

The Singapore Economic Review, Vol. 63, No. 1 (2017) 1–21  
© World Scientific Publishing Company  
DOI: 10.1142/S0217590817450047



## PRODUCTIVITY DYNAMICS OF CHINESE MANUFACTURING FIRMS

QU FENG\*, ZHIFENG WANG<sup>†</sup> and GUIYING LAURA WU<sup>‡</sup>

*School of Social Sciences, Nanyang Technological University  
14 Nanyang Drive, Singapore 637332*

*\*qfeng@ntu.edu.sg*

*†WANG0869@e.ntu.edu.sg*

*‡guiying.wu@ntu.edu.sg*

Published

China has experienced high-speed catch-up growth with an average annual rate of over 8% in per capita GDP in the past four decades. Using growth accounting, Zhu (Understanding China's growth: Past, present, and future. *Journal of Economics Perspectives*, 26(4), 103–124) finds that the growth of total factor productivity (TFP) accounts for 77% of China's per capita GDP growth during 1978–2007, and argues that China's TFP growth is mainly driven by resource reallocation due to market liberalization and institutional reforms. This paper aims to estimate China's aggregate productivity growth by applying three leading methods of estimating firm-level production function on Chinese manufacturing firms during 1998–2007, and quantify the contribution of resource reallocation to productivity growth. In addition, we also empirically compare the three estimation methods in this large data set.

*Keywords:* China's economic growth; TFP growth; production function; resource reallocation.

JEL Classification: D24, O14

### 1. Introduction

In the past four decades, China has experienced high-speed catch-up growth with average annual rates of nearly 10% and over 8% in GDP and per capita GDP, respectively. To explain the Chinese economic miracle, along with other 12 successful economies, *The Growth Report* (2008) from the World Bank emphasizes on some important ingredients, including globalization, strong government leadership, market allocation and high investment in physical capital and human capital. In terms of the role of government on economic growth, Jin *et al.* (2005) establish the association between fiscal incentives of Chinese local governments and the development of non-state enterprises. Using growth accounting, Zhu (2012) finds that the growth of total factor productivity (TFP) accounts for 77% of China's per capita GDP growth during 1978–2007, and argues that China's TFP growth is mainly driven by resource reallocation due to market liberalization and institutional reforms. Song *et al.* (2011) also point out that reallocation within the manufacturing sector due to financial frictions is an important source of productivity growth in China.

---

\*Corresponding author.

## 2 *The Singapore Economic Review*

Literature on China's productivity growth using aggregate-level data includes Young (2003), Zheng *et al.* (2009), Brandt and Zhu (2010), to name a few. In these studies, the estimates of TFP growth vary a lot due to different treatments on official deflator, capital share and human capital. In contrast to the studies using aggregate level data that are usually silent on industry variation, firm heterogeneity, and the link between productivity and observables, the recent literature focuses on productivity from estimating firm-level production function.

Jefferson *et al.* (2008) use OLS and fixed effects estimation on data of China's annual industrial survey during 1998–2005. Using the same data set, Brandt *et al.* (2012) conduct a more thorough study on estimating firm productivity and its determinants. Based on Tornqvist index and the recent proxy methods of estimating firm-level production function proposed by Olley and Pakes (1996, OP hereafter) and Akerberg *et al.* (2006, 2015, ACF hereafter), they find that up to two-thirds of the aggregate TFP growth in Chinese manufacturing is due to entry and exit during 1998–2007. In a study on the effect of reductions in tariffs on productivity of Chinese exporting firms, Yu (2015) also use the OP method and the system GMM method proposed by Blundell and Bond (2000, BB hereafter) to estimate firm-level production function. Recently, Ding *et al.* (2016) also employ the BB method to estimate firm-level productivity and examine the determinants of productivity of Chinese manufacturing firms.<sup>1</sup>

This paper aims to understand China's economic growth from the view of firm-level productivity growth. We present the productivity dynamics of Chinese manufacturing firms during 1998–2007, including productivity trend over time, industry pattern, and the link between firm productivity and observable firm characteristics, such as region, ownership, entry and exit, and exporting. In addition, as in Pavcnik (2002), we also examine how much the aggregate productivity growth can be explained by reallocation of resources from low productivity firms to high productivity ones within each industry.

Another motivation of this paper is to empirically compare the leading methods of estimating firm-level production function, that is, ACF and BB with the traditional OLS in this large data set.<sup>2</sup> OLS has the advantage of being computationally simple and stable. Compared with OLS, the ACF approach is able to deal with endogeneity issue due to the correlation between inputs and unobserved productivity. However, in the ACF approach firm fixed effects and firm productivity are not distinguishable. Different from the ACF approach, the BB approach is able to control for firm fixed effects, but its assumption on the productivity process is more restrictive.<sup>3</sup>

Based on estimating revenue-measured firm-level production function, our findings are as follows. First, the average annual aggregate TFP growth of Chinese manufacturing firms ranges from 3.75% to 5.99% during 1998–2007, supporting Zhu's (2012) estimate of

---

<sup>1</sup> For a detailed literature review on estimating and explaining China's TFP growth, see Ding *et al.* (2016).

<sup>2</sup> The motivation of empirically comparing three leading methods of estimating firm-level production function distinguishes our paper from Brandt *et al.* (2012). In addition, we quantify the role of resource reallocation in promoting productivity growth by a decomposition based on Olley and Pakes (1996) and Pavcnik (2002).

<sup>3</sup> For a theoretical comparison between these two approaches, see Section 5.3 of Akerberg *et al.* (2006). The limitation of the proxy methods is also discussed by Bond and Söderbom (2005).

annual TFP growth of 4.68% using aggregate-level data. Second, the contribution to aggregate weighted productivity growth from resource reallocation only happens in the late 1990s and the early 2000s thanks to the reforms of state-owned enterprises and the entry to the WTO, and declines to almost zero in 2007 in most industries. Third, among the observable characteristics, location and ownership robustly explain the firm-level productivity variation across different industries and from different estimation methods.

