China Economic Review 22 (2011) 133–150

Contents lists available at ScienceDirect

China Economic Review

Structural change, productivity growth and industrial transformation in China ☆

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ARTICLE INFO

Article history:
Received 15 November 2009
Received in revised form 1 October 2010
Accepted 26 October 2010
Available online 31 October 2010

JEL classification:
L16
D61
O14
D24
O41

Keywords:
Factor reallocation
Structural change
Productivity growth
Industrial transformation

ABSTRACT

China's industry has experienced robust growth under persistent structural reform since 1978. By estimating the stochastic frontier sectoral production function, we find that the TFP growth has exceeded the quantitative growth of inputs since 1992, but the contribution of productivity to output growth declines after 2001. Using a decomposition technique, we then find that the structural change has contributed to TFP and output growth substantially but also decreasingly over time. Empirical analysis reveals that the reforms in factor markets and industrial structure significantly account for the overall trend and the sectoral heterogeneity of factor allocative efficiency during the industrial transformation process.

1. Introduction

Kuznets (1979) states that "it is impossible to attain high rates of growth of per capita or per worker product without commensurate substantial shifts in the shares of various sectors." From this perspective, China presents a fortuitous research case because its economy has performed spectacularly well since its structural reform from central planning to markets in 1978. Between 1978 and 2008, China's GDP grew at 9.9% per year and became much more stable than before. Meanwhile, China's economic transition also underwent dramatic and continuing structural changes. By structural change we mean that production factors are reallocated from less productive industries or sectors to more productive ones.

The hypothesis that structural change is an important source of growth was initially developed in Lewis' classical models of a dual economy (Lewis, 1954) and is a central element in Maddison's growth-accounting literature (Maddison, 1987). The effect of structural change and factors reallocation in the theory of economic development is extensively used by Chenery, Robinson, and

☆ The authors appreciate the opportunity to present earlier drafts of this paper at WISE of Xiamen University 2009; the CCES (Fudan University) and EGC (Yale University) Joint Conference on Transition and Economic Development (TED) 2009; the 10th World Congress of the Econometric Society 2010 (ESWC2010). We are particularly grateful for the valuable suggestions of T.N. Srinivasan, Mark Rosenzweig, Cheng Wang. We also would like to thank Kaivan Munshi, Duncan Thomas, Dilip Mookherjee, Tim Besley, Yongmiao Hong, Ying Fang, Dean Karlan, Junsen Zhang, Zheng Song, Mushfiq Mobarak for their beneficial comments. The grant from Chang Jiang Scholar Appointment Program is also acknowledged.

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1043-951X/$ – see front matter
doi:10.1016/j.chieco.2010.10.003

Syrquin (1986) and Syrquin (1995), who show that it is an important factor explaining growth performances. The models of industrial development proposed by Lucas (1993) from the supply side and Verspagen (1993) from the demand side also stress the importance of structural change in productivity growth. Harberger (1998) vividly presents a "mushroom-process" where continuous factors shifts into specific dynamic sectors drive growth and then productivity varies considerably across sectors. This vision of growth contrasts with a "yeast-process" in which economy-wide growth tendencies predominate. Many researchers have found that the effect of structural change and factors allocation on economic performance is significantly positive (Akkemik, 2005; Berthelemy, 2001; Nelson & Pack, 1999; Ngai & Pissarides, 2007). Some researchers find that the effect does not exist or is very small (Caselli, 2005). In the examination of the role of structural change in productivity growth in the manufacturing sector of the four Asian NIEs, Timmer and Szirmai (2000) refer to this positive effect of factor reallocation across sectors on industrial growth as the structural-bonus hypothesis. This terminology has extensively been used since then.

In the case of China, the central government opted for the heavy-industry-oriented development strategy to catch up with the developed world after the overthrow of infant capitalism and 3 years of land reforms over half a century ago. The strategy of utilizing China's comparative disadvantage has resulted in the persistence of a dual economy, leading to massive distortion in the factor market. The danger of the imminent collapse of China's economy pushed the central government to commence economic reforms since 1978. The evolution of China's market economy from its old system necessitated profound structural changes. As shown in Fig. 1, for example, there is a substantial fall in the share of labor force in primary industry from 83.5% in 1952 to 39.6% in 2008 and a steady increase in tertiary industry, broadly consistent with the general characteristics of the structural transformation process documented in the literature of transitioning economies. The composition of labor force in second industry increased continuously from a low of 7.4% in 1952 to a peak of 27.2% in 2008 which is different from the experience of industrialized economies with a hump-shaped pattern. This indicates that China's industrialization is still in the early phase and has room to absorb more labor and further develop its labor-intensive sectors. Corresponding to this structural change, the share of industrial value-added has increased from a low of 17.6% in 1952 to a high of 44.1% in 1978 under the catch-up strategy and has remained stable around 40% until today. The share in primary industry decreased continuously to only 11.3% in 2008 while the share in services also grew sharply after the reform.

Many researchers investigate the effect of structural change across three strata of industry or across regions on China's productivity growth and economic performance; for example, see Fan, Zhang, and Robinson (2003), Fleisher and Yang (2003), Wu and Yao (2003), Heckman (2005), Au and Henderson (2006), Bhaumik and Estrin (2007), Bosworth and Collins (2008), Gong and Lin (2008), to name a few. They do not discuss the factor shifts across industrial sectors. Economists also believe that resources are restricted within sectors, and as the industrial development literatures suggest, it is necessary to reallocate the factors across sectors to boost industrial productivity and output growth. Moreover, China is on its way towards industrialization and the industry is the principal part of the Chinese economy. Industrial reform truly reflects China's entire transition experience; therefore, this paper emphasizes the structural reform in China's industry and assesses its affect on industrial development. Though scholars acknowledge the importance of structural change on industrial growth, very few researchers have tried to quantify the contribution to growth from restructuring the industrial structure and reallocating factors across sectors over time. To fill the gap, our study investigates the structural impact during the entire reform period (1980–2008) using the input and output panel of 38 two-digit industrial sectors in China. This differs from studies using aggregate data, which is unable to reveal the sectoral heterogeneity. We also do not choose the firm-level data due to its unavailability in the former two decades of reform period (1978–1998) and then its inability to capture the entire picture of Chinese industrial reform. To evaluate the factor allocation efficiency, we adopt the methodology developed by Battese and Coelli (1992) and Kumbhakar (2000) to estimate the

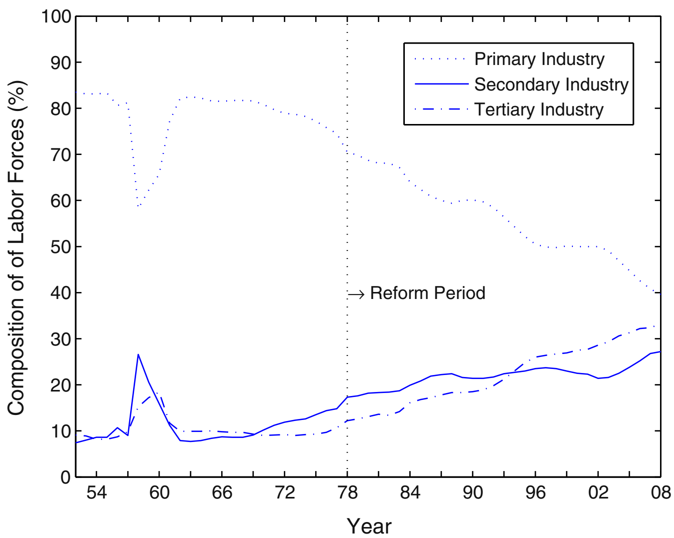

Fig. 1. Composition of labor forces of three strata of industry in China (1952–2008).

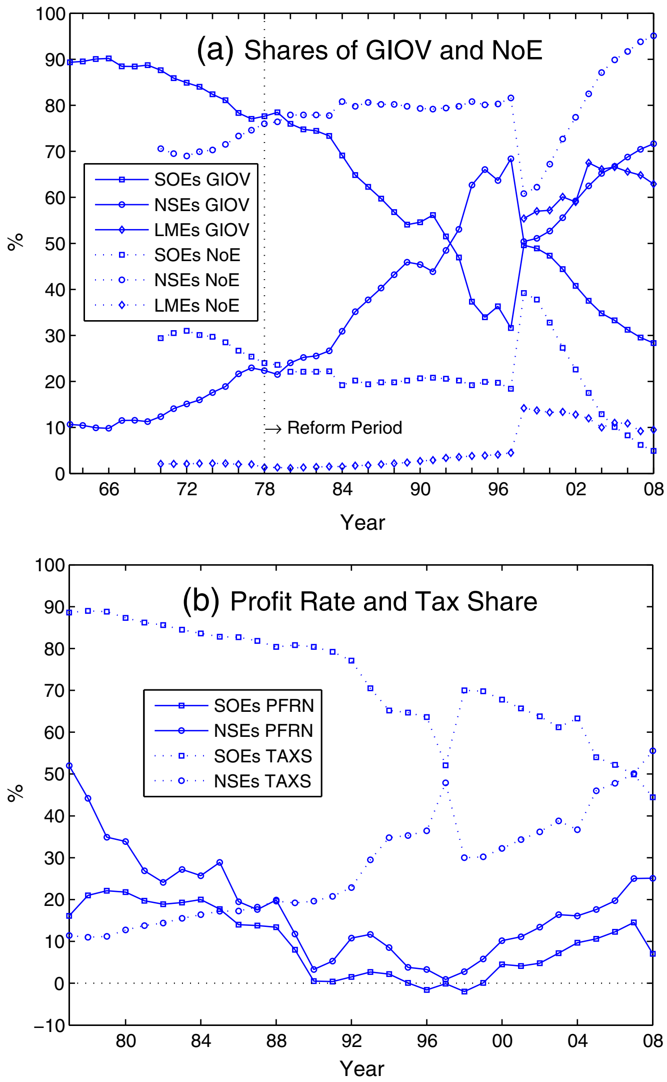

Fig. 2. The evolution of industrial structure in China. Note: GIOV—gross industrial output value; NoE—number of enterprises units; PFRN—profit rate to net value of fixed capital.[1]

sectoral stochastic frontier production function and decompose the measured total factor productivity (TFP). This technique differs from the shift-share analysis of decomposing the labor productivity or TFP, normally used in the studies of structural bonus such as Timmer and Szirmai (2000), Kumar and Russell (2002), Akkemik (2005) and some surveyed in Section 2.2.

