontier with data. The production frontier can change over time, and manufacturers may produce at a point that is less efficient than the frontier. Thus, it can capture both resource-allocation efficiency and technical efficiency and gives a more precise estimate of TFP growth than conventional approaches. Details about this approach can be found in Coelli (1996) and Fare *et al.* (1994), with the Malmquist index being introduced briefly in the appendix. The weakness of this approach is that the data of capital stock and employment are constructed following the relevant literature, and may not be that accurate.

The second approach features more accuracy of data but might over-estimate the productivity growth. It is the so-called control function method using firm-level data of more than 100,000 manufacturing firms each year. These firms are grouped as 29 sectors. The strength of this approach is that the data of capital stock and employment are collected from firms directly by the National Bureau of Statistics, and they are more reliable and accurate than the sector-level data that we compiled. It is also more convenient to use this approach to deal with a large cross-sectional data set. However, a production function is pre-set in this approach, with production assumed to be conducted on the frontier, suggesting it could overestimate the TFP growth as the technical inefficiency is assumed away. The strength and weakness of these approaches suggest that these two methodologies are complementary to each other, and they would give us a more complete picture of productivity growth than only relying upon one single approach.

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7 The share of ordinary exports in China's total exports has been rising in the past decade from about 45% in 2001 to 55% in 2011.

### 4.1 Estimates of Tradable Sector TFP Growth Using the DEA Methodology with Sector-Level Data

We compile sector-level data of value-added, capital stock and employment in the period 2000-2010 according to the relevant literature. The CEIC data base has nominal value added data for sectors in level for 2000-2007, and in growth year on year for 2007-2010. However, the sectors of CEIC in 2002, 2005, and 2007 do not fully match those in the I-O. Therefore, instead of using these CEIC data directly, we use the data of nominal value added in 2002, 2005 and 2007 from the I-O tables, and estimate value-added in other years based on the growth rate data. Real value added in each sector is obtained by deflating nominal value added by the corresponding sector's price inflation.

We follow He et al. (2007) in constructing sector-level capital stock. Aggregate capital stock data for the years 2000-2005 is taken from He et al. (2007) directly, while that for 2006-2010 we construct aggregate capital stock using their methodology. Assuming the ratio of each sector's capital stock to aggregate capital stock is the same as the ratio of the corresponding sector's urban fixed asset investment (FAI) to total urban FAI, we get the estimate for each sector's capital stock. Finally, we estimate the sector-level labour by multiplying national employment in the secondary industry with the share of urban employment in each sector in total urban employment in the secondary industry. According to the official statistics, employment in the secondary industry decreased in 2002, partly reflecting an underestimate of employment in the non-SOEs. Therefore, we adjust the employment of the secondary industry in 2002 following Wang et al. (2007). Employment in the secondary industry in subsequent years is then calculated based upon the annual employment growth rate from the official employment statistics.

Our research shows that most tradable sectors saw higher TFP growth in the first half of the past decade than in the second half (Table 2). Aggregate TFP growth of the tradable sector is 4.9% for 2001-2010, 5.7% for 2001-2005, and 4.2% for 2006-2010. The higher TFP growth in the first five years may partly reflect the impact of the entry into the WTO in 2001, which increased the openness of the Mainland economy, and helped promote its manufacturing sector's productivity growth. The impact of the WTO entry has likely faded over time. Metal smelting and pressing, computer and communication equipment, transportation equipment, and non-metallic mineral products had the highest TFP growth in the past decade, while clothes, electronic machinery and equipments, chemicals, and general purpose machinery had relatively lower TFP growth over the same period.

### 4.2 TFP Growth in the Non-Tradable Sectors

The share of labour income in total output was higher for the non-tradable sectors than for the tradable sectors, consistent with the fact that service sectors are in general more labour-intensive than manufacturing. In order to estimate productivity growth in the non-tradable sector with equation (5), we still need to parameterize the share of labour in total output for tradable sector and non-tradable sector, $S_T$ and $S_N$, and the ratio of non-tradable sector's wage growth to tradable sector's wage growth, *m*. $S_T$ and $S_N$ are calculated according to the IO tables of 2002 and 2007, with labour income being adjusted by labour compensation plus part of net taxes on production. As taxes on production include taxes on the labour employed, or compensation of employees paid during the production process, it would be problematic to assign all taxes on production as capital income. Therefore, we allocate part of the taxes on production to labour income and the rest to capital income according to the share of these two items in the sum of labour compensation and capital income. The ratio of $S_N / S_T$ is 1.115 in 2002 and 1.312 in 2007. In the research below we assume the value of $S_N / S_T$ for 2001-2005 is the same as that of 2002, and that for 2006-2010 is the same as that of 2007. However, wage growth in the non-tradable sectors has been slower than the tradable sectors in the past decade. Following Yang et al. (2010) and Ge and Yang (2010), we set *m* at 0.9, suggesting that the wage growth in the non-tradable sectors was around 90 percent of that in the tradable sectors.[8]

We find that productivity growth in the non-tradable sector was much lower than that of the tradable sector (Table 3). It was 3.3% during 2001-2005, 1.4% during 2006-2010, and 2.4% for the whole sample period of 2001-2010.[9] The average annual TFP growth for the whole economy was 4.5% for 2001-2005, 2.8% for 2006-2010 and 3.7% for 2001-2010.[10] It should be noted that there can be great intra-sector heterogeneity for non-tradable sectors, as found in Holz (2006). Specifically, he finds that education had the highest TFP growth during 1979-2002, while financial services had the lowest TFP growth. Overall, he finds tradable sectors' annual TFP growth was 4.12% during 1980-2002, higher than that of non-tradable sectors (2.56%).