Regarding the comparison of OLS, ACF and BB methods, using the large data set of Chinese manufacturing firms, we find that: first, these three estimates produce the same patterns on productivity growth over time and the contribution of resource reallocation to productivity growth. Second, in terms of magnitude, BB method gives a generous estimate of productivity growth, while ACF produces a conservative one. Third, the analysis of determinants of firm-level productivity based on OLS, ACF and BB estimates gives same signs of effects of region and ownership on productivity, but ACF and BB produce conflicting evidence on the exporting effect, either pooling all industries or among individual industries. This finding suggests that one should be cautious to analyze the determinants of productivity based on only one estimation method of production function.

This paper is organized as follows. Section 2 briefly describes the ACF and BB approaches of estimating firm-level production function. Section 3 gives a brief description of data and variables used in our empirical exercises. Section 4 reports the empirical results on firm productivity, and links it to observables by regression analyses. Finally, Section 5 concludes.

## 2. Estimating Firm Productivity

### 2.1. ACF approach

In a firm-level production function,

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \varepsilon_{it}, \quad (1)$$

$y$ ,  $l$ ,  $k$  and  $m$  represent log of revenue, labor, capital, intermediate input, respectively.  $\omega$  denotes firm's unobservable productivity, and  $\varepsilon$  stands for random shocks to production. Since the decision of inputs  $l$ ,  $k$  and  $m$  depends on the unobservable productivity  $\omega$ , OLS estimate for  $(\beta_l, \beta_k, \beta_m)$  is inconsistent.

To deal with this endogeneity issue, following the ideas of Olley and Pakes (1996), Levinsohn and Petrin (2003), Akerberg *et al.* (2006) use the intermediate input  $m$  as a proxy for  $\omega$ . Specifically, from profit maximization  $m_{it}$  is solved out as an increasing function of productivity, conditional on capital and labor:

$$m_{it} = f(l_{it}, k_{it}, \omega_{it}). \quad (2)$$

Assuming that  $f$  is invertible for  $\omega_{it}$ :

$$\omega_{it} = g(l_{it}, k_{it}, m_{it}), \quad (3)$$

#### 4 *The Singapore Economic Review*

implies that

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + g(l_{it}, k_{it}, m_{it}) + \varepsilon_{it} = \phi(l_{it}, k_{it}, m_{it}) + \varepsilon_{it}. \quad (4)$$

To consistently estimate  $(\beta_l, \beta_k, \beta_m)$ , a two-step procedure is applied. For estimation details, see Ackerberg *et al.* (2006).

### 2.2. *BB approach*

Blundell and Bond (2000) allow for firm fixed effects  $\eta_i$  in the production function:

$$y_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_m m_{it} + \eta_i + v_{it} + \xi_{it}. \quad (5)$$

The productivity shock  $v_{it}$  strictly follows an AR(1) process,

$$v_{it} = \theta v_{it-1} + e_{it}, \quad (6)$$

implying a dynamic panel model of production function:

$$y_{it} = \theta y_{it-1} + \alpha_l l_{it} - \theta \alpha_l l_{it-1} + \alpha_k k_{it} - \theta \alpha_k k_{it-1} + \alpha_m m_{it} - \theta \alpha_m m_{it-1} + \eta_i(1 - \theta) + e_{it} + \xi_{it} - \theta \xi_{it-1}. \quad (7)$$

Due to the persistence of productivity shock  $v_{it}$ , Blundell and Bond (2000) suggest using system GMM, instead of the first-difference GMM, to estimate the dynamic panel data model (7). The original input parameters  $\alpha_l$ ,  $\alpha_k$  and  $\alpha_m$  can be recovered by the estimates of parameters in (7). For estimation details, see Blundell and Bond (2000).

Besides ACF and BB approaches of estimating firm-level production function, we also use OLS for comparison. After obtaining input coefficient estimates, firm-level productivity is defined as the Solow residual, that is the difference between output (revenue) and its fitted value.

This paper is closely related to Ding *et al.* (2016) with some important differences as follows. First, to obtain robust results, we report empirical findings based on 3 methods: OLS, ACF and BB, instead of only on BB estimates. Second, Ding *et al.* (2016) use the one-stage approach including observable firm characteristics in addition to inputs in the production function, while this paper follows Brandt *et al.* (2012) and Yu (2015) to estimate firm-level production function and productivity, so that the input coefficient estimates are more comparable to the vast literature. Third, time dummies, instead of time trend, are used to control for year-specific effects in the production function estimation in this paper. Fourth, we deal with data slightly differently from Ding *et al.* (2016), who combine some industries together. Finally, we highlight the importance of resource reallocation in TFP growth using a Pavcnik (2002) decomposition, besides the Haltiwanger (2007) decomposition as in Ding *et al.* (2016).

### 3. Data and Variables

The data set used in this paper, same as Brandt *et al.* (2012), is the Annual Survey of Industrial Firms conducted by China's National Bureau of Statistics covering 1998–2007.

Firms are either state-owned or are non-state firms with sales above 5 million RMB. For the details of data, see Brandt *et al.* (2012).

We follow Brandt *et al.* (2012) to construct the real capital stock with a depreciation rate of 9%. The number of the employees is used as labor input. The intermediate input is defined as the input minus financial cost. Output and input data are deflated by the price indices provided by Brandt *et al.* (2012). Table 1 gives the description of the key variables.

The value of entry dummy is set to be 1 when the firm is observed in the sample for the first time, 0 otherwise. The exit dummy specifies whether a firm will exit the sample in year  $t + 1$ . The export dummy has a value of 1 if the export revenue is positive in a firm-year observation.

