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Abstract

China's economy grew by an impressive 10 percent per year over four decades. Productivity improvements within sectors and gains from resource reallocation between sectors and ownership groups drove that expansion. However, productivity growth has declined markedly in recent years. This paper extends previous macro and firm-level studies to show that domestic factors and policies contributed to the slowdown. The analysis finds that limited market entry and exit and lack of resource allocation to more productive firms were associated with slower manufacturing total factor productivity growth. Earlier reforms led to state-owned enterprises catching up to private sector productivity levels in manufacturing, but convergence stalled after 2007. Furthermore, the allocation of a larger share of credit and investment to infrastructure and housing led to lower returns to capital, a rapid buildup in debt, and higher risks to growth. China's growth potential remains high, but its long-term growth prospects depend on reversing the recent decline in total factor productivity growth.

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China's Productivity Slowdown and Future Growth Potential[1]

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Over the past four decades, China sustained remarkable average annual growth of 10 percent, while transforming from a rural agricultural society to an urban industrial one, and from a planned to a market-based economy. GDP per capita adjusted for inflation increased 24 times, average life expectancy rose by 10 years to 76.5 years in 2017, and more than 700 million people were lifted out of poverty, according to World Bank data.

Moreover, a significant proportion of this expansion was the result of increases in productivity. Productivity improvements within sectors as well as gains from the reallocation of resources between sectors—from agriculture to more productive modern industry and services—and between ownership groups—from inefficient state-owned enterprises (SOEs) to dynamic private firms—were especially important.

However, China has experienced a marked slowdown in growth in output per worker since the global financial crisis. In 2015–18, average GDP growth fell below 7 percent for the first time since 1991, to a large extent due to slowing growth in total factor productivity (TFP). Aggregate TFP growth slowed from 2.8 percent in the 10 years before the global financial crisis to 0.7 percent in 2009–18. In 2017, signs of improving labor productivity and TFP growth emerged but both remain significantly lower than their pre-crisis levels.

Although weaker productivity growth in China has coincided with—and likely been affected by—the recent decline in world productivity growth, the deceleration in China has been sharper. The main contribution of this paper is to examine the characteristics of the productivity growth slowdown using both macro- and micro-level data. We conclude that domestic factors and policy choices have contributed to the slowdown.

We update previous firm-level studies of manufacturing sector productivity and find that, while within-firm TFP growth has remained resilient, limited market entry and exit and lack of resource allocation to more productive firms have contributed to a slowdown in manufacturing TFP growth since 2008. The evidence points to considerable convergence in productivity between SOEs and private companies in manufacturing after market reforms were introduced in the 1990s, though SOEs remain less efficient than private firms in their use of capital. In addition, the relative profitability of manufacturing SOEs appears to have deteriorated as relative leverage rose after the global financial crisis. Overall, we find that the process of SOEs catching up to private sector efficiency has recently stalled.

Beyond the manufacturing sector, we use new capital stock estimates by sector to show that strong investment in infrastructure and housing has been associated with lower returns to capital. In response to the global financial crisis, China implemented a large fiscal stimulus which emphasized local government spending on infrastructure and housing. The allocation of a larger share of credit and investment to these sectors coincided with an increase in the sector-specific capital-output ratios. It has also contributed to a rapid build-up in corporate debt and larger macroeconomic imbalances, raising the risk of slower growth.

Nevertheless, in Section 3 we argue that, from the perspective of international convergence, China's growth potential remains significant. As per capita income and productivity are still far below those observed in advanced countries, there is significant room for catch-up growth through capital deepening (albeit crucially in the private sector), human capital accumulation, and improvements in TFP. The paper concludes with some policy recommendations to ensure that China realizes its potential for strong growth in light of recent external developments and domestic reforms.

1. Accounting for China's past growth performance

In the standard growth accounting framework, growth in output per worker can be allocated into contributions from changes in physical capital, employment, human capital (the education and skills of the labor force), and a residual, total factor productivity. TFP measures gains in economic efficiency (the quantity of output produced with a given quantity of inputs), including those driven by technological progress.

Assuming a Cobb-Douglas production function, output is a function of capital, labor, and TFP:

$$Y = AK^{\alpha}(LH)^{1-\alpha}.$$

Y, A, K, and α are measures of output, TFP, physical capital, and the capital share of income, respectively. L is labor and H accounts for educational attainment and the return to each additional year of education. Dividing both sides of the production function by the labor input L, taking logarithms of both sides, and taking first differences yields:

$$\Delta \ln(Y/L) = \alpha[\Delta \ln(K/L)] + (1-\alpha)\Delta \ln H + \Delta \ln A.$$

Growth in output per worker, $\Delta \ln(Y/L)$, is decomposed into contributions from growth in capital per worker, $\Delta \ln(K/L)$, increases in education per worker, $\Delta \ln H$, and a residual measure of improvement in TFP, $\Delta \ln A$.

The data on output (real GDP), employment and the labor share of income (i.e., labor compensation divided by GDP) are from China's National Bureau of Statistics (NBS). The capital stock estimates are from Herd (2020) and the human capital variable is from Penn World Table (PWT) 9.1 (Feenstra et al., 2015).[6]

In China, the growth contribution of TFP was particularly high in the initial stages of reform and opening, when many structural reforms were implemented. We estimate that TFP grew by 3.5 percent a year in the first decade (1979-1988) (Figure 1). Annual TFP growth averaged 3.1 percent in 1979–2008, generating 40 percent of growth in output per worker.[7] Bosworth and

[6] We use China's official national accounts. PWT 9.1 adjusts China's GDP growth down by an average of 2.1 percentage points in 1953–2017 (with a standard deviation of 4.4) compared with NBS data, arguing that "official statistics systematically overstate growth" (Feenstra et al. 2013 and 2015). In the PWT, average TFP growth in 1979-2008 was 1.6 percent and TFP contributed about 30 percent to growth in output per worker. Although the PWT output and TFP growth rates for China are on average lower than ours, the two sets of variables are highly correlated (correlation of 0.78 for output growth and 0.70 for TFP growth) and tell a similar story over time.

The quality of China's official statistics has received a lot of attention in the literature (see, for example, Adams and Chen, 1996; Holz, 2014; Maddison and Wu, 2008; Perkins and Rawski, 2008; Rawski, 2001). Four recent papers explore this issue after 2007. Clark et al. (2018) and Hu and Yao (2019) use satellite–recorded nighttime lights to estimate GDP. The former conclude that growth in recent years has been underreported in official statistics, while the latter find that official GDP has been systematically overestimated. Re-estimating GDP using value added tax revenues, Chen et al. (2019) find that official statistics overstated growth by 1.7 percentage points in 2008-2016. In contrast, linking trading-partner data on exports to China and China's GDP, Fernald et al. (2019) conclude that official statistics have become generally more reliable over time.

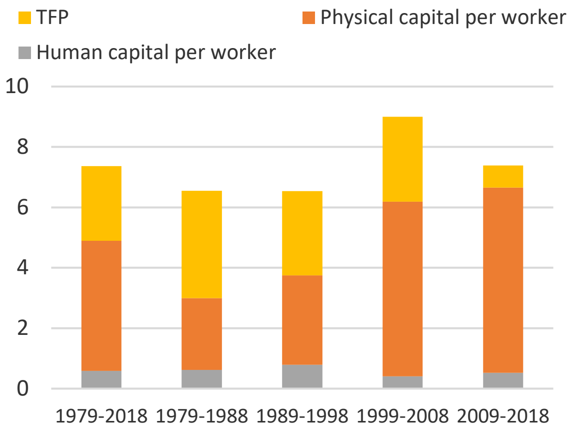
[7] An alternative way to calculate the growth contribution of TFP is to attribute to technology both the direct increase in GDP due to TFP growth and the indirect effect that results from the endogenous increase in capital in

Collins (2008) and Perkins and Rawski (2008) obtain similar results, while in Chow and Lin (2002), Feenstra et al. (2015), Woo (1997), Wu (2011), and Young (2003) the TFP share of growth is somewhat lower. Tian and Yu (2012) conduct a meta-analysis of 150 papers and find that the mean aggregate TFP growth is about 2 percent a year after 1978, accounting for about a fifth of GDP growth.

In the three decades before the global financial crisis, half of the increase in output per worker was due to capital deepening. Since 2008, growth has relied to a significant extent on capital accumulation which accounted for over 80 percent of growth in output per worker. High investment growth was in part driven by the large fiscal stimulus packages introduced first in in response to the 2009 global recession and later to cushion the 2015-16 growth slowdown (see below). In contrast, TFP growth decreased sharply to 0.7 percent a year in the same period. Other studies also estimate that aggregate TFP has declined in recent years (Wei et al., 2017; Wu, 2017). The TFP growth slowdown is explored further in the following sections.

Figure 1 Decomposition of growth in China's output per worker

(contributions to the average annual change in real output per worker, percent)



Source: Herd (2020); NBS; PWT 9.1; authors' calculations.