### 4.3 Estimates Using the Control Function Method with Firm-Level Data

Two issues should be addressed when using firm-level data to estimate TFP growth. One is the endogeneity problem and the other is the externality problem. Specifically, a firm determines its investment each period to maximize the present value of its lifetime profit flow, given the information such as its productivity level that is known to the firm itself but not available in the data. These unobserved factors can lead to a bias in the coefficient estimates of the production function. For instance, a firm that is very productive will invest more in its physical capital today to prepare itself for future production expansion. At the same time, the firm with a high level of TFP produces a high

8 Studies on other economies (Wagner and Hlouskova, 2004, for instance) show that the value of *m* could change over time. As there is no data for *m* in each year of the sample period, we assume it to be constant in our research. In addition, some economists argue that the value of *m* in some years could be close to unity in China. Against this backdrop, we will undertake some sensitivity analysis by setting it at unity to see to what extent the results of our estimates will change.

9 If *m* is set at unity, we find that non-tradable sectors' TFP growth would be 4.0% for 2001-2005, 1.9% for 2006-2010, and 3.0% for 2001-2010, still notably lower than the TFP growth of the tradable sectors during the corresponding periods.

10 We also conducted the above analysis by compiling tradable and non-tradable goods prices based on household consumption with data from 2000-2010. That is, we just consider tradable and non-tradable goods in the consumption basket. We also find that non-tradable goods prices have increased at a faster pace than tradable goods, but the inflation differentials between the two sectors are smaller than estimated from the production-based approach. As a result, the productivity differentials between the two sectors are also smaller accordingly. As the production-based approach presents a more complete picture than the consumption-based approach, we just report the results obtained from the production-based approach.

output. The TFP level that is captured by regression residual is simultaneously affecting the firm's input and output, causing biases in OLS estimates of the production inputs. We estimate the TFP growth of the tradable sectors in a trans-log production function at the industry level by using the control function approach to avoid the potential endogeneity problem. The control function approach follows Olley and Pakes (1996), Levinsohn and Petrin (2003), and Ackerberg et al. (2006)[11] and can provide consistent and efficient estimates in the presence of an endogeneity problem.

To solve the externality problem, we adjust the contributions from social infrastructural capital stock to TFP growth based on the work of He et al. (2007). Aggregate TFP growth estimated with firm-level data may be overstated because firm-level capital stock does not include infrastructure. Infrastructure fixed asset investment (FAI), which accounted for over 20% of the Mainland's FAI in the past decade, has helped the manufacturing sector to improve its productivity. We adjust the TFP estimates at the firm level by subtracting the contributions by infrastructure capital under the assumption that the magnitude of externalities is the same across sectors. Details on these methodologies are described in the appendix.

Our research using the firm-level data also shows that TFP growth in the non-tradable sectors has been much lower than that of the tradable sectors. The TFP growth in the tradable sector was 5.4% for 2002-2007, and accordingly, the TFP growth for the non-tradable sector was 3.2% over the same period (Table 4). The TFP growth estimated with the control function approach using the firm-level data is 0.8 percentage point higher than that estimated using the DEA approach with sector-level data. This may be due to the assumption that production is conducted on the frontier with technical inefficiency being assumed away, as mentioned earlier.[12] The details of each tradable sector's average annual TFP growth during 2002-2007 are shown in the appendix. While the communication and computer equipment sector has the highest TFP growth, the cultural machinery sector saw the slowest TFP growth.

# 5. Policy Implications

The productivity growth differentials between the tradable and non-tradable sectors in China have been much higher than those of developed economies. It is not surprising to see lower TFP growth in the non-tradable sectors, as pointed out by Obstfeld and Rogoff (1999), due to "its substantial overlap with services, which are inherently less susceptible to standardization and mechanization than are manufacturing and agriculture…", but the relatively large magnitude of productivity differentials merits attention.

[11] The term "control function" originates from the optimal control problem.

[12] Brandt et al. (2010), using firm level manufacturing data without controlling externalities, also find higher tradable TFP growth than using the aggregate data.