Since geographic differentiation and regional disparity are important features of China's economy (Naughton, 2007), we include regional effect when examining the determinants of firm-level productivity. Following Jefferson *et al.* (2008), we classify Chinese provinces into four regions: coastal, central, western and northeastern regions. The coastal region includes 10 provinces, i.e., Beijing, Fujian, Guangdong, Hainan, Hebei, Jiangsu, Shanghai, Shandong, Tianjin and Zhejiang. The northeastern region only includes 3 provinces, Heilongjiang, Jilin and Liaoning. 9 provinces of Anhui, Guangxi, Henan, Hubei, Hunan,

Table 1. Summary Statistics of Variables

| Symbol | Definition and Variables                            | Unit       | Mean  | Std. D | Form in Regression | # of Obs. |
|--------|---|------------|-------|--------|--------------------|-----------|
| $l$    | Number of employees                                 |            | 4.739 | 1.165  | log                | 2,019,897 |
| $m$    | Intermediate input minus financial costs            | 1,000 yuan | 9.477 | 1.449  | log                | 2,004,491 |
| $k$    | Capital stock following Brandt <i>et al.</i> (2012) | 1,000 yuan | 8.453 | 1.658  | log                | 2,014,493 |
| $y$    | Revenues  | 1,000 yuan | 9.789 | 1.432  | log                | 2,010,324 |
|        | Entry   | dummy      | 0.187 | 0.390  |                    | 2,049,297 |
|        | Exit  | dummy      | 0.104 | 0.306  |                    | 2,049,297 |
|        | Exporting   | dummy      | 0.269 | 0.443  |                    | 2,049,297 |
|        | Regional variables:                                 |            |       |        |                    |           |
|        | Central   | dummy      | 0.175 | 0.380  |                    | 2,049,297 |
|        | Costal  | dummy      | 0.677 | 0.468  |                    | 2,049,297 |
|        | Western   | dummy      | 0.084 | 0.277  |                    | 2,049,297 |
|        | Northeastern  | dummy      | 0.064 | 0.245  |                    | 2,049,297 |
|        | Ownership variables:                                |            |       |        |                    |           |
|        | SOE   | dummy      | 0.118 | 0.322  |                    | 2,049,297 |
|        | COE   | dummy      | 0.120 | 0.325  |                    | 2,049,297 |
|        | DPE   | dummy      | 0.359 | 0.480  |                    | 2,049,297 |
|        | HMT   | dummy      | 0.108 | 0.310  |                    | 2,049,297 |
|        | FIE   | dummy      | 0.098 | 0.297  |                    | 2,049,297 |
|        | OTHER   | dummy      | 0.197 | 0.398  |                    | 2,049,297 |

Source: National Bureau of Statistics of China over years of 1998–2007.

Inner Mongolia, Jiangxi and Shanxi belong to the central region. The western region consists of the rest of 10 provinces, Chongqing, Gansu, Guizhou, Ningxia, Qinghai, Shaanxi, Sichuan, Xinjiang, Tibet, and Yunnan.

The ownership dummy is defined by the registration types, including state-owned enterprises (SOE), collective-owned enterprises (COE), domestic private-owned enterprises (DPE), Hong Kong, Macao or Taiwan owned enterprises (HMT), foreign invested enterprise (FIE), and other types (Others).

#### 4. Empirical Findings

This section presents some empirical findings on productivity dynamics of Chinese manufacturing firms, and links the firm-level productivity to observables, including entry and exit, exporting status, location and ownership. In addition, the Pavcnik (2002) decomposition allows us to study how much productivity growth is accounted for by reallocation within each industry. Different from the existing literature, we present the results using three different methods of estimating firm-level production function, and emphasize on the robustness of the findings and cross industry variation.

##### 4.1. Productivity dynamics

Table 2 reports the estimated coefficients of production function by industry. According to our identification assumption, OLS is inconsistent due to endogeneity issue, while ACF and BB are consistent. The trade-off is, however, also clear. Among these 29 industries, there are only two negative and small coefficients for OLS, while there are seven and six negative coefficients for ACF and BB, respectively. Since OLS is less demanding in solving out the estimates from the minimization problems than ACF and BB, it seems that OLS could be more reliable in terms of calculation.

Similar to Yu (2015), we find that from all three methods, the coefficients of labor and capital are relatively small, below 0.1 in most cases, while the coefficients of intermediate input are relatively large, compared with the general literature on estimating production function using firm-level data, such as Pavcnik (2002). This reflects the facts of the low value-added generated by the Chinese manufacturing sector. For  $\beta_l$  and  $\beta_k$ , the BB estimates are generally bigger than the OLS and ACF estimates. Consequently, the BB's  $\beta_m$  estimates are smaller than the OLS and ACF estimates.

Figure 1 plots aggregated productivity growth of manufacturing firms during 1999–2007. These productivity growth rates are aggregated from firm-level productivity using firm revenue as the weights. The dashed-spots, solid and dotted lines represent productivity estimates based on OLS, ACF and BB approaches, respectively. Figure 1 shows that three productivity growth estimates are positive and fluctuate over years with a similar pattern. There is a big drop of productivity growth in 2001, followed by a steady increase until 2005. Table 3 reports annual aggregate productivity growth of the manufacturing sector and the 29 individual industries. The average annual productivity growth rates are 4.16%, 3.75% and 5.99% for OLS, ACF and BB estimates reported in columns 1, 5, 9 of the first row, larger than 2.85% obtained by Brandt *et al.* (2012) based on gross output.