Improvements within sectors, as well as gains from the reallocation of resources between sectors, were both important in raising China's labor productivity. Following the methodology in Timmer et al. (2015), labor productivity growth can be decomposed into changes in productivity within sectors and movement of workers across sectors:

$$\Delta P = \sum_i (P_i^T - P_i^0) S_i^0 + \sum_i (S_i^T - S_i^0) P_i^0 + \sum_i (P_i^T - P_i^0)(S_i^T - S_i^0).$$

ΔP is the change in aggregate labor productivity, while P_i and S_i are the labor productivity level and employment share of industry i. The superscripts *0* and *T* denote the initial and final period. The first term on the right-hand side of the equation measures productivity growth *within* individual sectors (weighted by the employment share of each sector). The second term indicates whether workers move to sectors with above-average productivity levels—*between-sector* productivity growth. The last term is a covariance term that captures the aggregate productivity effect of simultaneous changes in sectoral employment and productivity level. This *cross-sector* term is positive when labor is moving to sectors experiencing positive productivity growth and negative when workers relocate to sectors with negative productivity

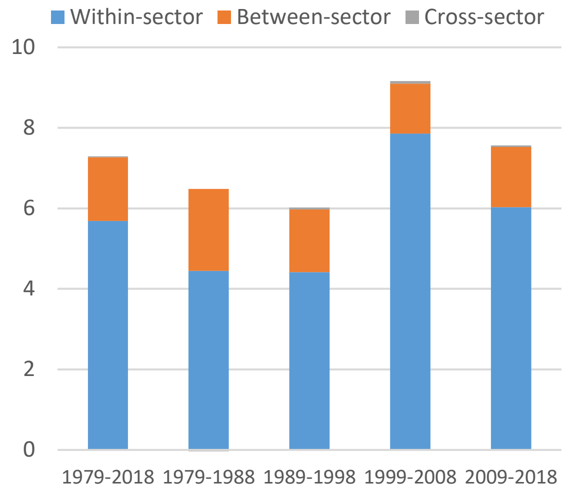
response to higher TFP. In this alternative calculation, TFP growth is multiplied by $1/(1-\alpha)$ (Barro and Sala-i-Martin, 2004, p. 457). Following this approach, TFP plays a much larger role, contributing 6.2 percentage points to growth (more than four-fifths of growth in output per worker) in 1979-2008. Using this alternative method of growth decomposition, Zhu (2012) also finds that TFP accounted for 78 percent of per capita GDP growth in China over the same period.

growth. The latter may occur when the marginal productivity of additional workers in expanding sectors is below that of existing activities in those sectors.[8]

China's development has been similar to that of other Asian countries—benefiting both from rapid within-sector productivity growth and significant structural change (Timmer et al., 2015). Over 1979-2018, productivity growth within sectors contributed 5.7 percentage points to aggregate labor productivity growth of 7.3 percent per year. The movement of workers between sectors generated the rest (Figure 2). The cross-sector term is positive, suggesting that labor generally moved to sectors with positive productivity growth, but its effect is very small.

Figure 2 Within-sector productivity growth versus movements of labor

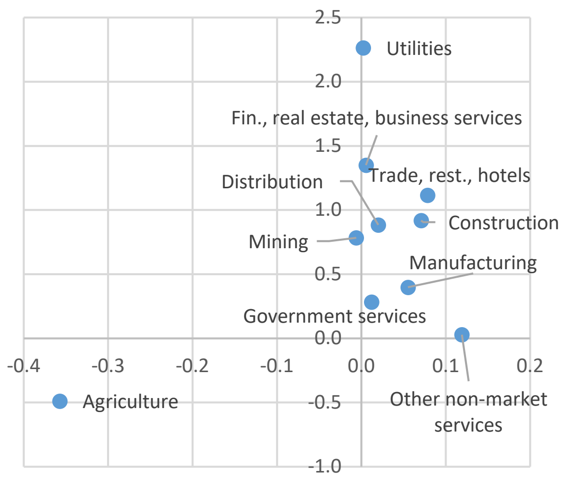
(annual average contributions to growth in labor productivity, percentage points)



Source: NBS; authors' calculations.

Figure 3 Labor moving out of agriculture

(log ratio of sectoral to aggregate labor productivity in 1978, y-axis; change in employment share 1978–2010, x-axis)



Source: GGDC 10-Sector Database, Timmer et al. (2015); authors' calculations.

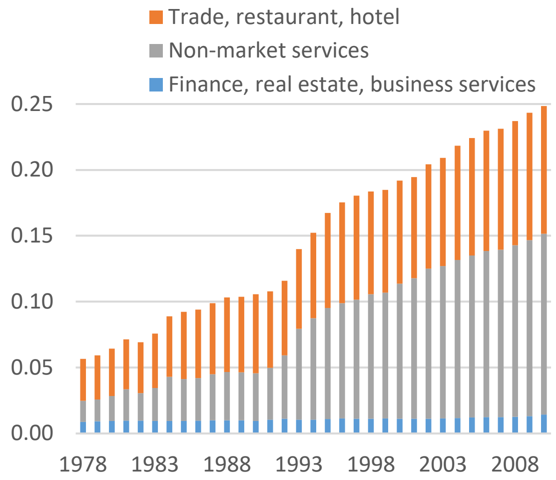
Tracking the standard path of industrialization, labor moved from agriculture to industry. In 1978, 75 percent of the labor force was in agriculture. That share declined to 27 percent in 2018, as the tight controls on rural-urban migration were gradually relaxed and workers relocated to sectors with higher productivity growth (Figure 3). Between 1978 and 2010, the employment shares of manufacturing and construction increased by 6 and 7 percentage points, respectively.

Labor also moved to services, mainly trade, restaurant and hotel and non-market (community, social, and personal) services. By 2010, labor productivity in non-market services was less than a fifth of the economy-wide level, while the employment share had risen by 12 percentage points to 14 percent of the labor force (Figures 4 and 5). In contrast, the employment share of financial, real estate, and business services, where productivity growth is very high, has remained around 1 percent over four decades.

[8] As in in McMillan and Rodrik (2011) and Timmer et al. (2015), this decomposition uses average rather than marginal labor productivity to compare productivity gaps across sectors. However, the reallocation of labor between two sectors affects output per worker in both sectors, likely reducing average productivity in the new sector. Hence, the gains from reallocation in the above analysis may be overestimated.

Figure 4 Labor moving to lower-productivity services

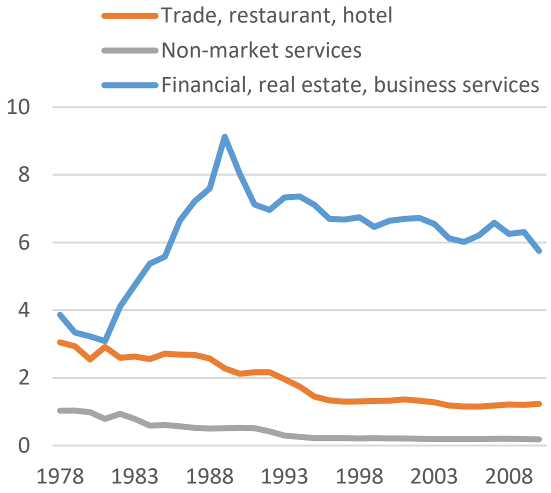
(share of total employment)



Source: GGDC 10-Sector Database, Timmer et al. (2015); authors' calculations.

Figure 5 Relative labor productivity

(ratio of sectoral to aggregate labor productivity)



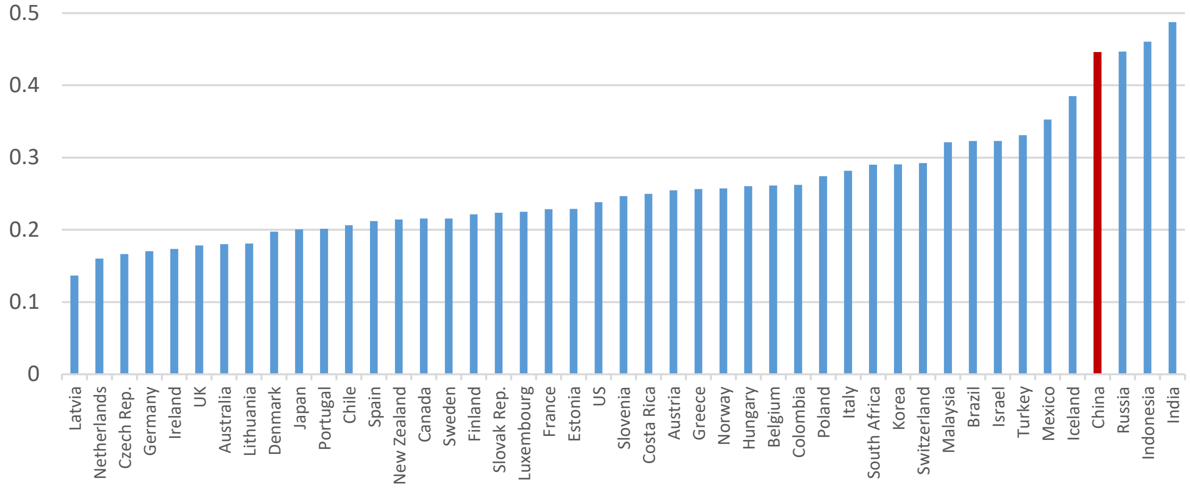
Source: OECD; authors' calculations.
Note: A higher STRI indicates a more restrictive regime.

In the decade after the global financial crisis, aggregate labor productivity growth in China weakened to 7.4 percent per year, from 9.0 percent in 1999-2008. A slowdown was observed across sectors but services experienced the largest decrease from an annual average of 8.1 percent in 1999–2008 to 4.6 percent in the most recent decade. Lower aggregate productivity growth has been partly due to China's economic rebalancing away from foreign demand and industry toward higher domestic consumption and services. Today resources are being reallocated from agriculture and, since 2013 and at a much slower pace, from industry into services.

Following Baumol (1967), the decline in productivity growth as the economy matures is almost inevitable but, in China's case, there is scope to improve labor productivity in services. As incomes rise, households spend more of their income on services. Correspondingly, higher income countries tend to have a higher share of employment in services, where productivity is generally lower than in industry. However, China could implement policies that boost service sector productivity. One area, for example, is market competition, as services in China have been much less open to competition and FDI than industry. By one measure—the OECD services trade restrictiveness index (STRI)—China, along with the Russian Federation, Indonesia, and India, ranks considerably below the OECD countries and has shown limited improvement over time (Figure 6).

Figure 6 Services trade restrictiveness index, 2018

(simple average of STRI across 22 service sectors)



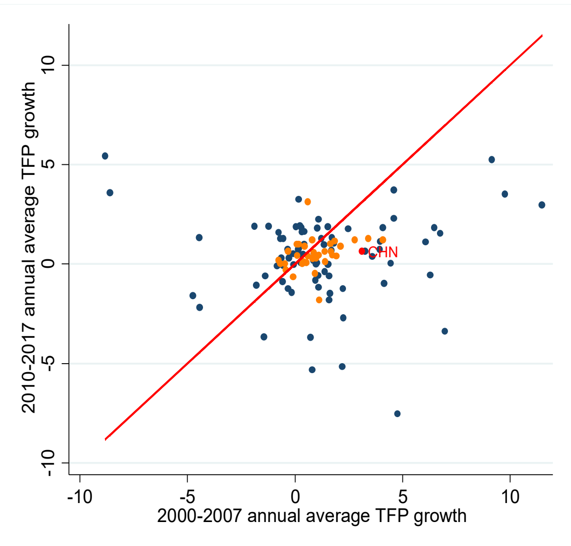
Source: OECD; authors' calculations.
Note: A higher STRI indicates a more restrictive regime.