As shown in Table 5, China's productivity growth differentials between the two sectors are in line with those of fast-growing emerging economies such as Korea during 1990-1997 before it accelerated service liberalization after the Asian financial crisis. The differentials are substantially higher than those of developed economies such as the US, Japan and EU-15 whose tradable and non-tradable sectors are both much more developed than China. The reason why Thailand and Indonesia have lower productivity differentials than China is that the productivity growth in their tradable sectors has been much lower than that of China's tradable sectors.

Various factors have led to the relatively productivity differentials between the tradable and non-tradable sectors in China. Although globalization makes it easier for the tradable sectors to catch up with their counterparts in the developed economies and thus increases their productivity relative to the non-tradable sectors, structural factors at home have also impeded productivity growth in the non-tradable sectors.[13] While each non-tradable sub-sector could have its own reasons for low productivity, there are some common factors that have led to lower productivity in China's non-tradable sectors on the whole.[14]

First of all, the low productivity growth in the non-tradable sector can partly be attributed to policy orientation. China's export-led growth strategy has benefited the manufacturing sector, while the service sector in general has been under-developed and not considered as a growth engine. Such a policy orientation results in bank credit and capital allocation being skewed towards the tradable sectors and hence higher productivity accordingly.

Secondly, over-regulations have also resulted in low productivity growth in certain non-tradable sub-sectors, such as education and health care, where human capital is a major contributor to productivity growth. It appears to be a common phenomenon that services have been tightly regulated in East Asia (Goswami et al., 2011). Over-regulations not only restrict competition among domestic participants but also deter the entry of overseas corporations that could be innovative. Although progress has been made in opening the Mainland's service sector upon joining the WTO and creating the Closer Economic Partnership Agreement (CEPA) between the Mainland and Hong Kong SAR, the licensing and operating requirements for overseas corporations to enter China's market remain burdensome. As pointed out in Fan (2011), excessive and discriminatory capital requirements continued to restrict foreign participants in industries such as banking, insurance, legal, telecommunications and constructions.[15]

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[13] Besides structural factors, non-tradable productivity growth is also affected by demand side effects, such as in the real estate industry, or by primary input costs, such as in water & electricity & gas, transportation services and, food industry.

[14] For instance, while low productivity in the agriculture sector can be due partly to the existing land allocation system which does not allow free transactions, over-regulation could be a reason for low productivity in healthcare services.

[15] Using a service trade restrictiveness index constructed for various service industries in China, Fan (2009) finds that, while trade barriers in distribution, banking and insurance industries have declined during the past decade, the telecommunication industry remains under tight restrictions. Using a similar index, Gootiiz and Mattoo (2009) find that China belongs to a group of countries with the most restrictive services policies with respect to service trade openness.

As productivity growth in the non-tradable sectors is critical to China's medium-term economic growth and inflation, it is necessary for the authorities to take action to raise productivity growth in the non-tradable sectors. While measures would differ across sub-sectors, structural reforms that create a competitive and innovative environment are important for improving the productivity of many sub-sectors. Tax reforms are also necessary to support the development of domestic private service providers. For example, a trial "refund upon collection" tax reform was put into place in end-2010 in Shanghai's Pudong New District, aiming at eliminating double taxation in the high-tech sector. In addition, it is useful to harmonize the existing policies and roles of regulatory bodies in different service industries. As suggested by Fan (2011), coordination among regulatory bodies can produce a policy mix in which policies are complementary and supportive to the overall development of the service sector

# 6. Concluding Remarks

In this paper we estimate productivity growth of the non-tradable sectors by studying the relative price movements of the non-tradable sectors vis-à-vis the tradable sectors. The main findings of the analysis can be summarized as follows:

- Prices of the non-tradable sectors have increased at a much faster pace than those of the tradable sectors in the past decade, implying a rapid appreciation in the IRER. While China's overall external competitiveness has not worsened that much thanks to competitiveness edges in its tradable goods prices as well as the generally slow appreciation in the renminbi NEER, rapid price increases in the non-tradable sectors, if they continue down the road, could lead to a noticeable deterioration in the external competitiveness. This is particularly true given that the degree of domestic contents (including domestic services) in China's exports has been increasing with the steady rise of the relative importance of ordinary exports.

- Productivity growth in the non-tradable sectors has been notably slower than that of the tradable sectors. Persistent and large differentials in productivity growth of the two sectors could imply that China may see higher inflationary pressures in the medium term, particularly in view of the changing landscape of labour supply.

- It is necessary for China to improve productivity growth in the non-tradable sectors in order to successfully rebalance its growth pattern, reduce inflationary pressures and maintain external competitiveness. While there have been various reasons for the relatively low productivity growth in the non-tradable sector, the lack of sufficient product market competition in the service sector appears to be an important factor. As such, speeding up the structural reforms, including opening up the service sector to private and foreign investors, is crucial to increasing the productivity in the non-tradable sectors.