Table 2. Production Function Estimation

| Industry | OLS       |           |           | ACF       |           |           | BB        |           |           | # of Obs. |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|          | $\beta_l$ | $\beta_k$ | $\beta_m$ | $\beta_l$ | $\beta_k$ | $\beta_m$ | $\beta_l$ | $\beta_k$ | $\beta_m$ |           |
| 13       | 0.054     | 0.040     | 0.892     | 0.043     | 0.035     | 0.910     | 0.111     | -0.007    | 0.932     | 122,720   |
| 14       | 0.046     | 0.047     | 0.910     | 0.006     | 0.051     | 0.938     | 0.134     | 0.035     | 0.909     | 48,640    |
| 15       | 0.053     | 0.054     | 0.900     | -0.063    | 0.055     | 0.998     | -0.090    | 0.106     | 0.848     | 33,534    |
| 16       | 0.119     | 0.214     | 0.785     | 0.620     | 0.251     | 0.542     | 0.404     | 0.401     | 0.541     | 2,397     |
| 17       | 0.038     | 0.032     | 0.888     | 0.002     | 0.014     | 0.979     | 0.064     | 0.161     | 0.824     | 170,680   |
| 18       | 0.103     | 0.043     | 0.823     | 0.162     | -0.014    | 0.893     | 0.112     | 0.073     | 0.824     | 95,148    |
| 19       | 0.082     | 0.027     | 0.875     | 0.070     | 0.008     | 0.940     | 0.160     | 0.140     | 0.685     | 47,176    |
| 20       | 0.030     | 0.039     | 0.882     | 0.133     | -0.032    | 0.982     | 0.040     | 0.281     | 0.771     | 42,771    |
| 21       | 0.087     | 0.039     | 0.872     | 0.067     | 0.025     | 0.923     | 0.159     | 0.009     | 0.617     | 22,984    |
| 22       | 0.011     | 0.047     | 0.905     | 0.070     | 0.078     | 0.835     | 0.092     | 0.164     | 0.789     | 58,947    |
| 23       | -0.006    | 0.104     | 0.890     | 0.222     | 0.040     | 0.845     | -0.133    | 0.387     | 0.565     | 41,749    |
| 24       | 0.071     | 0.056     | 0.843     | 0.095     | 0.026     | 0.905     | 0.175     | -0.040    | 0.529     | 26,066    |
| 25       | 0.059     | 0.061     | 0.855     | 0.129     | 0.044     | 0.836     | 0.015     | 0.214     | 0.680     | 17,400    |
| 26       | 0.031     | 0.054     | 0.876     | 0.017     | 0.031     | 0.938     | 0.161     | 0.064     | 0.823     | 144,141   |
| 27       | 0.000     | 0.092     | 0.883     | 0.088     | 0.146     | 0.764     | 0.152     | 0.152     | 0.551     | 41,182    |
| 28       | 0.027     | 0.032     | 0.916     | 0.006     | 0.018     | 0.957     | 0.214     | 0.022     | 0.766     | 10,009    |
| 29       | 0.043     | 0.050     | 0.870     | -0.006    | 0.028     | 0.971     | 0.439     | 0.439     | 0.439     | 23,516    |
| 30       | 0.050     | 0.048     | 0.863     | 0.060     | 0.063     | 0.856     | -0.005    | 0.054     | 0.869     | 92,200    |
| 31       | -0.004    | 0.048     | 0.920     | 0.088     | 0.157     | 0.810     | 0.005     | 0.079     | 0.901     | 169,436   |
| 32       | 0.052     | 0.039     | 0.897     | 0.051     | 0.013     | 0.946     | 0.098     | 0.167     | 0.657     | 47,344    |
| 33       | 0.085     | 0.030     | 0.871     | -0.010    | 0.013     | 0.953     | 0.026     | 0.045     | 0.709     | 35,214    |
| 34       | 0.054     | 0.047     | 0.869     | 0.062     | 0.031     | 0.923     | 0.017     | 0.082     | 0.797     | 107,054   |
| 35       | 0.021     | 0.045     | 0.893     | -0.011    | 0.039     | 0.950     | 0.071     | 0.034     | 0.704     | 149,652   |
| 36       | 0.004     | 0.045     | 0.904     | 0.068     | 0.076     | 0.824     | 0.253     | 0.285     | 0.524     | 82,886    |
| 37       | 0.054     | 0.049     | 0.874     | 0.215     | -0.028    | 0.891     | 0.184     | 0.149     | 0.654     | 94,958    |
| 39       | 0.066     | 0.042     | 0.866     | 0.051     | 0.038     | 0.903     | -0.089    | 0.173     | 0.758     | 117,375   |
| 40       | 0.076     | 0.050     | 0.858     | 0.052     | 0.162     | 0.779     | 0.119     | 0.170     | 0.657     | 65,487    |
| 41       | 0.038     | 0.053     | 0.852     | 0.097     | 0.011     | 0.891     | 0.070     | -0.008    | 0.240     | 27,950    |
| 42       | 0.080     | 0.042     | 0.847     | 0.081     | 0.038     | 0.868     | 0.226     | 0.198     | 0.642     | 38,510    |

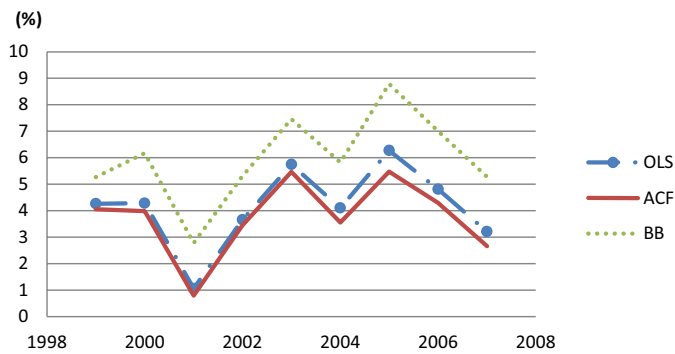
Notes: 1. For the definition of OLS, ACF and BB, please refer to Figure 1.

2. Number of observations refers to number of observations used in OLS estimation of production function.

These estimates support Zhu's (2012) estimate of annual TFP growth of 4.68% based on aggregate-level data during the same period.