The paper is organized as below. The process of industrial structural reform since 1978 and industrial productivity estimates in China are briefly surveyed in Section 2. In Section 3 we explain the panel data analyzed in this paper and address the methodology. We report the pattern of estimated factor allocative efficiency (so-called structural bonus) in Section 4, and in Section 5 we discuss how structural change, the driving force of industrialization in China, influences factor allocative efficiency. We offer conclusions in Section 6.

2. Review of industrial structural reform and productivity estimates in China

China has changed the industrial development strategy from heavy-industry-oriented before the reform in 1978 to based on the parallel importance of light and heavy industry under the reform period, which has released great productive energy, leading

[1] The sudden change of the trend of some variables in the year of 1998 is due to the inconsistency of the statistical scope provided in China Statistical Yearbook (before 1997, the industrial statistics includes both urban industry and rural industry at the township level; while the industrial figures reported after 1998 include state-owned and non-state-owned industrial enterprises only above the designated size, i.e., those with annual revenue from principal business over 5 million yuan).

to more stable and higher than average growth rate of industrial GDP (11.7% annually between 1980 and 2008). Accordingly, structural change has occurred and industrial productivity has been improved. Firstly, industrial reform and corresponding structural change in China during each reform period are briefly reviewed. Then we will survey the industrial productivity growth estimated in the literatures.

2.1. Structural reform in Chinese Industry

2.1.1. Trial phase (1978–1992)

The first period can be characterized by Deng Xiaoping's metaphor "crossing a river by feeling for the stones" (Mozhe Shitou Guohe), which reflected the exploratory nature of early reform.

Inspired by the successful reform in the countryside in the first 6 years of this period, the Chinese Communist Party (CCP) initiated industrial reforms in urban areas in 1984. The reform features at this phase only involved restructuring the operating rights of state-owned enterprises (SOEs) without touching on the issue of ownership rights. A contract responsibility system was mainly implemented in the large and medium-sized enterprises (LMEs) and a leasing system was used in small ones to transform SOEs' operating mechanisms in order to increase autonomy and incentives. Government also hardened SOEs' budget constraints by changing their fund resources from finance to credit (bogaidai).

Concurrently, the rural nonfarm industry, named township and village enterprises (TVEs), emerged and flourished. This development was timely, as the TVEs were able to absorb excess farm laborers who otherwise would have been compelled to leave their villages to search for employment. Two factors contributed to the success of TVEs. First, local governments were able to increase revenues due to the "fiscal contract system" in place since 1980. Second, the hybrid ownership of TVEs allowed them more flexibility in operations than SOEs while also affording them greater protection from local authorities than private enterprises (PEs). Such protection was crucial since private property rights were not clearly defined on paper. Meanwhile, special arrangements such as FDI (entirely owned and managed by foreign investors) and special economic zones to grant preferential treatment to attract FDI were boosting the birth of newly foreign funded enterprises (FFEs). Therefore, the non-state enterprises (NSEs), including TVEs, PEs and FFEs (most of them belonging to light industry), developed very fast at this stage; in 1993, its share of industrial gross output exceeded SOEs for the first time during the reform era, as shown in Fig. 2a.

In general, controversy and incomplete comprehension of sound economic theory followed the reform process during this period. The nature of this reform was gradual and incremental because a "dual track system" was in place whereby new entrants in non-state sectors was tolerated and occasionally encouraged while SOEs remained untouched. Such trials of reform resulted in the power rent-seeking, corruption, income disparity, inflation and so on, ultimately causing serious social unrest at the end of 1990s. After the setbacks and debates for several years, the target to establish the socialist market economy was finally clarified and announced at the 14th Party Congress in 1992.

2.1.2. Decisive reform (1992–2001)

This was the historically decisive stage of industrial reform characterized by substantial breakthroughs. Restructuring the ownership rights of SOEs was obviously the main achievement of industrial reform in this period.

Although SOEs reform in 1980s succeeded temporarily, deeply rooted problems remained. Jefferson et al. (1998) also states that the restructuring of SOEs without formal ownership conversion would meet with limited success. The lack of true private ownership structures was the major impediment to efficient operations. In fact, the short-term and opportunistic behavior of

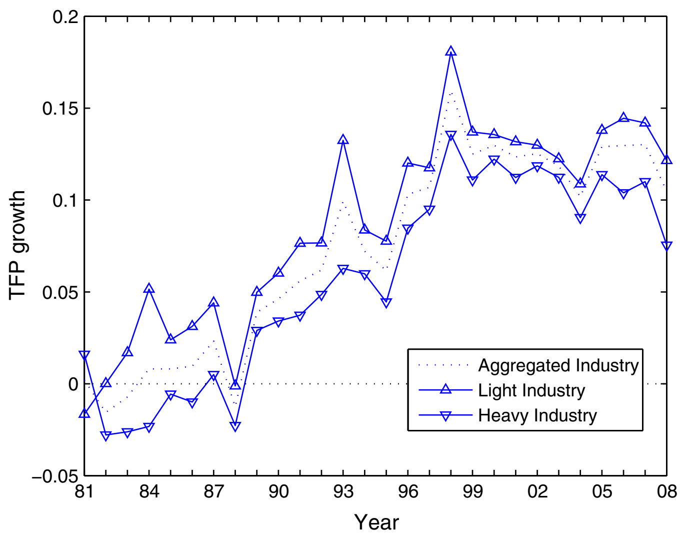

Fig. 3. TFP growth in China Industry (1981–2008).

enterprises' contractors, together with the presence of significant numbers of under-utilized employees, high asset-liability ratio resulted from the 10-year implementation of the policy "bogaidai," government apportionment of charges and social burden, etc. finally caused the serious financial deterioration of SOEs. In 1995, roughly half of the SOEs were unprofitable and required large subsidies for continuing operations. The whole state-owned sector posted its first net loss in 1996, as described in Fig. 2b. Not until then did Beijing realize that state ownership was the root cause of all the ills of the SOEs and that only radical structural change of their ownership rights would improve performance.

In 1997 the 15th Party Congress reaffirmed the shareholding system and made a call for the ownership structure change by employing the policy of "grasp the large and let go of the small" (zhuadafangxiao). Since then China's industry has seen an enormous wave of ownership restructuring. By grasping the large, the government retained direct control over some of the large SOEs in strategic industries. The state relinquished plenty of smaller SOEs in non-strategic industries to private ownership through a variety of means such as mergers, equity sales, auctions, and others. Thousands of SOEs that could not be sold were permitted to go bankrupt. As a result, as plotted in Fig. 2, the number of SOEs' units declined fast after 1998; its share to the total number of enterprise units has declined from 39.2% in 1998 to 27.3% in 2001. Fan (2002) also reported that more than 70% of small SOEs have been privatized or restructured in 3 years. By the end of 2000, the CCP announced that the modern enterprise system had been launched in as many as 84% of SOEs. Approximately 70% of SOEs were officially making profits and the net profits reached RMB 230 billion yuan (Movshuk, 2004).

As SOEs reform proceeded, non-state industry continued to exhibit its strong vitality, continuously increasing its proportion of gross output and taxes to state, and enjoying the higher profit ratios with respect to net value of fixed capital than the SOEs, also shown in Fig. 2. The ownership reform also extended to collective-owned enterprises (COEs), the only partner of SOEs before 1978, including the celebrated TVEs. From the mid-1990s onward, TVEs have been completely privatized through the creation of joint stock companies where the local governments are shareholders. Li and Rozelle (2000) reported that the privatization of rural industry was deep and fundamental and that the number of large and medium-sized COEs declined by 35%. At the same time, China put an export promotion regime into practice which boosted the development of export-processing enterprises. The effect was a trade surplus starting in1994 along with the status of being the world's top exporter. In a word, it was the rapid development of non-state industry that made the ownership reform of SOEs possible in the 1990s; the same reform that had failed only a decade earlier. NSEs not only absorbed widespread layoffs from SOEs due to the furlough policy (xiagang) but also provided massive capital during the course of shareholding reform of SOEs.

Necessary reforms to support SOEs conversion were also undertaken in the financial system. Establishment of stock exchanges was part of this plan; the exchanges have played a critical role in helping SOEs transform into joint stock companies that allow non-state capital investment. The massive bad debts that resulted from the policy of "bogaidai" implemented 10 years ago were transformed into equity overnight under the new policy of changing debts into shares (zhaizhuangu). The staggering deterioration of the SOEs' financial performance also accelerated the birth of the tax assignment system (fenshuizhi) and value-added tax (VAT) in 1994, which was considered to be positive for growth (Chen & Zhang, 2009). Another powerful reform at this stage was the fulfillment of product market prices. The transition from plan prices to true market prices has been one of China's greatest challenges since the reform. As known, in the 1980s, the well-known dual-track pricing system had to be implemented. In 1986, the central government once decided to liberalize all commodity prices within 5 years but this round of price reform was ended with high inflation, panic buying and social turmoil at the end of 1980s. When the new upsurge of economic reform came in 1992, the price of all industrial products, except a few important materials such as oil, was successfully liberalized during a deflationary period. A unified domestic products market has existed since the early 1990s and the phenomenon of products shortages, so familiar in a planned economy, disappeared. Pragmatically speaking, ideological and political clarity have contributed to the phase of decisive reform of China industry since 1992.