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**Table 1. Specifications of Tradable and Non-Tradable Sectors**

| Tradable | Non-tradable |
|---|---|
| Textile | Primary food products |
| Clothing | Food processing, beverages and tobacco |
| Paper and printing | Real estate |
| Oil processing | Water & electricity & gas |
| Chemicals | Education |
| Non-metallic mineral products | Communication services |
| Metal smelting and pressing | Transportation services |
| General purpose machinery | Health care |
| Special purpose machinery | |
| Transportation equipment | |
| Electronic machinery and equipment | |
| Computer and communication equipment | |

Sources: CEIC, 2002 and 2007 IO tables, and authors' estimates.

**Table 2. Annual TFP Growth across Sectors from the DEA Approach (%)**

| Sector | 2001-2010 | 2001-2005 | 2006-2010 |
|---|---|---|---|
| Textile | 3.9 | -0.5 | 8.4 |
| Clothes | -0.6 | 4.2 | -5.2 |
| Paper and printing | 4.8 | 1.7 | 7.9 |
| Oil processing | 3.4 | 6.3 | 0.5 |
| Chemicals | 2.6 | 2.9 | 2.4 |
| Non-metallic mineral products | 7.5 | 11.0 | 4.1 |
| Metal smelting and pressing | 12.7 | 14.2 | 11.2 |
| General purpose machinery | 2.3 | 3.8 | 0.8 |
| Special purpose machinery | 4.5 | 7.8 | 1.3 |
| Transportation equipment | 7.7 | 7.6 | 7.8 |
| Electronic machinery and equipment | 1.3 | 3.7 | -1.1 |
| Computer and communication equipment | 9.4 | 6.2 | 12.6 |

Sources: Authors' estimates.

**Table 3. Annual TFP Growth by the DEA Method (%)**

| | 2001-2005 | 2006-2010 | 2001-2010 |
|---|---|---|---|
| Tradable | 5.7 | 4.2 | 4.9 |
| Non-tradable | 3.3 | 1.4 | 2.4 |
| Whole economy | 4.5 | 2.8 | 3.7 |

Source: Authors' estimates.

**Table 4. Annual TFP Growth in 2002-2007 (%)**

| | DEA with sector-level data | Firm-level data |
|---|---|---|
| Tradable | 4.6 | 5.4 |
| Non-tradable | 2.4 | 3.2 |
| Whole economy | 3.5 | 4.3 |

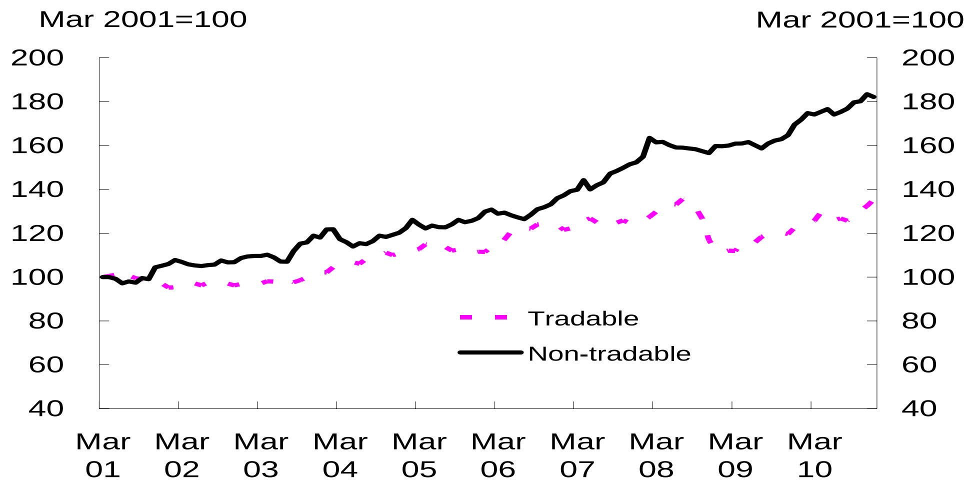
Source: Authors' estimates.

**Table 5. Productivity Differentials across Economies (%)**

| Economy | Period | Productivity differentials |
|---|---|---|
| China | 2001-2010 | 2.2 – 2.5 |
| Korea | 1990-1997 | 2.41 |
| Thailand | 1990-2006 | 0.24 |
| Indonesia | 1990-2006 | -1.03 |
| US | 1990-2004 | 0.73 |
| Japan | 1990-2004 | -0.43 |
| EU-15 | 1990-2004 | -0.2 |

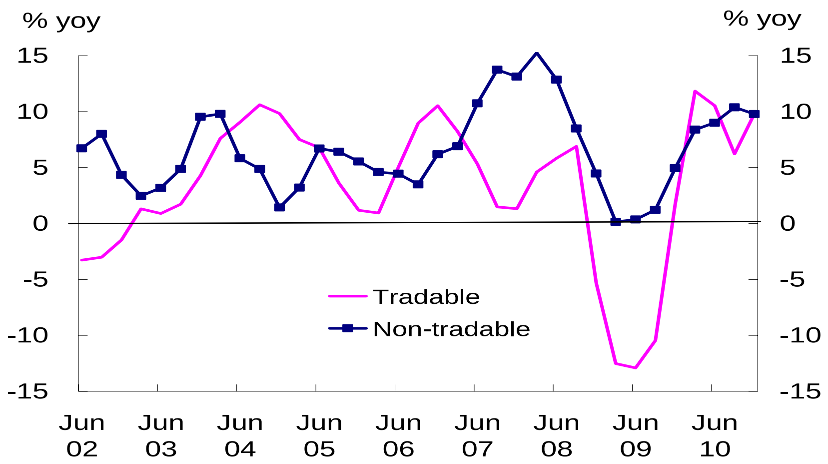
Sources: East Asia Seminar on Economics, IMF, ANU College of Asia and the Pacific, and authors' estimates.