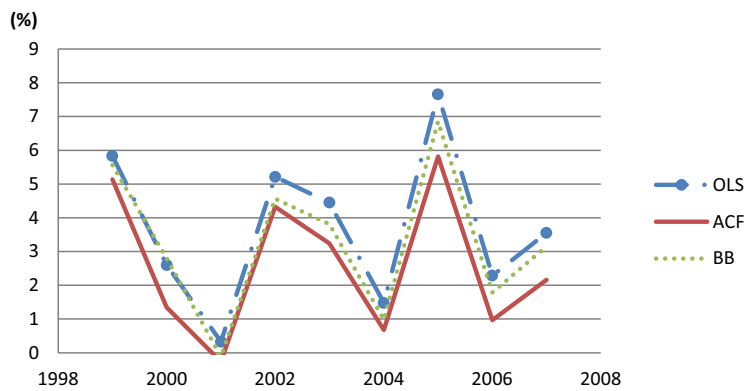
To explore cross industry variation, we also report aggregated productivity growth in Figures 2(a), 2(b) and 2(c) for three industries: textile, raw chemical materials and chemical products, and electronic and telecommunications equipment. These three industries are chosen because they belong to downstream, upstream and middle stream industries, respectively (Li *et al.*, 2015). In addition, as shown in Table 3 below, they present different productivity growth rates. The electronic and telecommunications equipment industry grows at a second highest rate in the whole manufacturing sector, while

8 *The Singapore Economic Review*

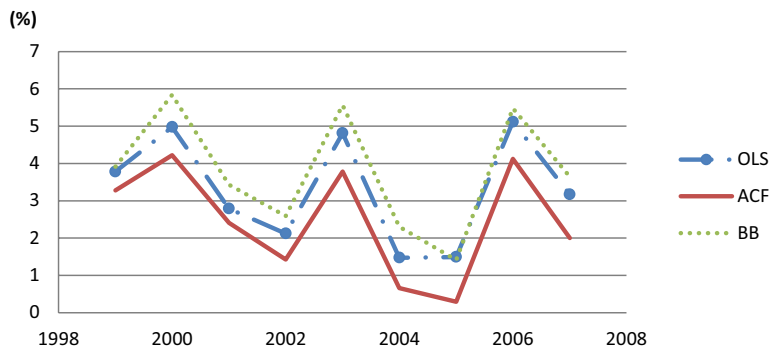


Notes: 1. This figure reports revenue-weighted aggregate productivity growth of all manufacturing industries.  
 2. OLS, ACF and BB represent productivity estimates based on OLS, Akerberg *et al.* (2006), and Blundell and Bond (2000) approaches, respectively.

Figure 1. Aggregate Productivity Growth



(a)



(b)

Notes: 1. Figures 2(a), 2(b) and 2(c) report revenue-weighted productivity growths of industries of textile, raw chemical materials, and electronic and telecommunications equipment, respectively.  
 2. For the definition of OLS, ACF and BB, please refer to Figure 1.

Figure 2. (a) Productivity Growth: Textile. (b) Productivity Growth: Raw Chemical Materials. (c) Productivity Growth: Electronic and Telecommunications



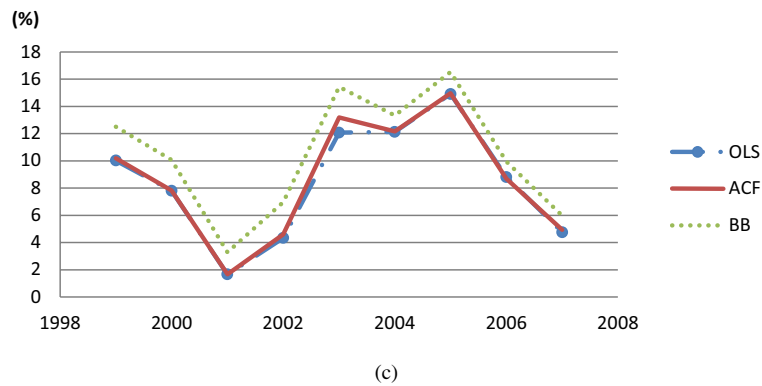


Fig. 2. (Continued)

the growth rates of textile and raw chemical materials industries are lower than the average. First, same as the all-industry aggregate productivity growth in Figure 1, these figures of industry-level productivity growth based on three different estimates follow a similar pattern over time. The OLS, ACF and BB estimates of productivity growth have positive annual averages, e.g., 3.30%, 2.47% and 3.80% for the industry of raw chemical materials and chemical products (code 26) reported in columns 1, 5, 9 of Table 3.

Second, however, different from aggregate productivity growth of the manufacturing sector, productivity growth in specific industry can be negative in some years. For example, the OLS, ACF and BB estimates of minimal annual productivity growth in the tobacco industry (code 16) are  $-2.23\%$ ,  $-1.50\%$  and  $-1.59\%$ , reported in columns 4, 8, 12 of Table 3. Some industries even experience negative annual aggregate productivity growth rates based on OLS and ACF estimates. Third, productivity growth varies across industry in terms of the average growth rate, volatility and pattern over time. For example, the annual average productivity growth rates of electronic and telecommunications equipment (code 40) are 8.49%, 8.68% and 10.44% for OLS, ACF and BB estimates, much higher than all-industry annual averages.

Finally, Figures 2(a)–2(c) of the three industry cases also indicate that there is no uniform order of the three different estimates of productivity growth. The ranking of OLS, ACF and BB can be random across industry, although a rule of  $BB > OLS > ACF$  seems more common in 17 out of 29 industries,<sup>4</sup> and a similar magnitude is observed in 6 out of the rest 12 industries.

Different from the negative productivity growth in five industries reported in Table 4 of Ding *et al.* (2016), our BB estimates of average annual productivity growth are always positive in column 9 of Table 3. In addition, it seems that our BB estimates of productivity growth are much larger than theirs.

<sup>4</sup>This is consistent with production function coefficient estimates. More than half of the ACF capital and labor coefficient estimates are smaller than those OLS estimates. The BB intermediate input coefficient estimate is generally smaller than the OLS estimate.