2.1.3. Assessment and adjustment (2001-present)

The industrial reform in 1980s and 1990s indubitably led to the substantial structural change and rapid growth of productivity and output; however, it was not without expense such as wasteful investment, high energy consumption, heavy pollution, etc. In general, social contradictions remain intricate and sometimes even intensify when GDP per capita of a transition country reaches US$1000 like China at the advent of millennium. It was natural for the controversy about the future reform directions to become heated. Therefore, re-assessment of growth model and further adjusting the economic structure became the main consideration of future reform by the leadership from the beginning of this century. The 16th Party Congress in 2002 firstly described the new road to the next stage of industrialization and proposed the sustainable development strategy. On this basis, its 3rd Plenum put forward the scientific outlook on development and the 4th Plenum raised the proposition of constructing harmonious society. Even so, the phenomenon of heavy industrialization reappeared at this stage which seems to deviate from the proposed new industrialization strategy. It could be attributable to the fanatical expansion of housing and car industries, the rapid urbanization, accelerated exports of energy and emission intensive products after the access into WTO, the continuous and massive infrastructure investment, and the new entry of private capital into heavy industries due to the low price of natural resources.

Fig. 2 also illustrates the structural change of Chinese industry during this stage. The number of LMEs units decreased slightly to 9.5% of total number of firms but their share of gross output rose from 57.2% in 2000 to a peak of 67.5% in 2003 and then fell to 62.9% in 2008. This statistic indicates that the small competitive enterprises may be underdeveloped and the degree of industry concentration was still high. China's industry enjoyed an increasing ratio of profit from negative or almost zero in the late of 1990s to 7% and 25% for SOEs and NSEs in 2008. In addition to supporting SOEs' reform directly, NSEs also contributed tax revenues to the state, the share of which increased from one third in 2001 to half in 2007 and 55.6% in 2008. The number and gross output of NSEs continued to rise. By the end of 2008, the shares of the gross industrial output and number of enterprises for NSEs are 71.7% and 95.1%, respectively, as opposed to 28.3% and 4.9% for SOEs.

Although the reform for 30 years has acquired great achievements, two major obstacles, the characteristics of every planned economy, are still in the way to future reform. One is the persistent dual economic system that restricts the further free allocation of production factors such as resources, labor and capital, etc. For example, the formation mechanism of market pricing in resource market is far from complete. The state still controls the pricing rights of over ten kinds of important resources such as product oil, electric power, etc. The low-price regulation of natural resources was unable to reflect its scarcity and stimulated the over-development of resource-intensive industries, that partly led to the heavy industrialization during the third period. Such accumulation of allocative distortion in factor markets will inevitably cause the increasing deterioration of factor allocative efficiency which should be reflected finally in the poor performance of growth and productivity in China's industry.

Another is the underlying weakness of SOEs and industry policy. Now, the SOEs have become the platform for government to implement its so-called industry policy. In 2003, China established the State Assets Commission (SAC) to administer the largest and best SOEs in pillar industries. As the product of the industry policy, these SOEs enjoyed dramatic expansion and concentration. The potential drawbacks is that weak corporate governance gives management the opportunity to steer the firm in terms of their own private interests while shielding themselves from risk under the umbrella of government protection. The phenomenon that some SOEs are slipping into the privileged groups by means of monopoly and the dual role of both player and referee of SAC and deviating from their radical target of public interest has recently given rise to a growing discontent of all people in the society that holds the SOEs. How to reform the SOEs successfully remains the challenge for China in the future.

2.2. Industrial productivity estimates in the literatures

Economic reform and structural change has led to substantial productivity and output growth in China during the reform period. Because productivity is not directly observable, many researchers are interested in estimating the total factor productivity (TFP) and its components attributable to technical progress, efficiency improvement, factor reallocative effect, and so on.

The Chinese aggregate TFP is firstly concerned and estimated in the studies. For example, Chow (1993, 2008) and Chow and Lin (2002) found that Chinese TFP growth was zero between 1952 and 1978 and 2.7% annually after 1979. Perkins (1988) shown that the averaged TFP growth of China was 4.1%, −1.4%, 0.6% and 3.8% in 1953–1957, 1957–1965, 1965–1976, 1976–1985, respectively. Perkins and Rawski (2008) estimated that annual TFP growth in China was 0.5% in 1952–1978 and 3.8% in 1978–2005, in which the TFP growth attained the peak of 6.7% between 1990 and 1995 and decreased after 1995. The TFP growth rate estimated by Borensztein and Ostry (1996) was −0.7% and 3.8% in 1953–1978 and 1979–1994 in China. Young (2003) reported that the TFP growth of nonfarm industry averaged over 1978–1998 was 3% using official data and 1.4% using corrected data. Holz (2006) estimated that Chinese TFP growth in 1953–1978 and 1978–2005 was −0.6% and 3.9%. Some studies focus on the estimates of provincial or regional productivity in China, for example, see Lin (1992), Chen, Yu, Chang, and Hsu (2008), Chen, Huang, and Yang (2009), Li (2009), Tuan, Ng, and Zhao (2009), to name a few. This paper aims at the productivity estimates in Chinese industry and surveys the related important literatures in Table 1. Since the initial work by Chen et al. (1988), there was a big surge of TFP estimates in Chinese industry as opposed to in other areas. Some studies estimated just Chinese aggregate industrial productivity (Bosworth & Collins, 2008; Woo, 1998); some studied the industrial productivity with different ownership types such as SOEs and TVEs (Jefferson et al., 2000; Wu, 1995; Zhang et al., 2003); and some estimated the TFP growth of different industrial sectors (Li & Lu, 2007; Zheng et al., 2003) and different firms (Jefferson et al., 2008; Li et al., 2008) and so on. As shown in Table 1, most of studies makes use of Solow residuals or regression of Cobb-Douglas and translog production function to estimate productivity; some uses parametric stochastic frontier function, similar to the methodology in this paper, and some adopts nonparametric deterministic frontier DEA framework and Malmquist productivity index (MPI) to estimate TFP. For example, Wu (1995) and Tu and Xiao (2005) employed the stochastic frontier production function to estimate the growth rate of TFP of SOEs, TVEs and LMEs; the former decomposed the estimated TFP into only two components of technical progress and efficiency, and the latter decomposed the productivity into four components including the structural effect.[2] There is also a big variability of estimates of industrial productivity growth among different studies, as surveyed in Table 1, from a low of −1.1% in Jefferson et al. (2000) to highly 18.4% of exits & entrants SOEs shown in Jefferson et al. (2008).

In the literatures, the effect of structural change on economic growth, so-called structural bonus, is normally measured by the productivity growth attributable to factors reallocation across different industrial sectors using conventional share-shift approach. As shown in Table 1, Woo (1998) decomposed the estimated TFP growth into net TFP growth (to reflect the technical progress) and labor reallocative effect, the contribution of the latter to Industry TFP growth being 23% and 66% at two phases. Li and Lu (2007) decomposed the estimated manufacturing TFP growth into two components of within-growth effect and total structural effect and found the contribution of the latter changed from positive to negative at two sub-periods. Total structural effect includes three terms of output structural effect, labor shift effect and capital shift effect, in which the first term was negative and the last two effect were positive but the capital shift effect dominated. Jefferson et al. (2008) also found the exceptional contribution to overall industrial productivity growth made by restructuring the exiting and entering firms in 2005 in relation to the level in 1998, in particular for SOEs (18.4%). Share-shift analysis was also used by Li et al. (2008) for Chinese firms during the period of the tenth

[2] Li, Liu, and Yun (2005) also used the stochastic frontier model to estimate Chinese TFP growth and decomposed it into three terms of technical progress and efficiency and scale effect, without the structural effect due to the lack of input price information. They estimated that Chinese TFP growth and decomposed technical progress, production efficiency and scale effect are 0.0307, 0.0309, -0.0063 and 0.0061, respectively, averaged over 1986-2000.

Table 1
TFP estimates and its decomposition for Chinese Industry in the literatures.

Researchers	Data	Inputs	Output	Methodology	Sample period	TFP growth and its decomposition (%)	
Chen, Wang, Zheng, Jefferson, and Rawski (1988)	SOEs industrial data	K, L	GIOV	Solow Residual; C-D or Translog Production Function Regression		SOEs TFP	
					1953–1985	2.6	
					1978–1985	5.9	
Woo (1998)	Industrial time series	K, L	IVA			Industry TFP	Labor Reallocative Effect
					1979–1984	3.3	0.8
					1985–1993	0.7	0.5
Jefferson, Rawski, Wang, and Zheng (2000)	Industrial time series	K, L, M	GIOV			SOEs TFP	Aggregate TFP
					1980–1996	1.7	2.8
					1992–1996	−1.1	1.5
Zhang, Shi, and Chen (2003)	TVEs industrial data	K, L	GIOV			TVEs TFP	Aggregate TFP
					1980–2000	6.7	3.7
Li and Lu (2007)	Manufacturing industry data	K, L	IVA			Manufacturing TFP	Total Structural Effect
					1985–1997	2.9	0.6
					1998–2003	18.4	−0.7
Bosworth and Collins (2008)	Industrial time series	K, L, Education	GDP			Industry TFP	Aggregate TFP
					1978–1993	3.1	3.6
					1993–2004	6.2	4
Jefferson, Rawski, and Zhang (2008)	Industrial firms data	K, L	IVA			Overall SOEs TFP	Exit & Entry SOEs TFP
					2005/1998	15.6	18.4
Li, Wang, and Zheng (2008)	Industrial firms data	K, L, M	GIOV			Industry TFP	Factor Allocative Effect
					2000–2005	17.2	8.9
Wu (1995)	Industrial panel data	Fixed Assets, Working Capital, L	GIOV	Stochastic Frontier Production Function Regression		SOEs TFP	TVEs TFP
					1986	4.4	3.9
					1991	1.8	5.2
Tu and Xiao (2005)	LMEs firms panel data	K, L	IVA			LMEs TFP	Factor Allocative Effect
					1996–2002	6.8	0.14
Zheng, Liu, and Bigsten (2003)	SOEs firms panel data	K, L, M	GIOV	DEA, MPI		Heavy Industrial TFP	Light Industrial TFP
					1980–1989	7	12
					1990–1994	8	6

Note: K—Capital; L—Labor; M—Intermediate Input; GIOV—Gross Industrial Output Value; IVA—Industrial Value Added. All estimates shown in this table come or calculated from the results in the corresponding literatures.