**Figure 1. Tradable and Non-Tradable Price Indexes**



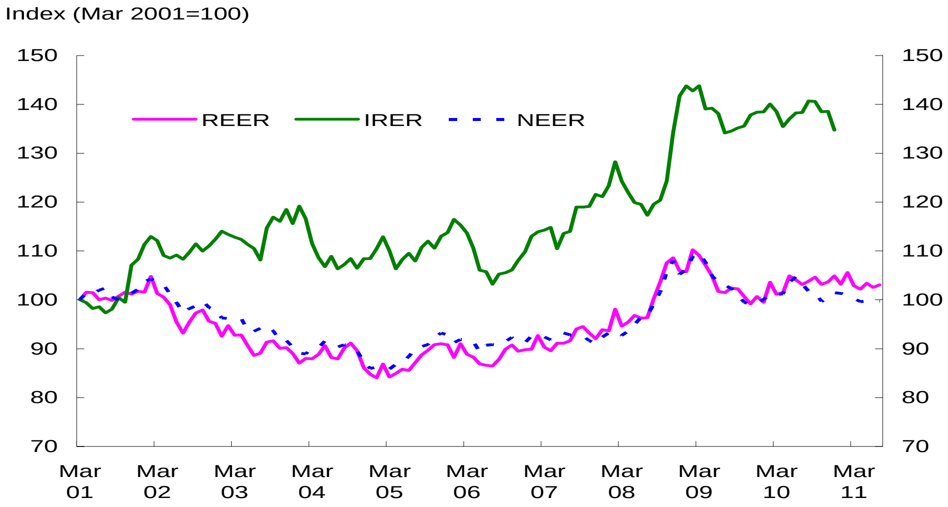

Source: CEIC and authors' estimates.

**Figure 2. Inflation Rates in Tradable and Non-Tradable Sectors**



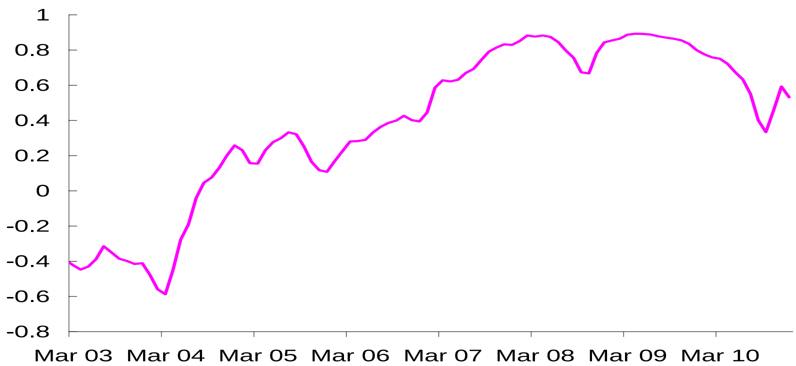

Source: CEIC and authors' estimates.

**Figure 3. Internal Real Exchange Rate and Real Effective Exchange Rates**




Sources: BIS and Authors' estimates.

**Figure 4. Correlation between IRER and REER**




Source: CEIC and authors' estimates.