2. Factors behind the recent slowdown in productivity growth

The post-global financial crisis slowdown in labor productivity growth in China was driven by a significant deceleration in TFP growth from 2.8 percent per year in the decade before the global financial crisis to just 0.7 percent afterwards. The growth contribution of physical capital accumulation increased over that period.

Figure 7 The recent widespread decline in TFP growth

(annual average TFP growth in 2010–17 (y-axis) versus 2000–07, percent)



Source: PWT 9.1; authors' calculations.
Note: An observation below (above) the 45-degree line indicates that a country's TFP growth was lower (higher) post-GFC compared with the pre-GFC period. OECD countries in orange.

A slowdown in TFP growth has been observed in many advanced and developing countries since the 2008 global crisis (Ball, 2014; Foda, 2016; Adler et al., 2017; Ollivaud and Turner, 2014). In the PWT 9.1 data, world TFP growth (excluding China) decreased from 1.2 percent in 2000–07 to 0.4 percent in 2010-17 (Figure 7). For advanced countries, the deceleration in TFP growth predates the crisis (Foda, 2016), pointing to a declining effect of the information and communication technology boom, an aging workforce, slower human capital accumulation, and slowing global trade integration, including the maturing of China's integration into world trade (Adler et al., 2017). Albeit less relevant in the case of China, other factors further reduced global TFP growth: overheating and resource misallocation before the crisis (Ollivaud and Turner, 2014;

IMF, 2009); constrained investment due to weak corporate balance sheets, tight credit conditions and higher uncertainty in the aftermath of the crisis (Adler et al., 2017).[9]

Although external factors may have contributed to the slowdown in China's productivity growth, we identify several important domestic causes based on evidence from the Industrial Enterprise Survey, as well as aggregate financial sector data. Unfortunately, firm-level data that are representative of the service sector are not available. Given the growing importance of services in China's economy, this is a significant shortcoming of our analysis.

2.1 Firm-level evidence of weaker productivity growth in manufacturing

First, manufacturing firm data show that market entry and exit have contributed less to productivity growth in recent years compared to the early 2000s. Second, after a notable convergence in returns to capital and labor and TFP between private and state-owned manufacturing enterprises (SOEs) before 2008, SOE productivity has deteriorated since then. We also uncover differences in productivity across China's provinces.

Aggregate TFP growth can be improved through two mechanisms. One is raising productive efficiency within firms through either innovation or adoption of more efficient existing technologies. The second is reallocating resources between firms, either by moving resources between existing firms or by the entry and exit of firms.[10]

Before the global financial crisis, the net new entry of firms accounted for more than two-thirds of TFP growth in China, while the reallocation of inputs to more productive firms was limited (Brandt et al., 2012). Compared with the United States, there were large gaps in the marginal products of labor and capital between manufacturing firms within the same sector in China in 1998–2005 (Hsieh and Klenow, 2009). There were also large gaps in the returns to capital—between SOEs and private firms, between regions, and between sectors within China in 2002–04 (Dollar and Wei, 2007). At the same time, TFP and the returns on labor of SOEs converged to those of private firms over 1998–2007, while the SOE returns on capital remained about 40 percent lower than private ones (Hsieh and Song, 2015). Differences in the marginal products of factor inputs (or returns to factor inputs) indicate the overall distortions some firms face within industries, such as firm-specific tax rates, subsidies, credit constraints, and trade barriers.

This paper updates through 2013 productivity estimates for China's manufacturing sector that were originally made for 1998-2007 (Brandt et. al, 2012, 2017). The basis of these estimates is the firm-level data that are collected as part of the NBS annual Industrial Enterprise Survey. The survey covers all industrial firms with annual sales above RMB 5 million before 2008 and above RMB 20 million thereafter. The estimation methodology and how we deal with several measurement challenges, including inconsistent data at the individual firm level between 2008 and 2009, lack of data on firm-specific prices, and no data for 2010, are described in the appendix. The new estimates allow a comparison of productivity growth in industry before and after the global financial crisis.

Average annual TFP growth in manufacturing fell from 2.0 percent in 1998-2007 to 1.1 percent in 2007-13. This decline was spread across industries: 24 of 28 sectors at the two-digit level had lower TFP growth in 2007–13 than in 1998–2007 (Figure 8). More than a quarter of all sectors also experienced a decline in productivity in levels. Large reductions were observed in metal products, food processing, timber processing, and petroleum refining.

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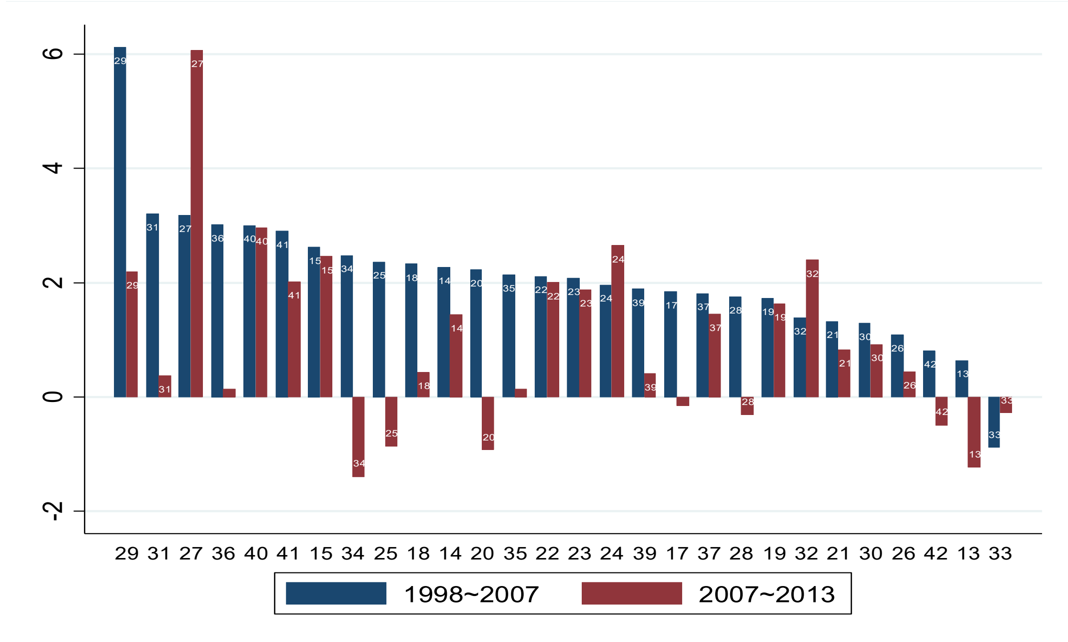
[9] IMF (2009) provides an overview of the literature explaining the link between crises and productivity growth.

[10] See Restuccia and Rogerson (2013) for a review of the literature on misallocation and productivity.

Figure 8 TFP growth by sector, 1998–2007 and 2007–13

(TFP growth by sector, 1998–2007 and 2007–13, percent a year)



Source: Authors' estimates based on NBS's Industrial Enterprise Survey.

Note: Excluding the tobacco sector which is an outlier. X-axis NBS industry classification: 14 food processing; 15 beverages; 17 textiles; 18 garments; 19 leather and furs; 20 timber and bamboo products; 21 furniture; 22 paper, paper products; 23 printing, record medium reproduction; 24 cultural, educational, sports goods; 25 petroleum refining and coking; 26 chemicals; 27 medical and pharmaceutical products; 28 chemical fiber; 29 rubber products; 30 plastic products; 31 nonmetal mineral products; 32 smelting of ferrous metals; 33 smelting of nonferrous metals; 34 metal products; 35 ordinary machinery; 36 special equipment; 37 transport equipment; 39 electric equipment and machinery; 40 electronics and telecommunications; 41 instruments and meters; 42 other manufacturing.

Industry TFP growth can be decomposed into improvements within incumbents (within-firm TFP growth in the first term on the right side) and three between-firm terms—reallocation of resources to more productive existing firms (term 2), entry of new firms (term 3), and exit of firms (last term):

$$\Delta y_t = \sum_{i \in C} \bar{s}_i \, \Delta y_{it} + \sum_{i \in C} \Delta s_{it} \, [\bar{y}_i - y_{t-k}] + \sum_{i \in E} s_{it} \, [y_{it} - y_{t-k}] - \sum_{i \in X} s_{it-k} \, [y_{it-k} - y_{t-k}],$$

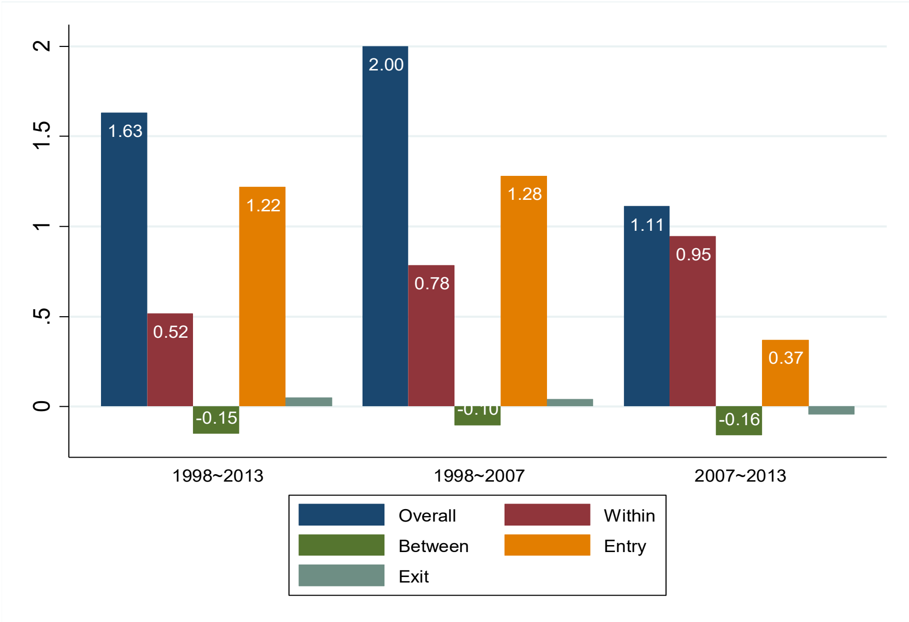
where y_t is industry TFP, y_{it} is TFP of firm *i* in year *t*, s_{it} is the output share of firm *i* in the industry, and *C, E,* and *X* denote the sets of continuing, entering, and exiting firms, respectively, within each industry. Following Haltiwanger (1997), we normalize current TFP levels of firm *i* by y_{t-k}, the industry average TFP in the initial period *t-k*, and use time-average weights for continuing firm, $\bar{s}_i$ and $\bar{y}_i$, as suggested by Griliches and Regev (1995). This amounts to splitting a third covariance term, containing $\Delta s_{it} \Delta y_{it}$ interactions, equally between the first two terms.