Five-Year Plan (2000–2005). The structural bonus of factor reallocative effect includes the static and dynamic shift effect for surviving firms and the restructuring effect for exiting and entering firms. They found that the contribution of structural effect on industrial productivity was over 50%. The share-shift approach of structural effect is under the two-stage analytical framework of estimation of productivity firstly and decomposition of estimated productivity secondly. It can only be used to decompose the overall TFP and measure the overall structural effect. To overcome such disadvantages of share-shift approach, this paper adopts the sectoral stochastic frontier production function to estimate sectoral TFP growth and decompose its sectoral structural effect due to factor reallocation simultaneously. To the best of our knowledge, Tu and Xiao (2005) surveyed in Table 1 is the only study using the same methodology as our paper in the literatures but concerns itself with just LMEs between 1995 and 2002, different from our study.

3. Data and model

3.1. Data

In this study, we are concerned with the effect of structural change on productivity and output growth among the two-digit industrial sectors, where we classify industrial sectors according to the new version of National Standard of Industrial Classification (GB/T4754) revised in 2002 in China. Data available for the period after the market reform since 1978 allows for the analysis of 38 different industrial sectors, which belong to three bigger categories of the industry: mining, manufacturing, and energy (electricity, gas and water) production and supply industry.[3]

The output data used in this study is sub-industrial value-added with the unit of RMB 100 million yuan at 1990 price level, denoted by Y, rather than gross industrial output value. This is because only two traditional factors, labor and capital stock, are used as inputs, not including intermediate materials. The labor input, L, is annual employed workers with the unit of ten thousand persons. The capital stock, K, at 1990 price level, is estimated by using perpetual inventory approach, which was firstly proposed by Goldsmith in 1954 and improved by Denison and Jorgenson later. If possible it is better not to use the net value of fixed assets

[3] All original data used in this study is collected from *China Statistical Yearbook* (1983–2009), *China Industry Economy Statistical Yearbook* (1988-2009), *China Compendium of Statistics* 1949–2004, *China Urban Life and Price Yearbook* (2009), etc., officially provided by National Bureau of Statistics of China. See Chen (in press) for a detailed discussion of the creation of input and output panel data for industrial sectors in China between 1980 and 2008. All figures used to draw the pictures or shown directly in the body of the paper are provided by ourselves based on the estimated data, if not stated otherwise.

directly as the proxy variable of the capital stock due to its simple accumulation of current values of all years and the inappropriateness to deflate it just using the price index of different year (Zhang et al., 2003).

Since the empirical work of Hoffmann (1958) and Chenery et al. (1986), the standard perception of industrialization is a general shift in relative importance from light to heavy industry. Light industry is of great importance normally at the early stage of industrialization and labor-intensive in nature with relatively low ratios of capital to labor; while heavy industry is at the middle or late stage and capital-intensive with relatively high ratios of capital to labor. Therefore, we divide all sectors into light and heavy industrial groups according to the ranking of capital to labor ratio (K/L) in 2004. That is, the light industrial group corresponds to the top half of sectors with the lower K/L ratio, and the heavy industry to the last half of sectors with the larger K/L ratio. We refer to them as light industry and heavy industry in brief from now on in this paper. This is because 38 sectoral patterns of structural bonus are too complicated to see clearly all at once, and sometimes the observation of the difference between the light and heavy industry instead is enough for the analysis.

The descriptive statistics of the variables used in the study for both light and heavy industry are presented in Table 2, which brings into focus the contrast between the two groups. The principal feature we obtain from this table is that the mean of capital stock in heavy industry is close to two times the size of the light industry, but the mean of industrial value-added and labor in the light industry is less than those in the heavy industry. The highest value-added (14867) is observed not in heavy industry but in the newly developing high-tech industrial sector, manufacture of communication equipment, computers and other electronic equipment in 2008 with the highest growth rate, 26.1%, averaged over the whole reform period as exhibited in Table 5 later. The highest capital stock is found in the sector of production and supply of electric and heat power in 2008 (20236). There is a higher degree of variability for capital but lower variability for labor and output within the heavy industry. The statistical information indicates that heavy industry should experience lower productivity than light industry, and there should be improvements of productivity due to more labor reallocation in light industry and more capital shifts within heavy industry.

3.2. Model

Stochastic frontier sectoral production function is specified as follows:

$$Y_{it} = f(X_{it}, t)e^{-u_{it}}e^{\varepsilon_{it}} \tag{1}$$

where, $i=1,2,\cdots,38$ represents 38 industrial sectors and $t=1,2,\cdots,29$ is the time trend variable for 1980–2008. Y_{it} is the output variable of industrial value-added; thus, input vector X_{it} just includes traditional factors of capital and labor. Stochastic disturbance term ε_{it} enters into the model in exponential form and is assumed to follow normal distribution of white noise. $f(\cdot)$ represents the production frontier. Leaving the stochastic term aside, the proportion of actual output Y_{it} to frontier $f(\cdot)$, i.e., $e^{-u_{it}}$, captures the technical efficiency (TE) of industrial production. If $u_{it}\geq 0$, TE lies between the range of (0,1], as expected; thus, u_{it} is often assumed to follow the truncated normal distribution on the right side of zero point.

Following Kumbhakar (2000), taking natural logarithm, differentiating with respect to t, and dividing by Y on the both side of Eq. (1), we obtain

$$\frac{\partial lnY_{it}}{\partial t} = \frac{\partial lnf(X_{it}, t)}{\partial t} + \sum_{j=1}^{2} \frac{\partial lnf(X_{it}, t)}{\partial lnX_{itj}} \frac{\partial lnX_{itj}}{\partial t} + \frac{\partial lne^{-u_{it}}}{\partial t} \tag{2}$$

where, $j=1,2$ corresponds to capital and labor, $\partial \ln f(X_{it}, t)/\partial \ln X_j$ is the output elasticity of factor j, denoted by α_{itj}. If the superior dot is used to represent the growth rate of a variable, then $\dot{Y}_{it} = \partial lnY_{it}/\partial t$, and $\dot{X}_{itj} = \partial lnX_{itj}/\partial t$. We define technical change (TC) to be $TC_{it}=\partial \ln f(x_{it}, t)/\partial t$, technical efficiency change (TEC) to be $TEC_{it}=\partial \ln TE_{it}/\partial t=-\partial u_{it}/\partial t$. We can rewrite Eq. (2) as

$$\dot{Y}_{it} = TC_{it} + \sum_{j=1}^{2} \alpha_{itj}\dot{X}_{itj} + TEC_{it} \tag{3}$$

Table 2
Descriptive statistics of main variables used in this study (1980–2008).

Variables	Mean	Standard deviation	Minimum	Maximum
Light Industry				
Value-added of Industry (100 million yuan)	562.58	1295.30	13.09	14866.73
Capital stock (100 million yuan)	644.61	731.84	13.49	4068.60
Labor (ten thousand workers)	163.10	145.41	15.00	756.00
Heavy Industry				
Value-added of industry (100 million yuan)	401.08	552.94	1.42	4143.60
Capital stock (100 million yuan)	1135.60	1972.40	12.52	20236.38
Labor (ten thousand workers)	104.84	97.01	7.00	456.10

Table 3
Estimates of stochastic frontier translog production function for sub-industries in China.

lnY	Coef.	S.E.	lnY	Coef.	S.E.
Constant	3.0824***	0.4916	(1/2)*(lnK)^2	−0.0365	0.0790
t	−0.0245	0.0245	(1/2)*(lnL)^2	0.1609**	0.0815
(1/2)*t^2	0.0095***	0.0008	t*lnK	−0.0165**	0.0068
lnK	0.9163***	0.2277	t*lnL	0.0178***	0.0059
lnL	−0.7919***	0.2365	mu	1.7219***	0.3275
lnK*lnL	−0.0033	0.0655	eta	−0.0261***	0.0030
Gamma	0.9016		Wald chi2(9)	1611.26***	

Note: *, **, *** indicate that the coefficient is statistically significant at the level of 10%, 5% and 1%, respectively.

The growth rate of total factor productivity (TFP) is traditionally defined as

$$\dot{TFP}_{it} = \dot{Y}_{it} - \sum_{j=1}^{2} s_{itj}\dot{X}_{itj} \tag{4}$$

where, $s_{itj} = w_{itj}X_{itj}/\sum_{j=1}^{2} w_{itj}X_{itj}$, w_{itj} is the price of factor j in i sector and at time point t. Thus, s_{itj} represents the actual input share of factor j to total cost in i sector and at t point and serves as the weight to build the total factor, the summation of it being 1.[4] Inserting Eqs. (3) into (4), we obtain

$$\dot{TFP}_{it} = TC_{it} + TEC_{it} + (RTS_{it}-1)\sum_{j=1}^{2}\lambda_{itj}\dot{X}_{itj} + \sum_{j=1}^{2}\left(\lambda_{itj}-s_{itj}\right)\dot{X}_{itj} \tag{5}$$

where, $RTS_{it} = \sum_{j=1}^{2}\alpha_{itj}$ represents the return to scale of industrial sector, summation of output elasticity of all factors. Thus, $\lambda_{itj} = \alpha_{itj}/RTS_{it}$ indicates the optimal marginal output share of factor j, equal to its output elasticity under the constant return to scale. Under the varying return to scale, the third term on the right side of Eq. (5) can be used to describe the productivity improvement resulting from the evolution of scale economy of industrial sectors, the so-called scale efficiency change (SEC).