# Appendix 1. Specifications of Tradable and Non-Tradable Sectors

**Table A1. Tradability across Sectors (Exports or Total Trade in Percent of Gross Output)**

| Sectors | 2002 Criterion 1 | 2002 Criterion 2 | 2007 Criterion 1 | 2007 Criterion 2 |
|---|---|---|---|---|
| Agriculture | 1.7 | 4.0 | 1.4 | 6.1 |
| Mining and washing of coal | 3.9 | 4.6 | 2.4 | 4.4 |
| Extraction of petroleum and natural gas | 3.7 | 37.3 | 1.8 | 62.3 |
| Mining and processing of metal ores | 1.3 | 26.5 | 1.3 | 67.7 |
| Mining and processing of nonmetal ores | 9.5 | 20.7 | 3.9 | 11.7 |
| Foods, beverages, and tobacco | 6.2 | 9.8 | 4.6 | 8.4 |
| Textile | 30.2 | 43.6 | 32.6 | 35.9 |
| Clothing, footware and caps; leather, fur, feather products | 41.9 | 48.3 | 31.4 | 34.8 |
| Timber processing and manufacturing of furniture | 16.9 | 21.7 | 22.1 | 24.5 |
| Paper, printing, educational and cultural products | 14.0 | 22.0 | 15.2 | 20.7 |
| Oil processing, coking, and nuclear fuels | 4.3 | 12.9 | 3.6 | 10.5 |
| Chemical | 10.1 | 26.7 | 11.7 | 26.4 |
| Non-metallic mineral products | 7.2 | 10.6 | 6.5 | 8.2 |
| Metal smelting and pressing | 3.0 | 14.2 | 8.4 | 15.5 |
| Metal products | 17.8 | 26.8 | 20.1 | 23.4 |
| General and special purpose machinery | 10.1 | 34.2 | 14.5 | 32.4 |
| Transportation equipment | 6.8 | 17.2 | 10.0 | 19.1 |
| Electrical machinery and equipment | 28.5 | 51.9 | 25.1 | 37.8 |
| Computers and communication equipment | 38.3 | 81.2 | 51.9 | 91.5 |
| Measuring instruments, office and cultural equipment | 87.8 | 183.2 | 66.3 | 146.9 |
| Other manufacturing | 20.6 | 25.4 | 21.2 | 24.8 |
| Production and supply of electrical and heat power | 0.6 | 0.8 | 0.2 | 0.3 |
| Production and supply of gas | 0.0 | 0.0 | 0.0 | 0.0 |
| Production and supply of water | 0.0 | 0.0 | 0.0 | 0.0 |
| Construction | 0.4 | 0.7 | 0.7 | 1.0 |
| Transportation and storage | 10.0 | 12.0 | 12.6 | 15.9 |
| Postage | 6.9 | 10.8 | 6.6 | 12.2 |
| Information transmission, computer services and software | 2.3 | 4.4 | 4.5 | 8.4 |
| Retail and wholesale | 14.8 | 14.8 | 13.9 | 13.9 |
| Hotels and catering services | 5.0 | 5.0 | 5.0 | 8.5 |
| Financial services | 0.3 | 4.1 | 0.4 | 1.1 |
| Real estate | 0.0 | 0.0 | 0.0 | 0.0 |
| Rental and business services | 19.6 | 34.3 | 27.2 | 47.7 |
| Scientific research | 0.0 | 0.0 | 1.9 | 47.1 |
| Education | 0.2 | 0.4 | 0.2 | 0.6 |
| Health, social security and welfare | 0.0 | 0.0 | 0.4 | 0.6 |
| Culture, sports, and entertainment | 11.5 | 17.2 | 9.3 | 17.8 |

Note: numbers in the grey areas are tradable goods.

Sources: CEIC, WIND, and authors' estimates.

# Appendix 2. The Malmquist Index

The general idea of the Malmquist index approach is to measure productivity with distance functions. For each period, $t = 1,...T$, the production technology $S_t$ models the transformation of inputs $X_t \in \Re_+^N$, into outputs, $Y_t \in \Re_+^M$,

$$S_t = \{(X_t, Y_t) : X_t \ can\ produce\ Y_t\} \ , \tag{A1}$$

the output distance function at *t* is then defined as

$$\begin{aligned} D_t(X_t, Y_t) &= \inf\{\theta : (X_t, Y_t/\theta) \in S_t\} \\ &= (\sup\{\theta : (X_t, Y_t/\theta) \in S_t\})^{-1} \end{aligned} \tag{A2}$$

Here $D_t(X_t, Y_t) \le 1$ if and only if $(X_t, Y_t) \in S_t$ and $D_t(X_t, Y_t) = 1$ if and only if $(X_t, Y_t)$ is on the frontier of technology. In order to estimate TFP growth, one needs to define distance functions for two periods of *t* and *t+1*. The Malmquist productivity index is defined as:

$$M(X_{t+1}, Y_{t+1}, X_t, Y_t) = \left[\left(\frac{D_t(X_{t+1}, Y_{t+1})}{D_t(X_t, Y_t)}\right)\left(\frac{D_{t+1}(X_{t+1}, Y_{t+1})}{D_{t+1}(X_t, Y_t)}\right)\right]^{1/2} \tag{A3}$$

which can also be expressed as

$$\frac{D_{t+1}(X_{t+1}, Y_{t+1})}{D_t(X_t, Y_t)} \times \left[\left(\frac{D_t(X_{t+1}, Y_{t+1})}{D_{t+1}(X_{t+1}, Y_{t+1})}\right)\left(\frac{D_t(X_t, Y_t)}{D_{t+1}(X_t, Y_t)}\right)\right]^{1/2}$$

with the term outside the brackets measuring changes in relative efficiency (the change in how far observed production is from the maximum potential production) between period *t* and *t+1*, and the term inside the brackets measuring the shift in technology between the two periods. Therefore,[16]

[16] One can see the link between the Malmquist index and the conventional measure of productivity growth estimated from a Cobb-Douglas production function below. Let the production function be $Y_t = A_t \prod_{n=1}^{N} (X_{n,t})^{\alpha_n}$, $\alpha_n > 0$, with $A_t$ denoting TFP in level. Under the assumption that observed production is the same as the production frontier, one can easily show that

$$M(X_{t+1}, Y_{t+1}, X_t, Y_t) = \frac{A_{t+1}}{A_t} = 1 + \Delta TFP_{t+1}.$$

In the presence of technical inefficiency, this approach would produce biased estimates of TFP growth.