Table 3. Annual Aggregate Productivity Growth During 1999–2007 (%)

| Industry Code | Industry                   | OLS         |         |         |         |             | ACF     |         |         |             |          | BB       |          |  |  |  |
|---------------|----------------------------|-------------|---------|---------|---------|-------------|---------|---------|---------|-------------|----------|----------|----------|--|--|--|
|               |                            | Average (1) | Std (2) | Max (3) | Min (4) | Average (5) | Std (6) | Max (7) | Min (8) | Average (9) | Std (10) | Max (11) | Min (12) |  |  |  |
|               | All-industry               | <b>4.16</b> | 1.51    | 6.27    | 1.06    | <b>3.75</b> | 1.43    | 5.48    | 0.79    | <b>5.99</b> | 1.69     | 8.79     | 2.78     |  |  |  |
| 13            | Food processing            | 3.14        | 4.71    | 7.91    | -6.31   | 2.90        | 4.78    | 7.89    | -6.72   | 2.60        | 4.80     | 7.72     | -7.17    |  |  |  |
| 14            | Food manufacturing         | 3.12        | 3.05    | 6.89    | -1.89   | 2.80        | 3.06    | 6.61    | -2.14   | 2.71        | 3.13     | 6.88     | -2.34    |  |  |  |
| 15            | Beverage                   | 3.14        | 2.70    | 8.08    | -0.37   | 2.16        | 2.84    | 7.89    | -1.57   | 4.20        | 3.12     | 8.75     | 0.23     |  |  |  |
| 16            | Tobacco                    | 1.97        | 3.45    | 7.07    | -2.23   | 4.02        | 3.58    | 9.30    | -1.50   | 3.39        | 3.71     | 7.99     | -1.59    |  |  |  |
| 17            | Textile                    | 3.71        | 2.31    | 7.66    | 0.33    | 2.60        | 2.14    | 5.81    | -0.26   | 3.26        | 2.21     | 6.85     | -0.12    |  |  |  |
| 18            | Garments and fiber         | 4.55        | 2.08    | 8.15    | 1.05    | 3.70        | 1.90    | 6.44    | 0.28    | 4.10        | 2.00     | 7.40     | 0.65     |  |  |  |
| 19            | Leather, furs              | 3.33        | 1.11    | 4.82    | 0.81    | 2.46        | 1.07    | 3.96    | 0.13    | 4.79        | 1.57     | 6.54     | 2.05     |  |  |  |
| 20            | Timber, bamboo             | 10.90       | 9.28    | 23.01   | -4.89   | 9.92        | 9.71    | 23.17   | -5.83   | 9.32        | 8.28     | 20.26    | -5.07    |  |  |  |
| 21            | Furniture                  | 5.95        | 3.75    | 13.92   | 1.14    | 5.48        | 3.93    | 13.88   | 0.59    | 10.12       | 3.30     | 16.70    | 5.63     |  |  |  |
| 22            | Papermaking and paper      | 5.24        | 3.10    | 12.50   | 1.46    | 5.71        | 3.06    | 12.82   | 1.82    | 5.30        | 2.95     | 12.00    | 1.60     |  |  |  |
| 23            | Printing                   | 4.47        | 3.53    | 8.50    | -2.30   | 4.70        | 3.17    | 8.14    | -1.80   | 6.51        | 3.49     | 10.75    | -0.38    |  |  |  |
| 24            | Cultural, educational      | 4.92        | 3.08    | 10.19   | 0.62    | 4.24        | 3.00    | 9.17    | 0.16    | 9.65        | 4.06     | 17.73    | 4.26     |  |  |  |
| 25            | Petroleum                  | -1.92       | 5.43    | 4.29    | -11.83  | -1.52       | 5.44    | 4.36    | -11.35  | 0.59        | 5.39     | 7.79     | -9.55    |  |  |  |
| 26            | Raw chemical materials     | 3.30        | 1.45    | 5.12    | 1.47    | 2.47        | 1.48    | 4.22    | 0.29    | 3.80        | 1.57     | 5.84     | 1.41     |  |  |  |
| 27            | Medical and pharmaceutical | 6.30        | 2.19    | 9.44    | 2.82    | 6.88        | 2.02    | 10.34   | 3.52    | 7.68        | 2.12     | 12.00    | 4.41     |  |  |  |
| 28            | Chemical fiber             | 2.08        | 6.15    | 10.09   | -8.69   | 1.54        | 6.28    | 9.59    | -9.87   | 4.11        | 5.95     | 12.82    | -4.55    |  |  |  |
| 29            | Rubber                     | 4.71        | 2.64    | 7.51    | 0.69    | 3.44        | 2.52    | 6.05    | -0.26   | 10.31       | 4.38     | 18.34    | 1.91     |  |  |  |
| 30            | Plastic                    | 6.44        | 3.37    | 13.96   | 2.25    | 6.30        | 3.34    | 13.77   | 2.21    | 6.71        | 3.39     | 14.26    | 2.38     |  |  |  |
| 31            | Nonmetal mineral           | 6.42        | 4.09    | 10.68   | 0.64    | 6.78        | 3.90    | 10.82   | 1.32    | 6.40        | 4.03     | 10.59    | 0.69     |  |  |  |
| 32            | Ferrous metals             | 2.17        | 4.50    | 9.71    | -4.24   | 1.37        | 4.73    | 9.34    | -5.44   | 5.84        | 3.78     | 11.17    | 0.43     |  |  |  |
| 33            | Nonferrous metals          | -0.94       | 6.44    | 7.55    | -10.24  | -2.25       | 7.17    | 7.65    | -13.14  | 3.05        | 4.43     | 8.03     | -3.37    |  |  |  |
| 34            | Metal products             | 3.41        | 0.91    | 4.60    | 1.92    | 2.56        | 0.79    | 3.66    | 1.25    | 4.57        | 1.21     | 5.89     | 2.37     |  |  |  |
| 35            | Ordinary machinery         | 3.25        | 1.42    | 6.14    | 0.78    | 2.30        | 1.29    | 4.93    | 0.04    | 6.94        | 2.38     | 11.61    | 3.41     |  |  |  |
| 36            | Special purpose equipment  | 3.91        | 2.14    | 6.47    | 0.30    | 4.81        | 2.06    | 7.25    | 1.24    | 7.48        | 2.09     | 9.88     | 4.32     |  |  |  |
| 37            | Transport                  | 4.05        | 2.34    | 6.56    | -0.34   | 3.32        | 1.98    | 5.45    | -0.59   | 7.04        | 2.73     | 10.38    | 3.76     |  |  |  |
| 39            | Electric                   | 1.47        | 2.41    | 5.26    | -2.29   | 0.85        | 2.57    | 4.71    | -3.19   | 3.34        | 2.07     | 6.65     | 0.24     |  |  |  |
| 40            | Electronic and telecom     | 8.49        | 4.30    | 14.90   | 1.66    | 8.69        | 4.40    | 14.95   | 1.67    | 10.44       | 4.45     | 16.52    | 3.28     |  |  |  |
| 41            | Instruments, meters        | 4.98        | 1.92    | 9.74    | 3.21    | 4.08        | 1.84    | 8.68    | 2.49    | 17.16       | 3.98     | 22.23    | 9.27     |  |  |  |
| 42            | Other manufacturing        | 3.65        | 1.80    | 5.31    | 0.57    | 3.32        | 1.76    | 5.09    | 0.32    | 3.92        | 2.13     | 6.24     | 0.80     |  |  |  |