New firms will contribute positively if they enter the productivity distribution at a level that is higher on average than incumbents. Their contribution will also be larger the more important they are in overall sales. Analogously, the exit of poorly performing firms should raise productivity. And reallocating resources in the sector toward more productive firms will also raise sector productivity growth.

Over 1998–2013, most of the increase in productivity—two-thirds—came from the entry of new firms (Figure 9).[11] To help put this in perspective, the rate of entry of new firms averaged 10 percent a year. The other primary source of growth was improving productivity of incumbents, which contributed 40 percent.

Figure 9 Decomposition of annual TFP growth in manufacturing, 1998–2013

(percent a year)



Source: Authors' estimates based on NBS's Industrial Enterprise Survey.
Note: Calculations exclude firms that switched between sectors in the sample period. The number of such firms was small.

Over the entire period, firm exit contributed negligibly to manufacturing productivity growth, reflecting one of several possibilities. Poorly performing firms either did not exit or exited but accounted for only a small percentage of aggregate output. Or the productivity of some firms that exited was average or better. Similarly, there were no gains from reallocating resources (labor, capital, and intermediate inputs) to more productive firms, which would have increased aggregate productivity, all else equal. In fact, the contribution was slightly negative. In advanced countries, this is the most important source of productivity growth,[12] and thus stands out as a possible major source of future productivity growth in China.

After 2007, average manufacturing productivity growth in China decreased almost by half. The most important reason for the decline was that the contribution of better entrants disappeared. In some sectors, the contribution of new entrants was actually negative, implying that these firms entered the productivity distribution lower than the sector average. One

[11] New firms are those that were established in either the current year or previous year (the date is given in the NBS survey).

[12] See, for example, Bartelsman and Dhrymes (1998).

possibility is that the entry process in these sectors depended less (and not more) on economic factors. So, the firms with the highest potential did not get the opportunity to enter.[13]

Estimates of the rate of entry of new industrial firms with annual sales above RMB 20 million indicate that, after falling slightly during the Asian financial crisis (1997), entry rates rose from less than 8 percent a year in the late 1990s to more than 12 percent in 2004. Subsequently, entry rates began to fall and by 2013 were 3.5–4 percentage points lower. This suggests that a potentially important reason for the declining role of new firms in manufacturing productivity growth was fewer new firms. In the end, most productivity growth in a sector came from incumbents.

2.2 The role of the state sector in manufacturing

Over the last 40 years, market-oriented reforms significantly transformed the state sector in manufacturing. Wholly or majority state-owned firms accounted for 40 percent of real value added in manufacturing in 1998 and for less than 7 percent in 2013. In addition to reducing the size of the state sector, the reforms also resulted in an increase in manufacturing SOE productivity. We follow the approach in Dollar and Wei (2007) to estimate the differences in productivity and profitability between state-owned and private firms before and after the global financial crisis. The pooled regression specification is:

$$\ln Y_{j,t} = \alpha + \beta_1 SOE + \sum year + \sum \beta_{2,t} year \times SOE + \sum industry + \sum year \times industry + \sum province + \ln employment_{j,t} + error_{j,t}.$$

In each of the five regressions, $Y_{j,t}$ is a measure of the performance of firm j at time t: the log of average real revenue product of capital (calculated as the ratio of real value added to the real capital stock), the log of average real revenue product of labor (real value added divided by total labor), TFP, return on capital, or leverage (i.e., the ratio of total liabilities to total assets). The equation includes a set of dummy variables: firm ownership, year, industry (at the 2-digit level), province, and interaction terms for year/ownership and year/sector. The ownership variable, *SOE*, takes the value of 1 for majority state-owned enterprises and 0 for all other firms.[14] The sum of the coefficients $\beta_1 + \beta_{2,t}$ is interpreted as the relative efficiency of SOEs compared to private firms, holding other factors constant.

Including additional dummy variables in the regression allows us to separate the influence of factors unrelated to ownership structure, such as regional differences (for example, if SOEs are overrepresented in regions with lower returns), industry- and year-specific shocks (say, if SOEs dominate an industry exposed to a large but temporary negative shock such as high commodity prices), and also firm size, with larger enterprises (in the number of workers) being generally less productive.

Confirming the results of Hsieh and Song (2015) for the period 1998–2007, the gaps between returns to capital and labor in SOEs and in private competitors within manufacturing have

[13] Brandt et al. (2020) report similar results at the prefecture level over time.

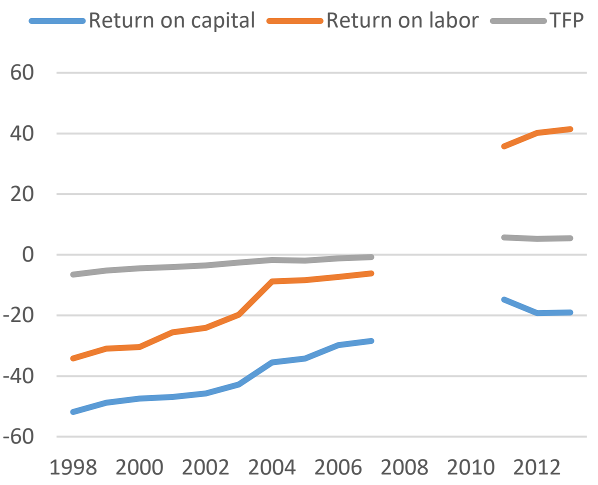
[14] SOEs are firms for which the state paid-in capital share is larger than 50 percent, and private are all other firms. Similar results are obtained if SOEs are firms with 30-percent or more state ownership and also if SOEs with foreign equity stakes are treated as non-SOEs (around 10 percent of majority state-owned companies had some foreign ownership in the later years of the sample; that share was smaller in the earlier years).

narrowed (Figure 10).[15] In the late 1990s, manufacturing sector returns to capital in SOEs lagged far behind private firms. Over time, the difference in returns declined to about 15 percentage points in 2011. This was still a sizable gap, which widened again after 2011, likely indicating continued SOE preferential access to capital.[16] The difference in the returns to labor between SOEs and private firms in the late 1990s was smaller than the one for capital—it declined over time and even turned positive in 2011–13.

The regression results for TFP show that the productivity gap between public and private manufacturing firms has also narrowed and become slightly positive in recent years. However, we interpret the differences in firm TFP with caution. Due to the lack of firm-level price data for outputs and inputs, only "revenue" TFP can be estimated (see the appendix). In revenue-based TFP measures, output is calculated using firm revenues deflated by industry-specific price indexes. Thus, revenue TFP combines quantity-based productivity and prices. Hence, differences in productivity between firms reflect changes in either efficiency or a firm's market power (i.e., firm mark-ups). For example, the efficiency of SOEs may decline relative to non-state firms, but a larger increase in mark-ups will result in a rise in their revenue productivity.

Figure 10 Relative efficiency of SOEs

(percentage points relative to private firms)



Source: Authors' regression estimates based on NBS's Industrial Enterprise Survey.
Note: The figure plots the coefficient on the ownership dummy by year.

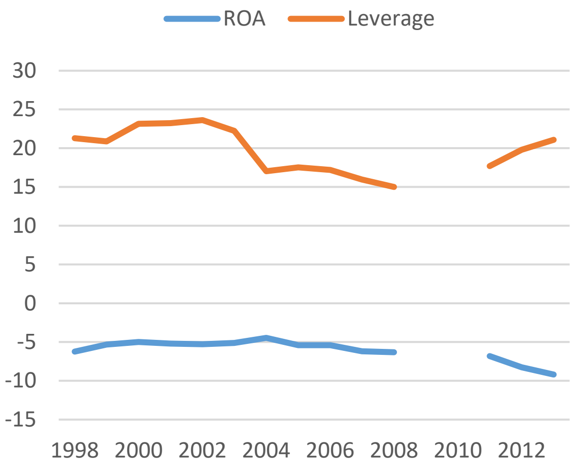
Finally, the estimated differences in return on assets (measured using operating profits) reveal that manufacturing SOEs were less profitable than their private competitors throughout the period. In 2013, SOE profits were 9.0 percentage points lower than those of private firms (Figure 11). The deterioration in relative profitability of the state-owned firms coincided with an increase in their relative indebtedness since 2008. While the leverage ratio (total liabilities over total assets) of SOEs relative to private firms in manufacturing was on a declining trend before the global financial crisis, our estimates suggest that relative leverage rose again. The latest available data—aggregate numbers based on China's Statistical Yearbook—suggest that the financial performance of SOEs weakened further between 2013 and 2016 but the negative trend may have started to reverse in 2017 (Figure 12).

[15] The regressions were estimated with standard errors clustered by firm. The results are available from the authors upon request.

[16] Cong and Ponticelli (2017) find that new credit under the 2009–10 economic stimulus package was allocated relatively more towards state-owned, low-productivity firms than to privately-owned, high-productivity firms. However, their results rely to a significant extent on the 2009–10 NBS Industrial Enterprise Survey data which we have found to be less reliable than in other years.