Efficiency change = $\dfrac{D_{t+1}(X_{t+1},Y_{t+1})}{D_t(X_t,Y_t)}$,

Technical change = $\left[\left(\dfrac{D_t(X_{t+1},Y_{t+1})}{D_{t+1}(X_{t+1},Y_{t+1})}\right)\left(\dfrac{D_t(X_t,Y_t)}{D_{t+1}(X_t,Y_t)}\right)\right]^{1/2}$.

The crucial problem in constructing the Malmquist index is how to estimate the production frontier. Assuming there are $k=1,...,K$ decision-making units (DMU, firms for example) using $n=1,...,N$ inputs $X^k_{n,t}$ in each period to produce $m=1,...,M$ outputs $Y^k_{m,t}$, the frontier technology can be constructed as follows:

$$S_t=\{(X_t,Y_t):Y_{m,t}\le\sum_{k=1}^{K}z_{k,t}Y^k_{m,t},\qquad m=1,...,M;$$
$$\sum_{k=1}^{K}z_{k,t}X^k_{n,t}\le X_{n,t},\quad n=1,...,N;\}$$

with $z_{k,t}\ge 0$ for constant returns to scale (CRS), $\sum_{k=1}^{K} z_{k,t}\le 1$ for non-increasing (NRS) returns to scale and $\sum_{k=1}^{K} z_{k,t}=1$ for variable returns to scale (VRS). In order to calculate the Malmquist index for DMU $k^{'}$, one needs to solve four linear programming problems:

$$\begin{aligned}&[D_t(X_{k',t},Y_{k',t})]^{-1}=\max\theta_{k'}\quad \text{subject to}\\ &\theta_{k'}Y^{k'}_{m,t}\le\sum_{k=1}^{K}z_{k,t}Y^k_{m,t},\quad m=1,...,M\\ &\sum_{k=1}^{K}z_{k,t}X^k_{n,t}\le X^{k'}_{n,t},\quad n=1,...,N\end{aligned}\tag{A4}$$

and

$$\begin{aligned}&[D_t(X_{k',t+1},Y_{k',t+1})]^{-1}=\max\theta_{k'}\\ &\theta_{k'}Y^{k'}_{m,t+1}\le\sum_{k=1}^{K}z_{k,t}Y^k_{m,t},\quad m=1,...,M\\ &\sum_{k=1}^{K}z_{k,t}X^k_{n,t}\le X^{k'}_{n,t+1},\quad n=1,...,N\end{aligned}\tag{A5}$$

with $z_{k,t}$ satisfying the corresponding conditions for CRS, NRS and VRS. $D_{t+1}(X_{k',t+1},Y_{k',t+1})$ is also computed using equation (A9) with *t+1* replaced with *t,* while $D_{t+1}(X_{k',t},Y_{k',t})$ is calculated employing equation (A10) with subscripts *t* and *t+1* transposed. The above linear programming problem is solved *K* times in each period and each linear programming produces a $\theta_{k'}$ and a vector of weights with elements of $z_{k,1}$, $z_{k,2}$ ,.. $z_{k,t}$ .

# Appendix 3. Control Function Approach and Adjustment of Externalities

The trans-log production function reads

$$y_{it} = \alpha_0 + \beta_K k_{it} + \beta_l l_{it} + \beta_{kk}(k_{it})^2 + \beta_{ll}(l_{it})^2 + \beta_{kl}k_{it}l_{it} + \theta(m_{it}, k_{it}) + \varepsilon_{it} \quad \text{(A6)}$$

where $y$, $k$, $l$, and $m$ are output, capital stock, labour, and intermediate input respectively (all in logs). In this equation, the traditional error term is split as a transmitted component $\theta(m_{it}, k_{it})$ and an i.i.d. component $\varepsilon_{it}$ [17]. Following Olley and Pakes (1996), we assume that the $\theta(m_{it}, k_{it})$ function follows a Markov process. Coefficient estimation is conducted in two steps. In the first step, we approximate $\theta(m_{it}, k_{it})$ by the second order polynomial in $m_{it}$ and $k_{it}$, and estimate equation (5) accordingly at the industry level by ordinary least squares (OLS).[18] In the second step, we construct a new variable $\mu_{it}$ in terms of output and labour:

$$\mu_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_{ll}(l_{it})^2 - \hat{\varepsilon}_{it} \quad \text{(A7)}$$

where ^ denotes the parameter estimates from the first step. The new regression function can be written as

$$\mu_{it} = \gamma_0 + \gamma_K k_{it} + \gamma_{kk}(k_{it})^2 + \gamma_{kl}k_{it}l_{it} + \theta(m_{it-1}, k_{it-1}) + \theta^2(m_{it-1}, k_{it-1}) + \eta_{it} \quad \text{(A8)}$$

where $\eta_{it}$ is an i.i.d error term. We approximate $\theta(m_{it-1}, k_{it-1})$ by the second order polynomial in $m_{it-1}$ and $k_{it-1}$, and estimate equation (7) accordingly by the OLS. The TFP in logs is calculated as

$$TFP_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_{ll}(l_{it})^2 - \hat{\gamma}_k k_{it} - \hat{\gamma}_{kk}(k_{it})^2 - \hat{\gamma}_{kl}k_{it}l_{it} \quad \text{(A9)}$$