Under the assumptions of a pure market economy like perfect competition and profit maximization, if the market price of factors can fully reflect its marginal product value, i.e., $w_{itj} = pf_{itj}$, then the equality of optimal output share and actual cost share ($\lambda_{itj} = s_{itj}$) holds, in which it is feasible to replace the cost share with its marginal output share when calculating TFP growth. In the case of a transition economy like China, however, such conditions and relationships usually fail to be satisfied due to underdeveloped factor markets and inefficient factor reallocation. The distortion where the actual factor allocation is far from its optimal combination is pervasive. Like a coin with two sides, of course, the distortion also provides more space for Chinese industry to increase productivity by adjusting structure and then reallocating factors than in a mature economy. Thus, the fourth term on the right side of Eq. (5) normally makes sense in China and is used to capture the structural effect or factor allocative efficiency change (FAEC), that is, the productivity change due to structural change and then factors reallocation. Under the two inputs of capital and labor, FAEC consists of two kinds of efficiency due to labor reallocation and capital reallocation, respectively; as $\lambda_{itK} - s_{itK} = -(\lambda_{itL} - s_{itL})$ holds, FAEC finally depends on the relative growth magnitude of two inputs. If the sum of labor and capital reallocation efficiency is substantial, structural change has an impact on productivity. In turn, we can expect that the FAEC term reflects the industrial restructuring efforts of the government starting from 1978 aiming at the reallocation of factors in order to increase industrial productivity and output growth.

Thus far, in terms of Eq. (5), the growth rate of TFP can be decomposed into four components, i.e. the change of productivity due to technical progress, technical efficiency, scale effect and factor reallocative effect. That is,

$$\dot{TFP}_{it} = TC_{it} + TEC_{it} + SEC_{it} + FAEC_{it} \tag{6}$$

In order to obtain the varying coefficients and statistics across sectors and over time, the more flexible translog form is specified for stochastic frontier sectoral production function used in this study. That is,

$$\begin{aligned} lnY_{it} = {} & \beta_0 + \beta_t t + \frac{1}{2}\beta_{tt}t^2 + \beta_K lnK_{it} + \beta_L lnL_{it} + \frac{1}{2}\beta_{KK}(lnK_{it})^2 + \frac{1}{2}\beta_{LL}(lnL_{it})^2 + \beta_{KL}lnK_{it}lnL_{it} + \beta_{tK}tlnK_{it} \\ & + \beta_{tL}tlnL_{it} - u_{it} + \varepsilon_{it} \end{aligned} \tag{7}$$

[4] In this study, the actual cost of labor and capital is measured by the total wages and the depreciation of fixed assets for different sectors over time.

Table 4
Aggregated industrial growth accounting analysis at each stage, averaged over all sectors.

Stage	Output growth	Capital		Labor		TFP growth	Decomposition of TFP growth			
							TC	TEC	SEC	FAEC
1981–1992	0.086	0.044	[0.39]	0.026	[0.61]	0.008	0.034	−0.027	−0.047	0.047
	100	51		30		9	40	−31	−55	55
1992–2001	0.130	0.033	[0.37]	−0.027	[0.63]	0.099	0.115	−0.035	−0.018	0.037
	100	25		−21		77	88	−27	−14	28
2001–2008	0.175	0.043	[0.51]	0.003	[0.49]	0.111	0.181	−0.043	−0.017	−0.009
	100	25		2		64	104	−25	−10	−5
1981–2008	0.125	0.040	[0.42]	0.002	[0.58]	0.067	0.102	−0.034	−0.029	0.028
	100	32		2		53	81	−27	−23	22

Note: The contribution is reported in the second line at each stage (unit: %). The summation of Capital, Labor and TFP growth contribution does not equal 100 because TFP growth is calculated by adding four decomposing terms, rather than traditional Solow residuals. Thus, the contribution summation of TC, TEC, SEC and FAEC equal that of TFP growth to output growth. The figures in brackets are averaged cost share of capital and labor inputs over time.

As defined previously, K and L are capital stock and labor. Following Battese and Coelli (1992) and Kumbhakar (1990, 2000), some assumptions are specified as follows,

$$u_{it} = u_i e^{-\eta t} \sim N^+\left(\mu, \sigma_u^2\right), \varepsilon_{it} \sim N\left(0, \sigma_\varepsilon^2\right), cov(u_{it}, \varepsilon_{it}) = 0 \tag{8}$$

Table 5
Sectoral growth accounting analysis in Chinese Industry, averaged over 1981–2008.

Industrial sectors	Output growth	Inputs contribution		TFP growth	Decomposition of TFP growth			
		Capital	labor		TC	TEC	SEC	FAEC
Coal Mi.	0.077	0.020	−0.003	0.060	0.108	−0.052	−0.004	0.009
Petroleum Ext.	0.021	0.074	0.013	−0.002	0.080	−0.049	−0.049	0.015
Ferrous Mi.	0.135	0.038	−0.006	0.043	0.098	−0.057	−0.048	0.050
Non-Ferrous Mi.	0.105	0.024	−0.009	0.067	0.103	−0.046	−0.020	0.030
Nonmetal Mi.	0.068	0.016	−0.023	0.092	0.095	−0.035	−0.020	0.052
Wood Exp.	0.023	0.004	−0.019	0.076	0.114	−0.056	−0.001	0.019
Food Proc.	0.144	0.042	−0.003	0.080	0.102	−0.025	−0.019	0.023
Food Ma.	0.154	0.034	0.010	0.071	0.105	−0.036	−0.025	0.027
Beverage	0.134	0.049	0.013	0.073	0.103	−0.025	−0.033	0.029
Tobacco	0.127	0.044	0.017	0.108	0.095	−0.002	−0.085	0.100
Textile	0.097	0.029	−0.010	0.100	0.111	−0.023	−0.002	0.014
Apparel	0.145	0.041	0.016	0.111	0.120	−0.026	−0.029	0.045
Leather	0.147	0.030	0.014	0.097	0.116	−0.034	−0.034	0.049
Wood Proc.	0.158	0.041	0.003	0.076	0.103	−0.035	−0.043	0.050
Furniture	0.132	0.041	−0.006	0.089	0.107	−0.039	−0.056	0.076
Paper	0.117	0.048	−0.004	0.067	0.099	−0.032	−0.026	0.026
Printing	0.137	0.035	−0.004	0.086	0.110	−0.036	−0.025	0.037
Cultural Articles	0.144	0.032	0.018	0.089	0.113	−0.036	−0.057	0.070
Petroleum Pro.	0.031	0.073	0.009	0.018	0.088	−0.038	−0.041	0.009
Chemical	0.108	0.040	−0.002	0.060	0.098	−0.023	−0.007	−0.008
Medicine	0.171	0.045	0.021	0.076	0.107	−0.021	−0.037	0.028
Fibers	0.161	0.058	0.008	0.026	0.086	−0.037	−0.049	0.027
Rubber	0.107	0.039	0.000	0.081	0.107	−0.030	−0.029	0.034
Plastic	0.157	0.064	0.003	0.067	0.101	−0.027	−0.037	0.031
Nonmetal Ma.	0.101	0.036	−0.015	0.078	0.098	−0.024	−0.006	0.009
Ferros Press	0.106	0.042	−0.002	0.049	0.094	−0.028	−0.008	−0.008
Non-Ferrous Pr.	0.135	0.044	0.010	0.044	0.093	−0.033	−0.027	0.010
Metal Products	0.120	0.035	−0.010	0.095	0.106	−0.021	−0.015	0.025
General Mac.	0.121	0.022	−0.014	0.084	0.106	−0.024	−0.002	0.005
Special Mac.	0.118	0.021	−0.017	0.087	0.108	−0.030	−0.004	0.014
Transport Eq.	0.178	0.034	0.003	0.077	0.108	−0.025	−0.009	0.003
Electrical Eq.	0.159	0.040	0.003	0.098	0.109	−0.013	−0.016	0.018
Computer, etc.	0.261	0.054	0.020	0.084	0.106	−0.010	−0.028	0.017
Measuring Inst.	0.151	0.022	0.000	0.091	0.113	−0.030	−0.019	0.028
Electric power	0.103	0.077	0.012	−0.007	0.077	−0.037	−0.025	−0.021
Gas Prod.	0.183	0.045	0.020	−0.024	0.087	−0.092	−0.087	0.068
Water Prod.	0.067	0.060	0.028	−0.037	0.088	−0.084	−0.056	0.014
Others	0.153	0.035	−0.003	0.109	0.115	−0.023	−0.021	0.037
Aggregated Industry	0.125	0.040	0.002	0.067	0.102	−0.034	−0.029	0.028

The coefficients η and all β in Eq. (7) require estimation. Based on the estimated coefficients, some statistics can be calculated correspondingly. For instance, the output elasticity of capital and labor is expressed as

$$\alpha_{itK} = \beta_K + \beta_{KK} lnK_{it} + \beta_{KL} lnL_{it} + \beta_{tK} t \quad (9-1)$$

$$\alpha_{itL} = \beta_L + \beta_{KL} lnK_{it} + \beta_{LL} lnL_{it} + \beta_{tL} t \quad (9-2)$$

The change of technical progress and technical efficiency could be computed by

$$TC_{it} = \beta_t + \beta_{tt} t + \beta_{tK} lnK_{it} + \beta_{tL} lnL_{it} \quad (10)$$

$$TEC_{it} = \eta u_i e^{-\eta t} = \eta u_{it} \quad (11)$$

Based on this, $RTS_{it}, \lambda_{itj}, SEC_{it}$ and $FAEC_{it}$ can be calculated, too.

4. Does structural bonus exist and matter in Chinese industrial transformation?

The estimated parameters of the stochastic frontier translog production function for Chinese sub-industries are reported in Table 3. The maximum likelihood estimates (MLE) perform very well for the sample of panel data. Only three out of 10 main coefficients are insignificant with the exact probability over 10%. The gamma value attains 0.9016, indicating that the variation of sectoral effect could explain most proportion of the variation in industrial growth. The Wald statistic of 1611.26 is in favor of the overall significance of the model specified in this paper.

The aggregated industrial growth accounting is reported in Table 4, which includes the growth rate and contribution of industrial value-added, capital stock, labor, TFP growth and its four decomposed terms during three sub-periods and the entire reform period, averaged over 38 industrial sectors. The sectoral growth accounting averaged over the sample period sees Table 5. Figs. 3 and 4 display the trend of estimated TFP growth, and four decomposed components of TFP growth during the whole period at the level of aggregated industry and disaggregated light and heavy industry.