Figure 11 Relative profitability of SOEs

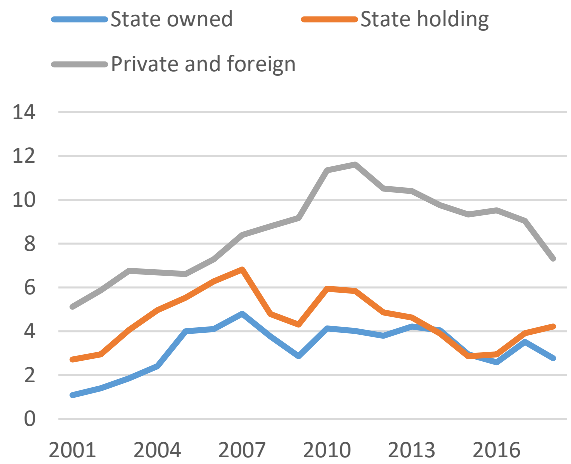
(percentage points relative to private firms)



Source: Authors' regression estimates based on NBS's Industrial Enterprise Survey.
Note: The figure plots the coefficient on the ownership dummy by year.

Figure 12 Return on assets of industrial firms, aggregate data

(profit as a share of total assets, percent)



Source: NBS; authors' calculations.

Starting in 1979, SOEs were given more autonomy and non-SOEs were allowed to enter the market, creating competition. After 1992, China prioritized ownership reforms, including passing the 1992 Company Law and 1993 Competition Law and developing an institutional framework for a business sector with diversified ownership. The authorities also allowed SOEs to shed redundant workers in the process of ownership change. In 1995, the policy of "grasping the large, letting go of the small" deepened SOE reform. In 2003, the State-owned Assets Supervision and Administration Commission (SASAC) was created with the goal to preserve and increase state-owned assets through restructuring and consolidation.[17] In line with other studies (e.g., Brandt and Zhu, 2010; Hsieh and Song, 2015), our results show that labor productivity and efficiency at manufacturing SOEs improved after 1998.

However, our findings also show that industrial SOE performance—both in terms of efficiency and financially—worsened after 2007. According to the multitask theory of SOE reform of Bai et al. (2006), SOEs are assigned a mix of commercial and policy objectives. As a result, SOEs play an important role in macroeconomic stabilization, maintaining social stability, investing in public infrastructure and in underdeveloped regions, which has come at the expense of financial performance. To be able to provide these public goods, SOEs have benefited from soft budget constraints, i.e. preferential access to government subsidies, tax exemptions, credit, and land (Kornai et al., 2003). The deterioration in SOE performance could be related to the fact that SOEs were called upon to fulfill their public policy objectives in the aftermath of the global financial crisis.

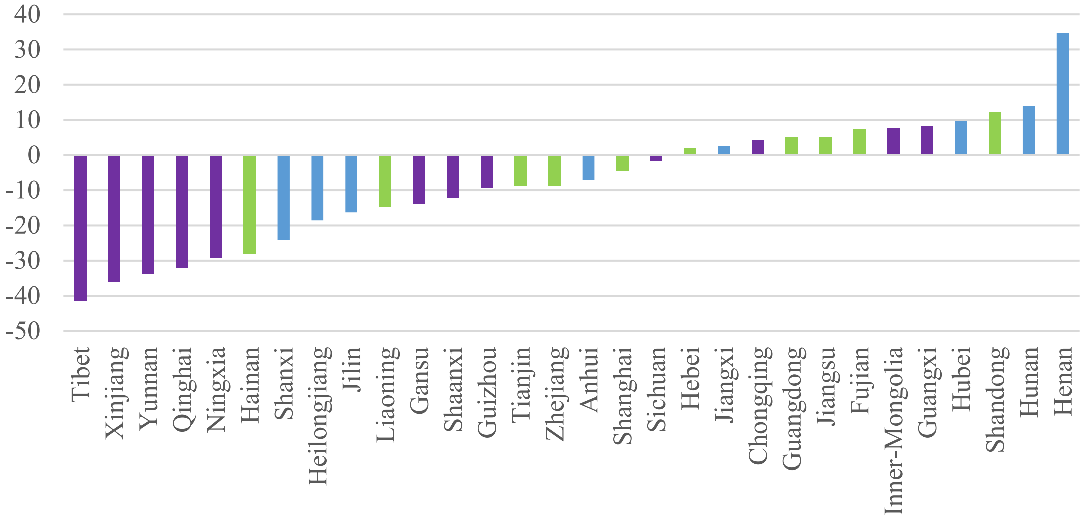
[17] Refer to Song (2018) for an overview of SOE reform in China.

2.3 Regional differences in productivity

In addition to difference in performance between SOEs and private firms, there is a large variation in returns across China's provinces. Firms in many provinces in the west have considerably lower returns to capital than firms in the central and eastern provinces (Figure 13). This is partly the result of the government's policies supporting regional development inland. Similarly, the returns to labor are on average lower in many western provinces.

Figure 13 Average difference in returns on capital across provinces, 1998–2013

(percentage points relative to Beijing, 1998–2013)

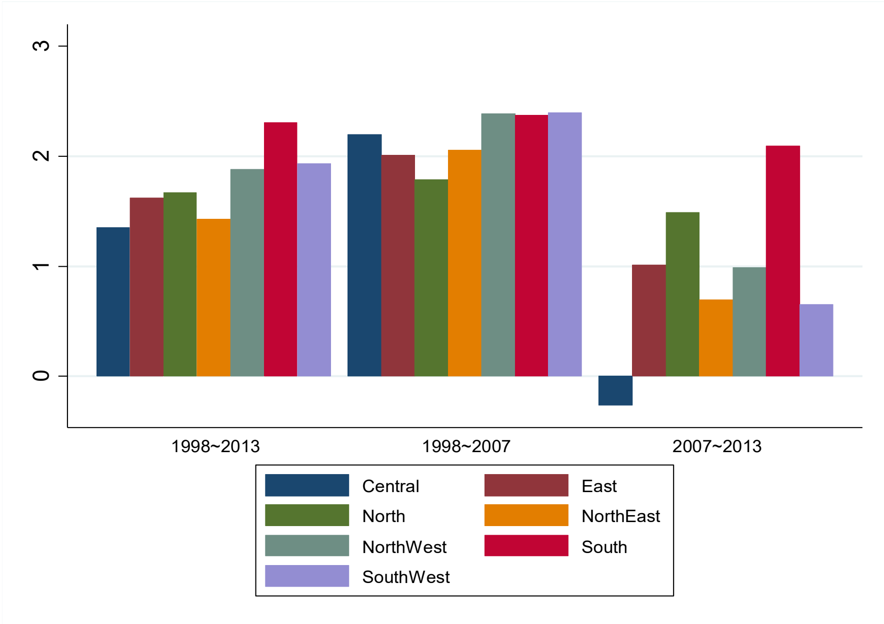


Source: Authors' estimates based on NBS's Industrial Enterprise Survey.
Note: The figure plots the coefficient on the on province dummies. Purple denotes a western province; green—an eastern one.

The difference in TFP growth performance between regions before and after 2007 is also notable. Remember the caveat that these relative comparisons may be biased if there were systematic differences between regions in the behavior of input and output prices. In 1998–2007, productivity growth was robust, observed in all regions, averaging around 2.0 percent a year (Figure 14). In 2007–13, productivity growth fell sharply in all but one region. Productivity growth fell least in the south, the region of the economy most likely exposed to the shock of the global financial crisis.

Figure 14 TFP growth by region

(percent a year)



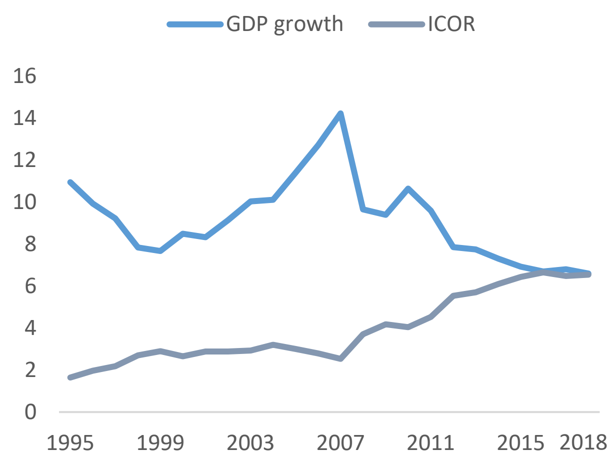
Source: Authors' estimates based on NBS's Industrial Enterprise Survey.

2.4 The declining efficiency of aggregate investment and credit

As TFP growth deteriorated, GDP growth has relied much more on investment in physical capital, but such investments have brought much lower returns to growth than in the past. In response to the global financial crisis, China implemented a large public sector stimulus which concentrated on investments in infrastructure and housing. Given that public infrastructure is no longer a major constraint on growth (see next section), government investment now faces the challenge of diminishing returns. China's incremental capital-output ratio (ICOR) has risen significantly in recent years, pointing to a declining impact of investment on growth (Figure 15).

Figure 15 ICOR and real GDP growth

(yoy, percent)

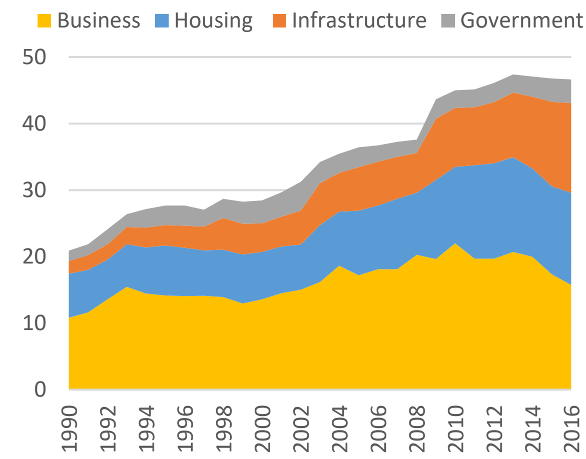


Source: NBS; authors' calculations.
Note: The ICOR is calculated as the ratio of average real gross fixed capital formation in periods *(t-1)* and *(t)* to the change in real GDP between *(t)* and *(t-1)*.