Where ^ denotes the coefficient estimates from the first and second steps. We take the simple average of $TFP_{it}$ across firms within a group to get the TFP for the corresponding sector.

17 The transmitted component is a state variable in Olley and Pakes (1996), which is supposed to affect a firm's investment decisions, while the i.i.d. component has no impact on a firm's decisions.

18 The industry classification in the firm-level data from the Annual Survey of Manufacturing conducted by the NBS is somewhat different from the classification used in our sector-level analysis, as the breakdown in the survey data is in greater details.

The externalities are adjusted as follows. The aggregate output of the whole economy in log, *y,* reads

$$y = \alpha + \varphi t + \phi k + (1-\phi)l + \lambda x + \xi_t \qquad \text{(A10)}$$

where $k$ and $l$ are aggregate (non-infrastructure) capital stock and employment in logs respectively, $x$ is infrastructure capital stock, and $\xi_t$ is an i.i.d. error term[19]. We estimate the parameter of contributions of externalities $\lambda$ in two steps. In the first step, we regress $(y-l)$ on its own lags, a constant, time *t*, and $(k-l)$, from which we calculate a "residual" $\hat{\varsigma}$ :

$$\hat{\varsigma}_t = (y_t - l_t) - \hat{\varphi}\, t - \hat{\phi}(k_t - l_t) \qquad \text{(A11)}$$

where ^ denotes the coefficient estimates. In the second step, we regress $\hat{\varsigma}$ on $x$ and a constant. The estimated coefficient $\hat{\lambda}$ is the contribution from externalities. Therefore the productivity growth net of externalities is the TFP growth of each sector $g_{TFPt}$ minus the contribution of the infrastructure capital:

$$g_{it} = g_{TFPit} - \hat{\lambda} g_{Xt} \qquad \text{(A12)}$$

where $g_{Xt}$ denotes growth in infrastructure capital.

[19] To estimate the non-infrastructure and infrastructure capital stock, we first estimate the non-infrastructure and infrastructure capital formation. Following He et al (2007), we proxy infrastructure fixed asset investment by fixed asset investment in six sectors, including "electricity, gas and water", "construction", "transport, storage, and postage", "education", "health care, social security and welfare", and "culture, sports and entertainment". We multiply the share of infrastructure fixed asset investment in total fixed asset investment with the national real gross capital formation to obtain the real infrastructure capital formation, which in turn is used to estimate the real infrastructure capital stock by perpetual inventory method. The non-infrastructure fixed asset investment is the national real gross capital formation net of real infrastructure fixed asset investment, which in turn is used to construct the non-infrastructure capital stock in the same way.

# Appendix 4

**Table A2. Annual TFP Growth of 2002-2007 Estimated with Firm-Level Data (%)**

| Name of industry | TFP growth |
|---|---|
| Agricultural & Sideline Food Processing | 4.2 |
| Food Manufacturing | 4.9 |
| Beverage Manufacturing | 6.6 |
| Textile Industry | 5.7 |
| Garment, Footwear & Headgear Manufacturing | 3.8 |
| Leather, Fur, Down and Related Products | 1.2 |
| Furniture Manufacturing | 3.3 |
| Paper Making and Paper Products | 8.0 |
| Printing and Record Medium Reproduction | 2.5 |
| Cultural, Educational and Sports Goods | 2.2 |
| Petroleum, Coking & Nuclear Fuel Processing | 0.4 |
| Raw Chemical Material and Chemical Product | 6.4 |
| Medical and Pharmaceutical Product | 4.8 |
| Chemical Fiber Industry | 8.1 |
| Rubber Product | 5.5 |
| Plastic Product | 2.7 |
| Non-Metal Minerals Product | 8.7 |
| Smelting and Pressing of Non-Ferrous Metal | 7.8 |
| Metal Product | 6.2 |
| Universal Equipment Manufacturing | 7.5 |
| Special Purpose Equipment | 7.3 |
| Transportation Equipment | 8.8 |
| Electric Machinery and Equipment | 3.4 |
| Communication, Computer & Other Electronic Equipments | 10.4 |
| Instrument, Meter, Cultural & Office Machinery | -10.0 |
| Handicraft & Other Manufacturing | -5.1 |

Sources: The NBS and authors' estimates.