Note: For the definition of OLS, ACF and BB, please refer to Figure 1.

#### **4.2. Productivity growth and reallocation**

Similar to Olley and Pakes (1996) and Pavcnik (2002), Table 4 presents the decomposition of aggregate weighted productivity into unweighted productivity and the covariance between a firm's productivity and its share of the industry output (revenue). A positive covariance indicates the contribution to the aggregate weighted productivity resulting from the reallocation of resources from low-productivity firms to high-productivity firms within the industry.

Table 4 reports the decomposition for three industries: textile, raw chemical materials and chemical products, and electronic and telecommunications equipment. Column 1 reports the OLS weighted aggregate productivity levels, minus its level in 1998, so that they can be interpreted as growth relative to 1998. For example, in textile industry, the aggregate productivity grows by 6.7% in 2000 relative to 1998 based on OLS. Unweighted productivity and covariance growth are 4.8% and 1.9%, reported in columns 2 and 3, indicating that the contribution of resource reallocation to aggregate weighted productivity growth is 28% in 2000. This contribution declines to 6.4% in 2002. The same decomposition based on ACF and BB estimates, reported in columns 4–9 of Table 4, delivers the same message that efficient reallocation of resources and market shares only happens during 1999–2001 in the textile industry.

In the electronic and telecommunications industry, the contributions of resource reallocation to aggregate weighted productivity growth are mostly positive, but declining to almost 0 at the end of period of 1999–2007. This pattern is robust to OLS, ACF and BB estimates of productivity.

In the appendix, we also report the decomposition for other 26 industries. Consistent with the finding in Table 4 above, reallocation of the resources and market share from the less to more productive firms diminishes in late years. This suggests that resource reallocation of manufacturing firms due to the major reforms of state-owned enterprises in the late 1990s and the entry to the WTO in 2001 has been realized. To further promote productivity growth, more market liberalizations in factor markets and financial systems are needed.

#### **4.3. Productivity determinants**

To explain the productivity variation among different industries, regions and ownerships, we link firm-level productivity to these observables. In addition, we also include firm-level characteristics, e.g., entry, exit and exporting status, which are beyond the existing analysis using aggregate-level data.

Table 5 reports the regression results of pooling all industries based on the three estimates of firm-level productivity: OLS, ACF and BB. First, consistent with the analysis using aggregate-level data, firm-level productivity varies significantly across regions and ownerships. On average firms in costal regions have higher productivity than those in central and western provinces. In addition, foreign and private firms are more productive than state-owned firms, after controlling for other factors, industry and year dummies.