Much of the increase in the economy-wide ICOR can be explained by lower returns to capital in infrastructure and real estate. During the years of rapid deterioration in the ICOR, the composition of investment in China changed significantly. The share of capital formation in the business sector declined, while the shares of infrastructure and housing increased (Figure 16). At the same time, the capital-output ratio in the infrastructure sector almost doubled, and that in housing increased by 56 percent, contributing most of the rise in the aggregate capital-output ratio (and thus in the ICOR) (Figure 17). By comparison, the capital-output ratio in the business sector went up by about a quarter (Herd, 2020).

Figure 16 Gross capital formation by sector

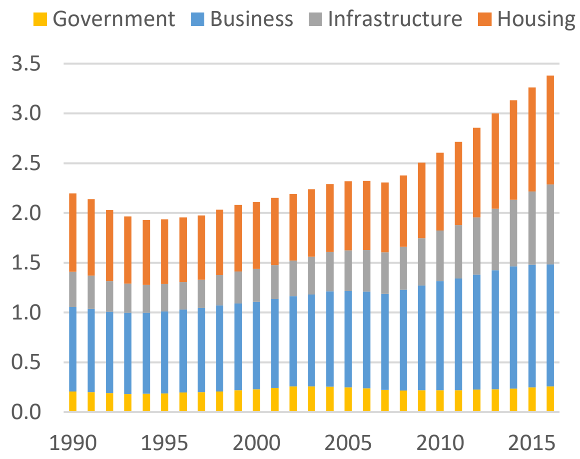
(share of total gross capital formation, current prices, percent)



Source: Herd (2020).

Figure 17 Capital output ratio by sector

(ratio of capital to total GDP)

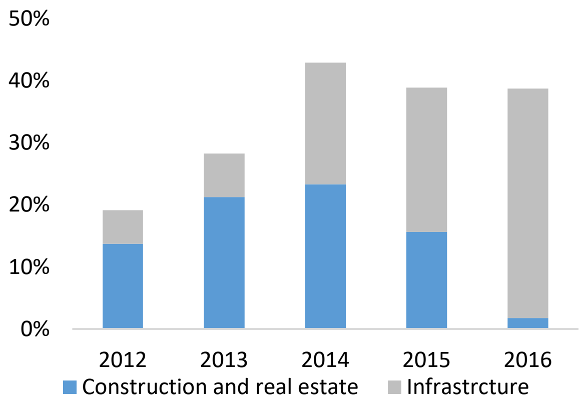


Source: Herd (2020).

The public investment stimulus also contributed to high corporate leverage. Credit to the nonfinancial sector grew by more than twice the pace of GDP. A significantly larger share of new credit went to infrastructure in 2014–16 (Figure 18). In 2016, infrastructure, construction, and real estate accounted for 50 percent of the outstanding stock of debt (Figure 19).

Figure 18 Share of new bank credit to infrastructure, construction, and real estate

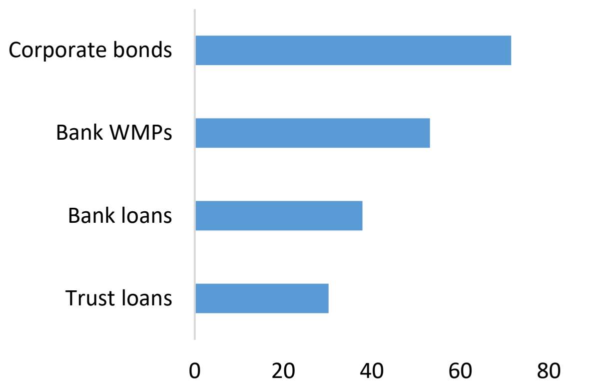
(percent of all new bank credit to the corporate sector)



Source: CBRC anunal report; authors' calculations.

Figure 19 Share of infrastructure, construction, and real estate debt, 2016

(percent of selected types of corporate debt stocks)

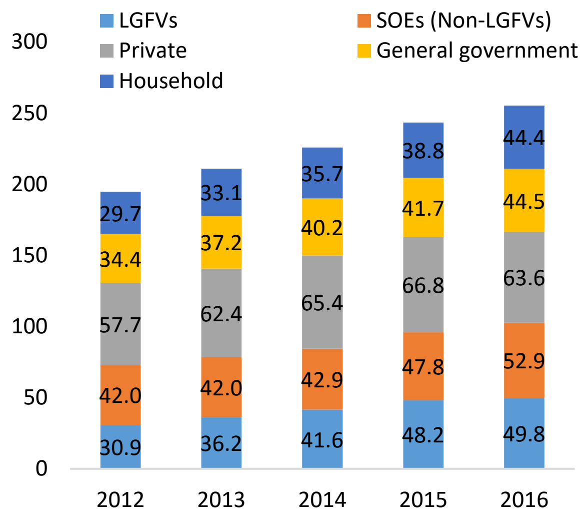


Source: CBRC annual report; Wind Info; CEIC; China Bank WMP annual report; Trustee Association of China; authors' calculations.

SOEs accounted for most of the recent rise in corporate leverage, and the fastest-growing component of SOE debt was for local government financing vehicles (LGFVs). SOE debt rose from 73 to 103 percent of GDP in 2012–15 (Figure 20). Accelerated debt accumulation by LGFVs explains the rapid increase in the share of SOE debt (Bai et al., 2016). Based on the Wind database sample of firms in China that issue bonds, the liabilities of LGFVs that issue bonds grew by more than 20 percent a year during 2012–16 if the effect of the local government debt swap program is netted out (Figure 21).[18] In contrast, the liabilities of other enterprises increased by 13 percent a year in 2015–16. While the headline growth in LGFV liabilities declined in 2015 and 2016, this can be attributed to the bond swap scheme that transformed part of their debt into government bonds.

Figure 20 Estimated composition of debt

(percent of GDP)

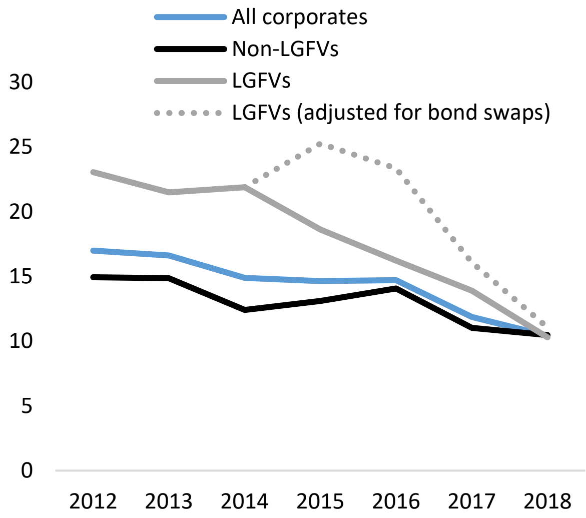


Source: BIS; PBC; Wind Info; CEIC; Authors' calculations.

Note: Corporate decomposition estimated based on information from bonds and bank credit.

Figure 21 Growth in liabilities of LGFVs and other corporations

(annual growth in total liabilities, percent)



Source: Wind Info; authors' calculations.

The recent boom in public investment and credit to the corporate sector is reflected in the growing exposure to risk among smaller regional banks and the rapid increase in shadow banking activities. Empirical evidence links the acceleration in shadow banking growth after 2012 with the financing needs of LGFVs, including the rollover of maturing bank loans taken on at the time of the 2009 fiscal stimulus (Chen et al., 2017).

Regional banks now account for a large share of aggregate assets in the banking sector and their portfolios tend to be riskier compared with the Big 4 state-owned banks.[19] While the four largest banks accounted for the majority of assets before the financial crisis, their share fell to 37 percent in 2016 (central policy banks accounted for another 10 percent). Smaller banks held most banking assets, with their assets increasing at double the rate of the Big 4 banks (Figure 22). And the exposure of smaller banks to risk grew rapidly in 2015–16. The share of

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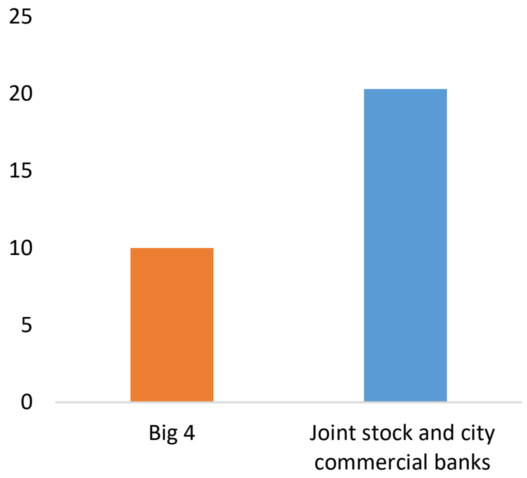
[18] The local government debt swap program was introduced in 2015 to convert LGFV debt recognized as public into local government bonds.

[19] Bank of China, China Construction Bank, Industrial and Commercial Bank of China, and Agricultural Bank of China.

investment receivables (often representing shadow credits of nonbank affiliates) reached 16 percent of the total assets of smaller banks, compared to 1.6 percent for the Big 4 (Figure 23). Adding to financial vulnerabilities, many wealth management products (WMPs) were held by banks off-balance sheet. WMPs equaled 18.5 percent of the assets of smaller (joint stock and city commercial) banks in 2016, as opposed to 8.7 percent for the Big 4.

Figure 22 Growth of total assets, 2015-16 average

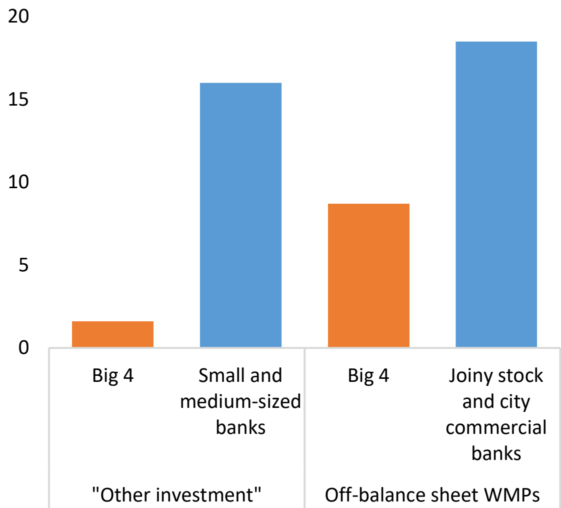
(annual average growth in total assets, percent)



Source: PBC; WIND Info; authors' calculations.