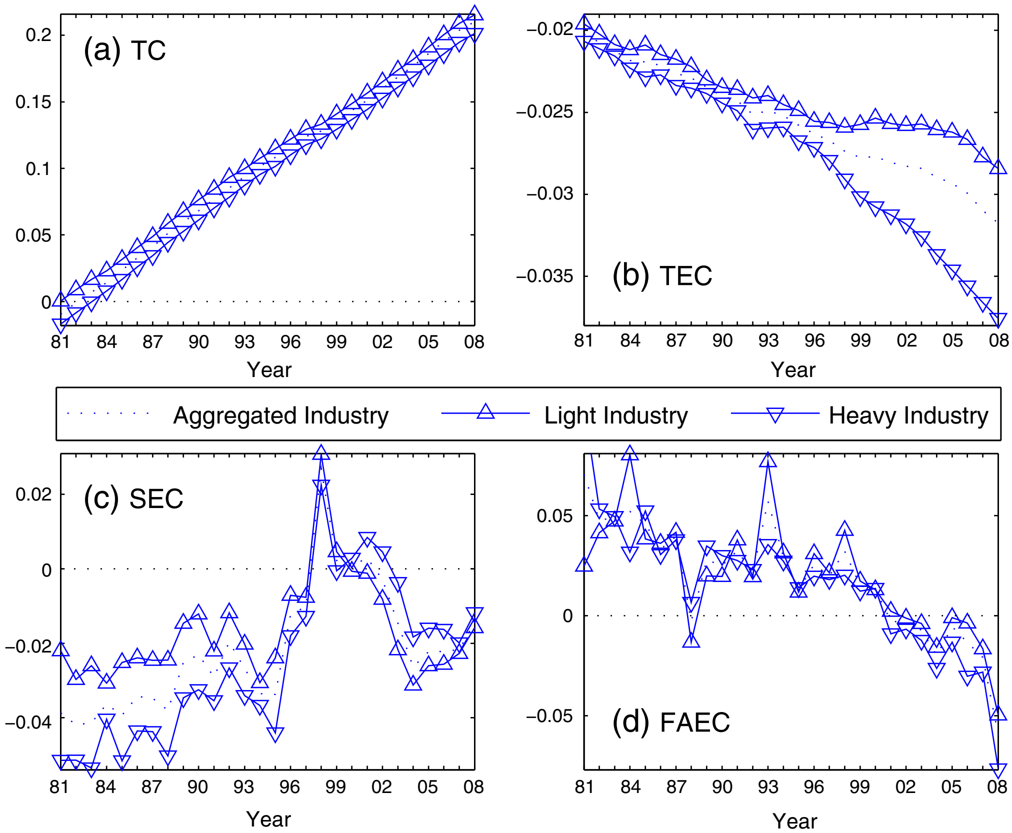

Fig. 4. Decomposition of TFP growth in China's Industry (1981–2008).

Obviously, the massive industrial structural reform has led to increasing industrial productivity and output growth. The aggregated growth rate of industrial value-added and estimated productivity is 12.5% and 6.7%, respectively, over the entire reform period. At the first stage between 1981 and 1992, growth in TFP is extremely slow of 0.8% per year and accounted for only 9% of output growth, which is 8.6%. The remaining 81% of output growth is attributable to increases in factor inputs, 51% and 30% for capital and labor. The fact that productivity increased more slowly than the rate of inputs indicates that Chinese industry is still experiencing extensive growth at this early stage, which is consistent with the experience from East Asia in the 1960s and 1970s, suggesting that inputs accumulation is more important than productivity gains in the economic take-off stage (Berthelemy, 2001; Lucas, 1993; Young, 1995). The Chinese industrial growth pattern is transforming from extensive at the first stage into intensive in the following two stages, supported by the evidence that 9.9%–11.1% growth of productivity has exceeded around 3%–4% of capital accumulation, the highest contribution among factors. The contribution of productivity to output growth attains the highest level (77%) in the 1990s but declines to 64% after the turn of new millennium, indicating that the current role of productivity in industrial transformation is still not stable in China. Components of TFP growth include the change of technical progress (TC), technical efficiency (TEC), scale efficiency (SEC) and factor allocative efficiency (FAEC). As demonstrated in Table 4, the contribution of FAEC to TFP growth dominates in the initial stage of the reforms, accounting for 55% of output growth. Since 1992, the structural change and corresponding factor reallocation has contributed decreasingly to productivity but still ranks second in the following two sub-periods, only lower than TC. The factor reallocation from less productive sectors to more productive ones has increased output growth by 2.8% annually over the whole reform period and is accounted for 22% of output growth and 42% of TFP growth. Thus, we find a significant factors allocative effect, or so-called structural bonus; this is main focus of our study.

Table 5 shows the importance of light industries such as the manufacturing of apparel, furniture and cultural articles and high-tech industries like the manufacture of communication equipment, computers and electronic equipment, transport equipment and medicine, which grow rapidly in output, productivity and reallocative efficiency. Slowly growing sectors are almost heavy industries such as extraction of petroleum and natural gas, processing of petroleum and coking, production and supply of water, and electric and heat power, which show below-average output growth and low or even negative TFP growth and factor allocative efficiency. The different sectoral characteristics of productivity and its decomposition is condensed into light and heavy industry as depicted in Figs. 3 and 4, in which the light industry with low ratio of capital to labor does enjoy higher productivity growth, the change of technical progress and efficiency and factor reallocative efficiency, than heavy industry. Therefore, there exists a mushroom effect (sector-specific effect) during the process of Chinese industrial transformation as described by Harberger (1998). The opposite yeast effect (industry-wide effect) is also found in our figures that both light and heavy industry experienced similar trends to the aggregated industry. That is to say, in addition to heterogeneous factors, some general economy-wide factors such as the common macroeconomic policy and external economic environment play a role in industry, too. These factors tend to affect most sectors at the same time, rather than a limited number of sectors and, hence, improve the productivity in all industrial branches. As Nelson and Pack (1999) revealed for East Asian economies, the aggregated industrial productivity and its decomposition represented by the dotted line in Figs. 3 and 4, also seem to be driven by the expansion of the modern sectors in light industry.

Corresponding to the different stage of industrial structural reform, the growth of TFP in China's industry increases but is far from being steady between 1981 and 2000 and then becomes stable in the new millenium. This is consistent with the evidence found by Li (1997) for Chinese industrial enterprises in 1980s, Sun and Tong (2003), Yusuf, Nabeshima, and Perkins (2005), Jefferson and Su (2006) in 1990s and Bai, Lu, and Tao (2009) in 1998–2005. As plotted in Fig. 4, technical progress is the only

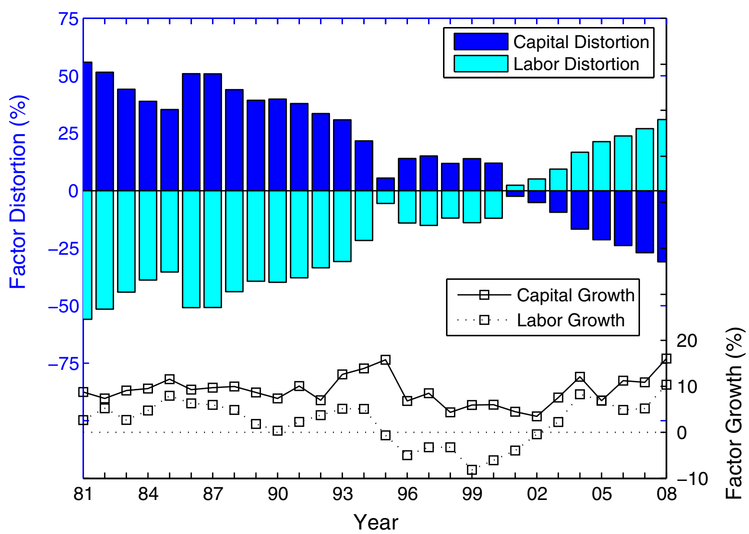

Fig. 5. Factor distortion of Chinese Industry at the aggregate level (1981–2008).

factor contributing at an increasing rate and more to TFP growth than factor reallocative effect. Mukherjee and Zhang (2007) referred to this as the paradigm of adaptive innovation that the imported technology and know-how by China from abroad through absorbing plenty of inflow of FDI and establishing many foreign funded enterprises became the key to China's industrial success. Fisher-Vanden and Jefferson (2008) also argued that China's science and technology effort during the past 25 years has been moving away from a state-dominated system to one in which the locus of innovation has devolved to firms, research institutes, and universities, and technology markets have been rapidly developing in China meanwhile. The negative change of technical efficiency and scale economy partly offsets the positive contribution of TC and FAEC to TFP growth due to their relatively small magnitude. After 2000, we can see the technical efficiency of heavy industry deteriorates but its scale economy ameliorates more than that of light industry. Overall, the return to scale (RTS) is decreasing for China's industry during the whole period; the positive effect temporarily appeared from 1998 to 2002 shown in Fig. 4c being mainly caused by negative growth of labor in that period rather than increasing RTS. This phenomenon is also found by Tu and Xiao (2005) and could be explained by the restriction of free factor reallocation and limitation of optimal inputs combination during the industrial production process, like scarce capital in light industry and skilled-labor in heavy industry.

Fig. 4d presents estimates of the structural effect, i.e., productivity change due to factors allocation (FAEC), for the whole sample period. In 1981–1991, the new reform policy and the overnight liberation of strict controls of labor from agriculture, at least to TVEs, released the vast potential energy of restricted production factors. This led to the most significant allocative efficiency of 4.7% on average, 55% of output growth, that remedied the primarily low growth of technical progress and negative TEC and SEC and pushed the early growth of TFP forward. At the second stage, such factors as the total liberalization of product markets, the massive conversion of SOEs into NSEs, and the export-oriented development strategy, etc. still impose the positive but lower structural bonus on industrial productivity (3.7%).