Figure 23 Selected commercial bank indicators, 2016

(as a share of balance sheet assets, percent)



Source: CEIC; PBC; Wind Info; authors' calculations.

The recent rapid expansion in credit to the nonfinancial sector is likely to have hindered productivity growth from two important perspectives. First, the allocation of credit toward infrastructure and housing has reduced the resources available to higher-productivity sectors and firms. For example, LGFV borrowing through loans and bonds crowded out investment by domestic private firms (Huang et al., 2017). Second, the growing burden of nonfinancial sector debt, at 250 percent of GDP in 2019, will itself slow growth in the medium term if it is not addressed through deleveraging. Empirical evidence suggests that the negative impact of a high debt burden on growth can be considerable even in the absence of a financial crisis (Reinhart et al., 2012). Significant debt service costs increasingly crowd out resources available for investment. Furthermore, high debt levels tend to raise risk premia and financial market stress, which drives interest rates higher and discourages investment.

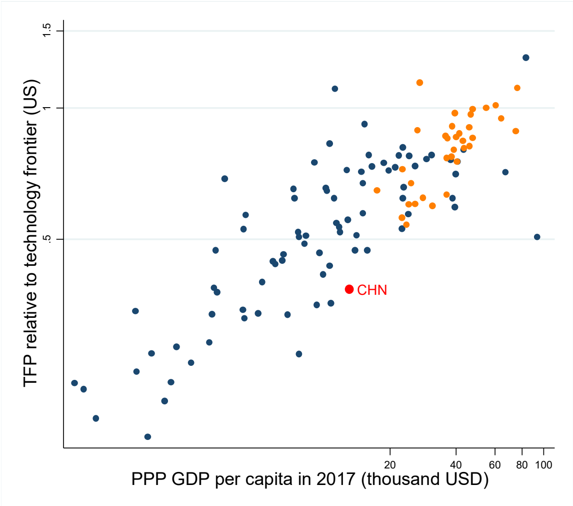
3. China's still high growth potential

Even after four decades of 10-percent growth per year, China's growth potential remains high. Per capita income in China is less than a quarter of the high-income country average at market exchange rates and less than a third in PPP terms. Despite advances in sectors such as e-commerce, fintech, high-speed trains, renewable energy, and electric cars, China generally remains distant from the global technological frontier. TFP is less than half that in the United States and lags the TFP levels in a number of middle-income countries (Figure 24). Hence, there is scope for China to catch up to global leaders through the transfer of technology and state-of-the-art management practices. In addition to catch-up growth, China will continue to build capacity for innovation to extend the global technology frontier (World Bank and DRC, 2019).

China will also have to continue to invest in its human capital, as the quality of its labor force catches up to the OECD countries (Figure 25). Over 30 years, China has made primary education universal and expanded access to education at all levels. To obtain greater benefits from technology diffusion from abroad and to nurture frontier discovery, China now has to focus on investing in the skills of its labor force (Eaton and Kortum, 1996; Seck, 2012).

Figure 24 China's TFP relative to the global technology frontier, 2017

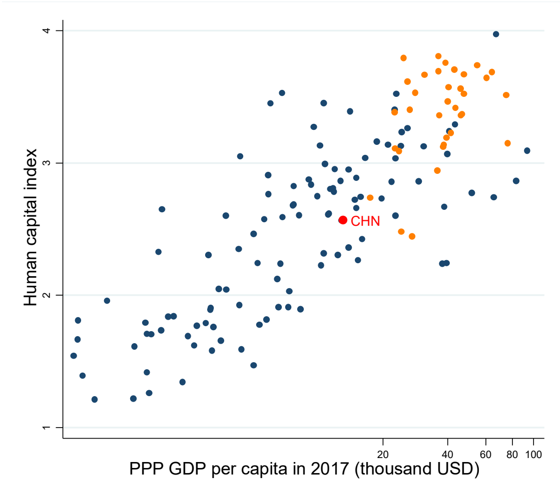
(both axes in log scale)



Source: PWT 9.1; authors' calculations.
Note: OECD countries in orange.

Figure 25 Human capital index, 2017

(x-axis in log scale)



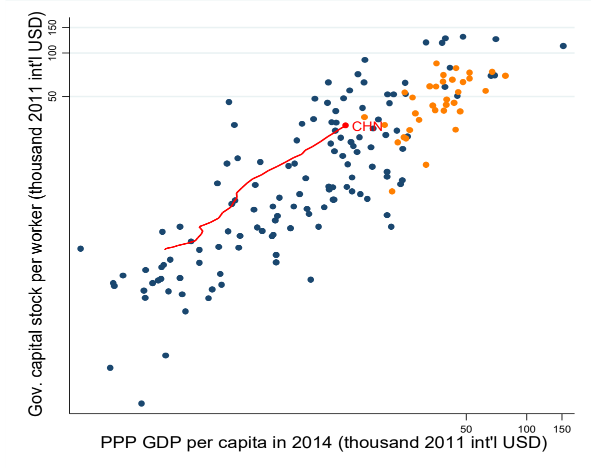
Source: PWT 9.1; authors' calculations.
Note: OECD countries in orange.

Over the past four decades, China has made such great strides in physical capital deepening that its government capital stock per worker has already reached OECD levels (Figure 26).[20] This suggests that there may be limited economic gains from future high growth in government investment. But there is scope for rapid growth of private capital. Starting from a very low base in the 1970s, private sector capital increased at a remarkable pace but remains considerably below advanced country levels (Figure 27).

[20] Government investment in the IMF data set accounts for capital spending by central and subnational governments, so that comparable data are available for a large number of countries. The total infrastructure stock for China is possibly underestimated, as infrastructure investment by state-owned enterprises (SOEs) is included in the private capital stock. For details refer to
https://www.imf.org/external/np/fad/publicinvestment/data/info.pdf.

Figure 26 Government capital stock per worker

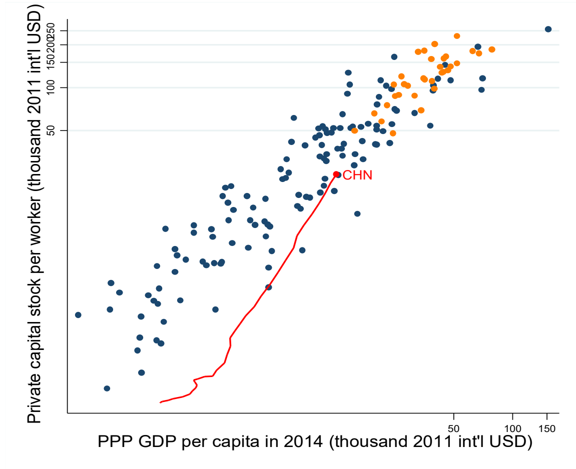
(China's general government capital stock per worker at historical levels of income per capita (red line) compared with 2014 levels in other countries, thousand 2011 international US dollars, log-scale)



Source: IMF; PWT 9.1; authors' calculations.
Note: OECD countries in orange.

Figure 27 Private capital stock per worker

(China's private capital stock per worker at historical levels of income per capita (red line) compared with 2014 levels in other countries, thousand 2011 international US dollars, log-scale)



Source: IMF; PWT 9.1; authors' calculations.
Note: OECD countries in orange.

4. Policy implications

The macro- and firm-level evidence presented above identifies a sharp drop in productivity growth as an important driver of China's declining economic growth. To enhance productivity growth in recent years, China's policy makers have focused on fostering innovation. By some measures, China's innovation capacity has improved steadily in recent years, placing the country 14th on the Global Innovation Index (Cornell University et al., 2019).

At the same time, China remains, on average, quite distant from the global technology frontier and thus has substantial remaining potential for catch-up growth. The adoption of more advanced technology and management skills from high-income countries, as well as improving the efficiency of resource allocation, can provide a less costly and more certain source of growth over the medium term.

However, China's access to foreign technologies has become more challenging in recent years. The country's overseas investment expansion has raised concerns in high-income countries over reciprocity in investment conditions. In 2017, China introduced a negative list for FDI which restricts foreign investment in listed sectors and requires equal treatment of domestic and foreign firms in the rest of the economy. In 2018, foreign ownership restrictions in financial services and car, ship, and aircraft manufacturing were reduced and, in 2020, a new FDI law will take effect. These measures address some of the concerns over market access, intellectual property rights, and foreign investor protection, but their impact will depend on successful implementation.

Achieving productivity growth through reallocation will require deepening reforms to increase the role of the market, the private sector, and competition. China has recently introduced policies to improve the business climate. Besides the above measures to allow more foreign investment, in 2019 China climbed up to 46th in the World Bank Ease of Doing Business rankings, gaining more than 30 positions from the previous year (World Bank, 2019). The analysis in this paper points to additional reforms necessary to facilitate market entry and exit, deal with debt distress, and harden the budget constraints of local governments and SOEs.

The exit of less efficient firms is one of the main sources of productivity growth in many countries, but in China the contribution of market exit to productivity growth is negligible and even negative in 2007–13. Strengthening market institutions for the effective management of insolvency, firm restructuring, and bankruptcy could accelerate productivity growth. These institutions are also critical for the efficient pricing of risk in financial intermediation and credit allocation. China has recently made some progress in this area, with rising corporate defaults and debt restructuring through creditor committees affecting the pricing of risk in credit markets, but more reform is needed (IMF, 2019).

This paper has also underlined the importance of achieving a more efficient, market-based allocation of credit to improve productivity growth. Deeper reforms that change the incentives and constraints for subnational governments are necessary. Over the past 40 years, local governments have been a key driver of development, operating under strong incentives to maximize regional growth and investment. However, future productivity-led growth will entail elevating the role of markets in allocating resources largely through imposing stricter financial discipline.

A comprehensive budget reform in 2014 required local governments to shift from off-budget borrowing through LGFVs to issuing bonds and adhering to medium-term budget and debt sustainability frameworks. However, implementation in 2015–16 was mixed. Tight bond quotas and high investment growth targets set by Beijing meant that many local governments resorted to off-budget public-private partnerships (PPPs), government-guided investment funds, and continued borrowing by LGFVs.