From 2001 on, the disadvantages of extremely underdeveloped factor markets and plausible industry policy begins to be felt. The industrial restructuring like the inclination to emphasize higher value-added industries, the reappearance of heavy industrialization, and industrial diversification led to the abandonment of the promotion of the traditional labor-intensive manufacturing sectors such as textiles and the encouragement of factors shift towards high-performing industries like electrical and electronic machinery sectors, towards certain high-profit industries such as mining and the manufacture of non-metallic mineral products, even towards services away from the industry. Thus, the contradiction between structural adjustment and employment becomes acute. The high-tech and heavy industries are unable to absorb much labor. The labor-intensive industries that once hired massive workforces are experiencing the shrink and facing the dilemma that they could not attract enough workers due to abnormal enterprises environment for long, or they would lose labor cost competitiveness by raising wages and improving the working environment. Regulations like enforcing the new labor contract law in labor market intensifies the contradiction and causes the shut-down of many small enterprises and layoff of many laborers, especially peasant workers. All these factors have acted as a negative allocative efficiency, −0.9% on average, at the third stage that drags the increasing trend of productivity in China's industry.

Table 6
Analysis of the determinants of factors allocative efficiency change (FAEC).

FAEC (%)	Model 1 (1981–2008)				Model 2 (1994–2008)			
	HT/IV		System GMM		HT/IV		System GMM	
	Coef.	Robust S.E.	Coef.	Robust S.E.	Coef.	Robust S.E.	Coef.	Robust S.E.
Cons	2.1323***	0.3951	7.1721***	1.6261	1.7029***	0.4942	6.9964***	1.8196
FAEC_lag1(%)	0.7882***	0.0110	0.5986***	0.0167	0.9063***	0.0229	0.8599***	0.0466
Sectoral characteristics								
ln(Y/L)	−0.0676**	0.0305	−0.0561	0.0352	−0.0797***	0.0284	−0.0873**	0.0417
ln(EI)	−0.1459	0.0923	−0.4913*	0.2609	−0.2085*	0.1229	−0.4555*	0.2629
PTYR(%)	0.0051*	0.0028	0.0039*	0.0020	0.0043*	0.0024	0.0042	0.0028
Dummy variables								
D1	0.0870**	0.0355	0.0488*	0.0261	0.0885**	0.0444	0.0655*	0.0385
D2	−2.0268**	0.9286	−1.7559*	0.9883	−1.0910***	0.4024	−1.2770*	0.7029
Structural variables								
ln(K/L)	−0.7823***	0.2298	−2.1126**	0.9578	−0.7670***	0.2956	−2.1121***	0.5489
D1*ln(K/L)	0.1279	0.0893	0.7331*	0.4024	0.0989	0.0683	0.4123	0.2812
D2*ln(K/L)	−0.4715***	0.1755	−1.2890***	0.4735	−0.4104**	0.1729	−1.0556***	0.2995
SOYS (%)					−0.0507***	0.0151	−0.0388***	0.0110
LMYS(%)					−0.0347**	0.0139	−0.0143	0.0107
FFYS(%)					0.0269***	0.0095	0.0304**	0.0132
rho	0.5988				0.4830			
Number of observations	1064		1026		570		532	
Overall significance test	24502***		8950***		5563***		4571***	

Note: *, **, *** indicate that the coefficient is statistically significant at the level of 10%, 5% and 1%, respectively.

Previous researchers normally emphasized the positive role of factors shift in productivity growth, the so-called structural bonus; however, the most important finding in this paper appears to be the reversal of structural bonus in the post-2001 period. The evidence that the growth in TFP attributable to factor reallocation follows a declining trend is also found in some literatures. Dowrick and Gemmel (1991) show that the gain from a labor reallocation tend to decrease over time as a country's level of development increases and argue that in his sample period of 1990s, the potential in many developing countries for such productivity gains from labor reallocation was still quite high, unlike more advanced countries. Berthelemy (2001) reveals that productivity gains achieved through the implementation of a successful structural adjustment policy could not be sustained beyond a point where the economy came close to efficient macroeconomic management. And TFP gains through structural change were not likely to occur in the absence of appropriate adjusting policies that should keep factor distortions and wastes at the lowest possible level. Fan et al. (2003) states that the effect of structural change once predominant on past rapid growth will inevitably slow as the structure of the economy (e.g., the shares of agriculture, industry, and services) reaches a new balance.

5. How does structural reform impact structural bonus?

The pattern of structural bonus exhibited in Fig. 4d could be observed roughly from Fig. 5, which is based on the definition of FAEC expressed by the fourth term on the right side of Eq. (5). As reported in Table 4, there is a stagnancy at 37%–39% in share of actual capital cost, s_K, averaged over the first two stages and fast increase to 51% over the third period, and a symmetrically change in the averaged share of actual labor cost, s_L, which reflects a real transformation across sub-industries, that is, the rapid development of labor-intensive light industry in 1980s and 1990s and the reappearance of capital-intensive heavy industrialization after 2001. Accordingly, the averaged output elasticity of labor, λ_L, increases continuously from only 2% at the first stage to 35% and 57% averaged in the following two stages and that of capital, λ_K, decreases symmetrically, the capital deepening in Chinese industry. Overall, the averaged cost shares for capital and labor are 42% and 58%, respectively, as opposed to 72% and 28% of output elasticity of capital and labor. The difference between the optimal and actual inputs share thus resulted in the allocative distortion in labor and capital, as depicted in Fig. 5. The convergence between the optimal and actual inputs share gradually reduces the distortion at the first two stages and, after 2001, the departure of actual inputs share from the optimal one leads to the reappearance of inputs distortion towards the opposite direction. Therefore, it is no surprise that a move to another disequilibrium after reaching an equilibrium point from a long period of one disequilibrium will change different reallocative effects of factors from positive to negative since 2001.

Because the distortion of labor and capital has the same magnitude and the opposite sign, according to Eq. (5), the pattern of factor reallocation efficiency is in fact driven by the higher than labor rate of capital growth finally, as also shown in Fig. 5. Dessus, Shea, and Shi (1995) and Akkemik (2005) demonstrate that the labor reallocation effect was substantially higher than the capital reallocation effect because labor was a scarce and very important resource for Taiwan and Singapore, respectively. For China, the reverse holds.[5] Qin and Song (2009) find that the tendency of over-investment typical of centrally planned economies, the so-called investment hunger, remains in China today. By showing decelerating growth in total factor productivity and diminishing investment returns during the 1990s, Zhang (2003) suggests that China's overall fixed-asset investment has gone too far, especially with regard to its labor resources. Since the late 1990s, corresponding to labor growth in Fig. 5, the industry in China undergoes a massive labor force reduction due to the policy of furlough (xiagang) and "grasp the large and let go of the small" (zhuadafangxiao). Official employment data showed that the number of workers employed by state industrial enterprises fell from 44.0 million in 1995 to 15.5 million in late 2002, a 65% decline. Urban industrial collectives saw an equally severe decline in employment, from 14.9 million in 1995 to 3.8 million in 2002. Moreover, the 13.8 million workers added to payrolls of private and foreign-funded industrial firms did not compensate for the 39.6 million jobs lost in industrial firms of the state and collective enterprises (Frazier, 2006).

Since structural change and then factor reallocation have played a substantial role in industrial productivity and output growth in China, we need a more in-depth study of the restructuring-growth nexus. How can we explain the visible pattern of the yeast process of structural bonus through structural reform? Why has structural change led to the different mushroom effect of structural effect across sectors, or between light and heavy industry? As revealed in Fig. 4d, though exhibiting similar pattern, the factor allocative efficiency in light industry is higher than that in heavy industry at most of the time points. We need to analyze the forces that drive the yeast and mushroom process of structural bonus. Table 6 reports the regression analysis of factor allocative efficiency (i.e. structural bonus) on its determinants by using dynamic panel data models. The regression is undertaken over two periods, 1981–2008, and 1994–2008, respectively, based on the availability of the corresponding data. The nexus variable, FAEC, is the dependent variable taking the form of percentage. The explanatory variables are introduced as below. The natural logarithm of capital to labor ratio (lnK/L) represents the reform of investment and employment structure in factor market and is used as the important structural variable to explain structural bonus for both models. It also serves as the variable of individual characteristics to reflect sectoral endowment of resources. There exists possible endogeneity for this variable because FAEC is also constructed by the product of the factor distortion and the growth rate of factors such as capital

[5] In addition to the abundant labor forces in China, the tighten labor regulations in China, new labor contract law, will both increase the cost share of actual labor inputs, and slow the growth rate of labor inputs. The former helps correct the labor distortion, therefore improving FAEC and TFP, but the latter will lower the contribution of labor reallocation to total FAEC and then TFP growth.

and labor. Two dummy variables, D1 (1 for low K/L group and 0 otherwise) and D2 (1 for the period of 2001–2008 and 0 otherwise), and their interactive form with ln(K/L) are employed to capture the heterogenous mushroom effect and the time pattern of structural bonus. In Model 2, in addition to ln(K/L) and its product term with D1 and D2, we introduce three structural variables—SOYS (share of SOEs' industrial gross output), LMYS (share of LMEs' industrial gross output) and FFYS (share of FFEs' industrial gross output) to capture how the structure change of ownership, size and foreign investment affect the structural bonus. To obtain robust estimates, we control for several characteristic variables of individual sector. Since Chinese industry is often characterized by high growth, high investment, high energy consumption and low profit. The chosen control variables are natural logarithm of industrial value-added per capita (lnY/L), natural logarithm of energy intensity, i.e. energy consumption per value-added (lnEI), and ratio of profit and tax to gross output (PTYR). To avoid the resulting error term reflecting a systematic pattern due to the influence of lagged FAEC on current FAEC, both models include, among other things, the lagged dependent variable, FAEC_lag1, as the independent variable to extract the entire history of the right hand side variables; in this case, all explanatory variables introduced previously represent the effect of new information. In both the fixed and random effects settings, the difficulty is that the lagged dependent variable is correlate with the disturbance, even if it is assumed that the disturbance is not itself autocorrelated. The unit of all explanatory variables except dummies, ln(Y/L), ln(EI) and ln(K/L) is also a percentage. To control for the possible endogeneity, and estimate the time in varying variable like D1 while still maintaining the assumption that the sectoral effect is correlated with the explanatory variables, two methods of Hausman and Taylor Instrumental Variable (HT/IV) and System GMM by Arellano and Bover are used to estimate both models for robustness check. Also, the robust standard error are reported to correct the heteroscedasticity and autocorrelation probably remained in the residuals. As shown in Table 6, most variables are statistically significant at least at the 10% level. The value of rho represents the ratio of individual effect variance to the total variance, which is 0.60 and 0.48 for HT/IV estimates of two models. Wald statistics reveal that four estimates in this study are overall significant.

Four estimates reveal that the current FAEC significantly depends on the previous FAEC with the coefficient of autocorrelation at lag 1 being relatively high of 0.60 to 0.91. Following Kumar and Russell (2002), who check the effect of output per worker on productivity, we investigate the influence of output per capita (lnY/L) on the productivity growth due to factors reallocation. The estimated coefficient is negative for four estimates and statistically significant for three of them, which indicates that the factor reallocation efficiency declines over time with the growth of industry, similar to the findings of Dowrick and Gemmel (1991). This evidence is in line with the theory of economic convergence that as the level of industrial development rises the adjusting space to push growth upward becomes smaller and smaller (Kumar, 2006). The increase of energy intensity significantly reduces the allocative efficiency - 1% rise of energy intensity decreases FAEC by 0.1459–0.4913%. The heavy industry normally has high growth of energy intensity and, thus tends to experience low allocative efficiency as opposed to light industry. The positive coefficient of PTYR indicates that, as expected, the sector with high profit rate, like non-state industries in China, does experience significantly high factor reallocation efficiency. The significantly positive coefficients of D1 for four estimates are statistically in favor of the findings revealed in Fig. 4d that light industry, as defined in our study, enjoys the higher than heavy industry growth of FAEC by 0.05%–0.09%. The significantly negative coefficients of D2 for four estimates also confirm the conclusion found in Fig. 4d that the factors allocative efficiency deteriorates after the turn of new century. The estimated coefficients of dummy variables in fact favor the presence of mushroom effect and yeast effect of structural bonus in Chinese industry.

After controlling for the sectoral characteristics, we find that, in heavy industry, a 1% increase of capital to labor ratio (lnK/L), the general structural variable in both models, significantly decreases the factor allocative efficiency by 0.77–2.11%; on average, the effect of ln(K/L) on FAEC in light industry is higher than that in heavy industry by 0.10–0.73%, although not significantly; after 2001, the structural effect of ln(K/L) on FAEC is significantly lower than that in former two decades by 0.41–1.29%. This too statistically confirms the overall yeast effect that FAEC declines over time even deteriorates after 2001 with the capital deepening, and the mushroom effect due to capital and labor reallocation across industrial sectors during the entire reform period. The capital to labor ratio is employed here to serve as the proxy of unbalanced investment and employment structure in China's industry, the typical features of underdeveloped factor markets. It is the rapid changing rather than constant growth of capital per capita that leads to increases in labor productivity unable to go hand in hand with increases in TFP, as revealed by the negative coefficient of ln(Y/L) in the regression analysis. The ascent of industrial capital productivity since the late 1990s after the long-term decline, found in Fisher-Vanden and Jefferson (2008), seems not yet to cure the investment hunger; on the contrary, the remaining over-investment trend today deteriorates the allocative efficiency. Qin and Song (2009) ascribe this deterioration to imperfect capital markets, investment structural unbalance and the rigidity of structural change, etc. They argue that policy-induced impulsive investment behavior is still prevalent, soft loans are still available from the banking system, misallocation of financial resources is possible due to imperfect capital markets and investment structure is severely unbalanced especially in view of the state sector. Gong and Lin (2008) assert that, in contrast to most OECD countries, the major financial resource for investment in China is credit. The easy and cheap credit provided by the government via its state banking system is certainly an important transitional feature of the Chinese economy. It reflects the strong intention of government to use its monetary policy to promote economic growth in addition to usual demand management. Li and Xia (2008) declare that the state factor-allocation system in China still controls a vast amount of factor resources such as capital in the forms of bank loans, subsidies and land. Chinese banks have been asked by the government to provide easy credits to the SOEs. In the absence of non-state financial institutions to allocate financial resources more efficiently, the financial sector under state monopoly tended to reinforce the already unequal distribution of financial resources in favor of SOEs. Fung, Kummer, and Shen (2006) report that over half of capital investments were made by SOEs from 1998 to 2002, but the heavy investment of SOEs did not produce output proportional to their investment as compared to that of non-state firms. Thus, it is not surprising to find out the negative influence of capital to labor ratio on structural bonus.

The estimated coefficients of ownership structural variable, SOYS, are statistically significant. A 1% increase of the share of SOEs' industrial gross output reduces the factor allocative efficiency by 0.0388–0.0507%. Overall, the reform of ownership structure converting state industry to non-state ones from the latter of 1990s indeed ameliorates the factor reallocation efficiency, indicating that the reform of SOEs in China is also a reform of the government's regulatory practices from a grabbing-hand approach to a helping-hand approach, also found by Wan and Yuce (2007). This finding mirrors the studies of Li (1997), Sun and Tong (2003), Jefferson and Su (2006), Bai et al. (2009), etc. They discover that the (labor) productivity has been improved by the ownership rights reform in China since the late 1990s. The survival of SOEs is, to a great extent, at the expense of state asset efficiencies due to the agency problem; thus, ownership reform is vital to incentives and to economic performance. In order to ensure the long-term viability of high industrial growth, the restructuring of large SOEs will be the crux of the next wave of reform. Industrial concentration is the core of the theory of industrial organization and the expansion of LMEs helps to increase the degree of industrial concentration. A 1% rise of share of LMEs' industrial gross output significantly reduces the factor allocative efficiency by 0.0347%, which means that industrial concentration will not remedy allocative limits but complete competition of many medium and small-sized firms might. In addition to private enterprises, FFEs including those from Taiwan, Hong Kong, and Macau have developed greatly after the reform. Revealed by Table 6, 1% increase of the share of FFEs' industrial gross output significantly increase FAEC by 0.0269%–0.0304%. As Yusuf et al. (2005) state, the combination of structural reform such as state ownership, LMEs and foreign funded enterprises enhances the overall productivity due to factor reallocation and differentiates them among sectors, which statistically confirms the yeast and mushroom effect of structural bonus found in our estimates in Section 4.

6. Conclusions

This paper investigates the impact of structural reform on the performance of Chinese industry using a panel data set of 38 two-digit industrial sectors over the entire reform period between 1980 and 2008. We apply a stochastic frontier model and decomposition method to measure the changes in total factor productivity and its part due to factor reallocation across industrial sectors. We also use dynamic panel data model to analyze the determinants of structural bonus. We offer basic conclusions and their policy implications below.

1. Since the industrial development strategy converted from heavy-industry-oriented to the parallel importance of light and heavy industry reflecting the comparative advantages in 1978, China's industry has experienced spectacular growth and continuously increasing productivity. The higher than input factor rate of TFP growth after 1992 indicates that the growth model of Chinese industry seems to be transformed from being extensive to intensive. But this transformation is not stable or sustainable due to the decreasing contribution of productivity to output growth currently.
2. The factor inputs could affect industrial growth either directly through a volume effect, like capital accumulation, or indirectly through an efficiency effect that promotes productivity by reallocating the factors from less productive sectors to more productive ones. The growth accounting reveals that, on average, factor allocative efficiency plays a substantial role in industrial growth by pushing productivity upward. Technical progress and capital accumulation account for more industrial growth than FAEC, while labor inputs, technical efficiency and scale effect account for less. We find that the change of factor reallocative efficiency declined over time, especially after the new millenium.
3. The efficiency of factor reallocation results from the structural change since the industrial reform in 1978. Timmer and Szirmai (2000) refer to the positive efficiency effect as structural bonus. We also discover that the structural bonus did exist and matter in both the yeast and the mushroom processes of Chinese industrial transformation. Dynamic panel model regression suggests that the reforms of investment structure, ownership rights structure, size structure and foreign funded enterprises etc. in China significantly contributed to structural bonus at the former two stages, but also to the deterioration of the efficiency effect after 2001.

The factors that drive the deterioration of allocative efficiency since 2001 and produce the difference of allocative efficiency between light and heavy industry highlight the future reform directions for Chinese industry. The most urgent reform is to continue the development of factor markets. In order to relieve the factor distortion and establish long-run sustainable industrialization, it is necessary to reform the dual-track resource allocation system, balance the investment structure, provide non-state enterprises equal access to resources, and develop non-state financial institutions, as suggested by Fung et al. (2006), Gong and Lin (2008), Li and Xia (2008), Qin and Song (2009), etc. Those sectors that are exploiting China's comparative advantage successfully should be supported and promoted. Because labor regulations do have a significantly negative bearing on long-run growth, as found by Calderon, Chong, and Leon (2007), the new labor contract law should be enforced more judiciously. The most challenging reform is to deepen the restructuring of state industry. Indeed, the speed of reforming its SOEs has distinguished China from other formerly centrally planned economies, and thus it has attracted much attention in the economics literature. Based on the negative correlation between state ownership and performance, many researchers recommend that the Chinese government should continue to divest the state ownership until it is a minority shareholder (Bai et al., 2009; Hovey & Naughton, 2007; Wan & Yuce, 2007). This transfer of ownership is a promising path to long-term sustainable growth.

Even if the government decides not to reduce the state to a minority shareholder, it can still improve allocative efficiency by lowering barriers of entry that currently privilege SOEs. In addition, the government could be more impartial in its treatment of NSEs. Only the fair market competitive environment can guarantee the efficient allocation of production materials and encourage state industrial enterprises to act as rational economic entities. The dilemma facing government is to develop market-orientated industry while at the same time coping with the possibility of high unemployment and consequent social unrest.

Acknowledgement

The sponsorship by Shanghai Leading Academic Disciplines Project (#B101), State Innovative Institute of Project 985, Ministry of Education (09YJA790046 and 2009JJD790011), and Natural Sciences Foundation (#70873022) are gratefully acknowledged. Thanks also goes to Tiefeng Qian and Ye Jin for their research assistance.

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