Since 2016, the authorities have undertaken addition measures, such as drawing a national inventory of contingent government liabilities and requiring LGFVs to be transformed into SOEs with no preferential treatment or government guarantees (World Bank, 2017). In 2019, new rules specified that public investment should be channeled to sectors where resources cannot be effectively allocated by the market.[21] Financial regulators set new limits on wealth management products and on interbank market funding; more comprehensive monitoring of bank risks, including those off-balance sheet; improved bankruptcy provisions; the use of creditor committees to restructure debt; and new rules for asset management products that are consistent across the different regulatory bodies to minimize arbitrage. A State Council Financial Stability and Development Commission was also established to improve regulatory coordination. These policies led to a deceleration in growth in credit to the non-financial sector from 19.4 percent in 2016 to 10.3 percent in 2018. LGFV borrowing and infrastructure investment slowed considerably and non-bank financing began to contract in 2018.

Additional measures are necessary to ensure the sustainability of recent fiscal reform gains. First, long-run productivity growth and financial sustainability can be promoted through a clear shift in emphasis in the performance evaluation criteria for local officials, with less emphasis on economic growth and investment and more emphasis on prudent budgetary and debt management. Second, the central government should avoid burdening subnational governments with unfunded mandates, including implicit directives to finance a public investment stimulus. National priorities for public investment in excess of what can be financed sustainably at the local level should become the explicit financial responsibility of the central government. With time, as effective markets for local government debt develop, they can do

[21] State Council Order No. 712 [2019]: www.gov.cn/zhengce/content/2019-05/05/content_5388798.htm.

more to impose financial discipline on local governments, as in many other countries. The need for imposing administrative restraints from above will diminish.

As local government budget constraints are gradually hardened to enforce greater financial discipline, programs will also be needed to resolve debt distress at individual local governments and banks. The government takeover and recapitalization of three mid-sized banks in May-August 2019 have underscored this risk. China has the requisite buffers to deal with debt distress in an orderly manner, but a resolution regime which is applied consistently across banks will also be required.

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Appendix

There are a number of data availability and measurement issues in the construction of the post-2007 productivity estimates on the basis of the NBS Industrial Enterprise Survey. First, we have access to data for 2008, 2011, 2012, and 2013. Data for 2009 sum up to reported totals for above-scale firms in China's Statistical Yearbook (which reports aggregate sector-level data) but are inconsistent at the individual firm level with data for 2008 and 2007. There are also no firms that report 2009 as their year of establishment. As a result, we chose not to use them. We do not have data for 2010. Another challenge is the lack of firm-specific input and output prices. To eliminate outliers (for example, due to measurement/recording errors), we trimmed 5 percent of the extreme values on both ends of the distribution for each year and industry pair.

Second, value added at the firm level is not reported after 2008 and needs to be imputed using an identity that links value added with other variables in the survey. Third, after 2010, the minimum-size threshold for a firm to be included in the sample rose from sales of RMB 5 million to RMB 20 million. Depending on the size distribution of productivity and the share of total sales by firms with sales between RMB 5 million and RMB 20 million, this may bias the comparison of sectoral TFP before and after 2010. Fourth, there is a significant increase in reported employment in 2013. Finally, there appears to be a systematic upward bias in the reported gross value of industrial output (GVIO) that increases over time.

We explain below how we deal with each of these challenges. The implication of the second issue for estimated productivity and productivity growth is difficult to sign. If the 2013 employment data are left uncorrected, it would lead to an underestimation of TFP growth. The change in the firm survey inclusion threshold and the upward bias in GVIO, on the other hand, may lead to a slightly overestimated productivity growth after 2007 relative to previous years.

a. Missing years and lack of firm-specific prices

To deal with the large gap in observations between 2008 and 2011, we use translog production function estimates at the two-digit sectoral level obtained from the unbalanced firm-level data in 1998-2007 to estimate productivity in levels at the firm level in 2008, and then in 2011-13. Brandt et. al. (2017) provide a detailed discussion of the original production function estimation. We updated the input, output, and capital stock deflators through 2013 for purposes of converting nominal values into real.

Because firm-specific prices are not available, we have to use input and output deflators at the sector level.[22] As a result, we are only able to estimate firm "revenue" productivity. An important implication of this for our analysis is that differences in measured revenue productivity between firms within a sector will be a product of the differences in "true" efficiency as well as differences in firm market power as reflected in their markups over marginal cost. The same is true for changes over time in firm-level revenue productivity. Thus, for example, an increase in a firm's revenue productivity can be a consequence of either an improvement in efficiency or an increase in markups because of expanding market power.

[22] However, the use of sector-level price deflators does not pose problems for the estimation of the coefficients of the production functions.

Fortunately, we do not face the same problem at the sector level. By aggregating revenue productivity over all firms within a sector, using as weights each firm's market share, we obtain a measure of true production efficiency in that sector.[23] Differences between years in this measure provide a measure of the change in true productivity. Note that this will not hold true when aggregating revenue productivity within a sector separately by type of firms, e.g. SOEs versus private, entrants versus incumbents. Differences in true productivity by type of firm will be conflated with changes in relative market power between firm types. Only under the assumption that relative market power remains the same, i.e. input and output prices change at the same rate by type of firm, will changes in revenue productivity map exactly into changes in efficiency.

b. Imputation of value added

In order to recover TFP from a gross output production function, we need to impute the values of intermediate input for years when the information is missing. There are two issues to address, one is for variable intermediate input and the other is for variable labor cost. We first use the information on output value, sales revenue, and sales cost to estimate production cost. Under the assumption that production cost is proportional to output value by the same factor as the sales cost over sales revenue ratio, we obtain an estimate of total production cost as output times the ratio of sales cost to sales revenue. We then subtract labor cost and capital depreciation from the total cost to impute the cost of intermediate input:

Intermediate input = output × sales cost/sales revenue – labor cost – depreciation

However, the information reported on labor costs changes over time. For 1998-2002, we have data on the wage bill, employment insurance, and welfare; for 2003 we also have pension benefits; for 2004-07 housing benefits; for 2008 the wage bill and welfare; and for 2011-13 only the wage bill. To obtain a consistent measure of labor cost, we use the 2004-07 data to construct a 4-digit industry multiplier—the average of the ratio of total labor cost (the sum of the wage bill, employment insurance, welfare, pension and housing funds) over the wage bill—and apply this multiplier to the value of the wage bill in years with incomplete information.

The imputed value added has three components: operating profits before tax (term 1); adjusted labor cost (term 2), capital component (term 3), and value added tax (VAT) (term 4).

Imputed value added = output × (1– sales cost/sales rev) + wage bill × industry multiplier + depreciation + VAT

c. Impact of inflated GVIO on the imputed values of VA and TFP

Over time, the total value added for above-scale firms increases relative to GDP by industry as reported in the national accounts. The inflation in the reported GVIO (*output* in the equation above) affects imputed value added through the first term. Given that the share of that term in

[23] This can be seen by noting that $TFPR_{it} = \omega_{it} + \epsilon_{it} + \left(p_{it}^{Q} - \overline{p_t^{Q}}\right) - \beta_m \left(p_{it}^{M} - \overline{p_t^{M}}\right)$, where $TFPR$ is revenue productivity, ω_{it} is efficiency, and $\left(p_{it}^{Q} - \overline{p_t^{Q}}\right)$ and $\left(p_{it}^{M} - \Delta\overline{p_t^{M}}\right)$ are the deviations of firm output and input prices from the sector means. Aggregating over all firms, we are left with $TFPR = \omega$.

value added is around 50 percent, the inflation in VAT would be about 50 percent of the inflation in GVIO.

The inflation of GVIO affects estimated TFP via two channels: directly through the bias in our measure of output; and indirectly through the imputed input in the gross output production function. Recall that output is included in the first term of the equation for imputed intermediate input above.

Given a ratio of sales cost to sales revenue of 85 percent, labor and capital costs of roughly 13 percent of total cost (or 11 percent of total output value), and intermediate input of 87 percent of total cost (or 74 percent of total output value), an inflation by a factor of Y in GVIO will result in the inflation by a factor of X in imputed intermediate input:

$$X = (0.85 \times Y - 0.11)/0.74,$$

where $0.85 \times Y$ is the inflated estimate of total cost and 0.11 represents the reported (accurate) labor and capital cost. Given an output elasticity of materials of 0.8, the bias in the TFP estimate will be equivalent to $(Y - 1) - 0.8 \times (X - 1)$.

d. Employment data for 2013

Total employment rises by 40 percent between 2012 and 2013 in the firm-level data, with an increase observed across all firm types, sectors, and regions, and is not related to the entry of new firms. Rather, it is a product of an overall shift of the distribution of firm-level employment to the right. The NBS did not report aggregate employment for above-scale firms in the 2014 and 2015 Statistical Yearbooks but reported totals for 2013-15 in the 2016 Yearbook. Total employment by sector is also reported in the 2013 China Economic Census Yearbook, which was published in 2015. We use the employment figures reported by province and by sector from the Census to adjust downwards the data in the Industrial Enterprise Survey.

e. Change in minimum-size threshold

After 2010, the minimum-size threshold for a firm to be included in the sample rose from sales of RMB 5 million to RMB 20 million. If the firms with sales between RMB 5 million and RMB 20 million are systematically different from the larger firms, the analysis of productivity could be biased. For example, if these firms have higher levels of productivity on average, removing them from the sample will reduce the estimate of industry-level TFP. Thus, in comparison with TFP in earlier years, TFP growth would be underestimated.

To examine this possibility, we regress firm-level TFP on an indicator for firm size (RMB 5 million to RMB 20 million and above) and include industry fixed effects. The results show that the productivity of these firms is on average lower than that of larger firms. This “discount” declines over time and is much smaller in 2008 than in 2007 but, conservatively, it is about 15 percent. Second, the role of these firms has declined over time and by 2008 they comprised 4.1 percent of output. Given that industry TFP is a weighted average of individual firm TFP, these results suggest that industry TFP and TFP growth are overestimated after 2010 and 2008, respectively, compared to earlier years. However, the bias is not likely to be too great as these firms represent a relatively small share of the aggregate.