Table 4. Decomposition of Aggregate Productivity Growth: Three Industries

| Industry               | Year  | OLS                        |                             |                | ACF                        |                             |                | BB                         |                             |                |
|------------------------|-------|----------------------------|-----------------------------|----------------|----------------------------|-----------------------------|----------------|----------------------------|-----------------------------|----------------|
|                        |       | Aggregate Productivity (1) | Unweighted Productivity (2) | Covariance (3) | Aggregate Productivity (4) | Unweighted Productivity (5) | Covariance (6) | Aggregate Productivity (7) | Unweighted Productivity (8) | Covariance (9) |
| Textile                | 1998  | 0.000                      | 0.000                       | 0.000          | 0.000                      | 0.000                       | 0.000          | 0.000                      | 0.000                       | 0.000          |
|                        | 1999  | 0.050                      | 0.024                       | 0.026          | 0.040                      | 0.019                       | 0.021          | 0.041                      | 0.025                       | 0.016          |
|                        | 2000  | 0.067                      | 0.048                       | 0.019          | 0.045                      | 0.030                       | 0.014          | 0.066                      | 0.065                       | 0.002          |
|                        | 2001  | 0.055                      | 0.048                       | 0.007          | 0.026                      | 0.023                       | 0.003          | 0.069                      | 0.089                       | -0.020         |
|                        | 2002  | 0.095                      | 0.089                       | 0.006          | 0.057                      | 0.058                       | -0.001         | 0.113                      | 0.140                       | -0.027         |
|                        | 2003  | 0.121                      | 0.129                       | -0.008         | 0.073                      | 0.091                       | -0.017         | 0.142                      | 0.192                       | -0.049         |
|                        | 2004  | 0.107                      | 0.147                       | -0.040         | 0.063                      | 0.106                       | -0.043         | 0.171                      | 0.256                       | -0.085         |
|                        | 2005  | 0.176                      | 0.208                       | -0.032         | 0.115                      | 0.156                       | -0.041         | 0.226                      | 0.302                       | -0.076         |
| Raw chemical materials | 2006  | 0.185                      | 0.220                       | -0.035         | 0.117                      | 0.162                       | -0.045         | 0.240                      | 0.321                       | -0.082         |
|                        | 2007  | 0.215                      | 0.253                       | -0.038         | 0.136                      | 0.185                       | -0.050         | 0.275                      | 0.359                       | -0.084         |
|                        | 1998  | 0.000                      | 0.000                       | 0.000          | 0.000                      | 0.000                       | 0.000          | 0.000                      | 0.000                       | 0.000          |
|                        | 1999  | 0.025                      | 0.012                       | 0.013          | 0.014                      | 0.011                       | 0.004          | 0.006                      | 0.016                       | -0.010         |
|                        | 2000  | 0.082                      | 0.048                       | 0.034          | 0.057                      | 0.040                       | 0.017          | 0.081                      | 0.066                       | 0.015          |
|                        | 2001  | 0.105                      | 0.061                       | 0.044          | 0.074                      | 0.046                       | 0.028          | 0.119                      | 0.097                       | 0.023          |
|                        | 2002  | 0.127                      | 0.068                       | 0.058          | 0.090                      | 0.046                       | 0.045          | 0.153                      | 0.118                       | 0.035          |
|                        | 2003  | 0.176                      | 0.131                       | 0.045          | 0.126                      | 0.103                       | 0.023          | 0.217                      | 0.191                       | 0.026          |
| 2004                   | 0.175 | 0.136                      | 0.039                       | 0.117          | 0.103                      | 0.014                       | 0.244          | 0.227                      | 0.017                       |                |
| 2005                   | 0.167 | 0.136                      | 0.031                       | 0.101          | 0.097                      | 0.004                       | 0.240          | 0.224                      | 0.016                       |                |
| 2006                   | 0.198 | 0.176                      | 0.022                       | 0.126          | 0.133                      | -0.007                      | 0.287          | 0.273                      | 0.014                       |                |
| 2007                   | 0.215 | 0.195                      | 0.020                       | 0.136          | 0.144                      | -0.008                      | 0.319          | 0.301                      | 0.018                       |                |

Table 4. (Continued)

| Industry                          | Year  | OLS                        |                             |                | ACF                        |                             |                | BB                         |                             |                |
|-----------------------------------|-------|----------------------------|-----------------------------|----------------|----------------------------|-----------------------------|----------------|----------------------------|-----------------------------|----------------|
|                                   |       | Aggregate Productivity (1) | Unweighted Productivity (2) | Covariance (3) | Aggregate Productivity (4) | Unweighted Productivity (5) | Covariance (6) | Aggregate Productivity (7) | Unweighted Productivity (8) | Covariance (9) |
| Electronic and telecommunications | 1998  | 0.000                      | 0.000                       | 0.000          | 0.000                      | 0.000                       | 0.000          | 0.000                      | 0.000                       | 0.000          |
|                                   | 1999  | 0.059                      | -0.011                      | 0.070          | 0.068                      | -0.010                      | 0.078          | 0.106                      | 0.001                       | 0.105          |
|                                   | 2000  | 0.144                      | 0.048                       | 0.095          | 0.151                      | 0.057                       | 0.094          | 0.218                      | 0.084                       | 0.133          |
|                                   | 2001  | 0.130                      | 0.041                       | 0.089          | 0.151                      | 0.056                       | 0.095          | 0.247                      | 0.093                       | 0.154          |
|                                   | 2002  | 0.120                      | 0.070                       | 0.050          | 0.147                      | 0.091                       | 0.056          | 0.254                      | 0.138                       | 0.116          |
|                                   | 2003  | 0.243                      | 0.139                       | 0.104          | 0.296                      | 0.169                       | 0.126          | 0.428                      | 0.234                       | 0.194          |
|                                   | 2004  | 0.393                      | 0.312                       | 0.081          | 0.449                      | 0.359                       | 0.090          | 0.585                      | 0.403                       | 0.182          |
|                                   | 2005  | 0.465                      | 0.437                       | 0.029          | 0.511                      | 0.472                       | 0.039          | 0.643                      | 0.525                       | 0.118          |
| 2006                              | 0.545 | 0.539                      | 0.006                       | 0.583          | 0.573                      | 0.010                       | 0.718          | 0.633                      | 0.085                       |                |
| 2007                              | 0.576 | 0.610                      | -0.034                      | 0.609          | 0.648                      | -0.038                      | 0.741          | 0.712                      | 0.028                       |                |

Notes: 1. The decomposition is based on Olley and Pakes (1996) and Pavcnik (2002).

2. For the definition of OLS, ACF and BB, please refer to Figure 1.

Table 5. Determinants of Productivity: All Industries

| Dependent Variable: | OLS                 |                      |                      | ACF                 |                      |                      | BB                  |                      |                      |
|---------------------|---------------------|----------------------|----------------------|---------------------|----------------------|----------------------|---------------------|----------------------|----------------------|
|                     | (1)                 | (2)                  | (3)                  | (4)                 | (5)                  | (6)                  | (7)                 | (8)                  | (9)                  |
| Productivity        |                     |                      |                      |                     |                      |                      |                     |                      |                      |
| Entry ( $t_0$ )     | 0.007***<br>(0.001) | 0.029***<br>(0.001)  | 0.003***<br>(0.001)  | 0.040***<br>(0.001) | 0.056***<br>(0.001)  | 0.032***<br>(0.001)  | 0.035***<br>(0.001) | 0.044***<br>(0.001)  | 0.012***<br>(0.001)  |
| $t + 1$             | 0.010***<br>(0.001) | 0.046***<br>(0.001)  | 0.004***<br>(0.001)  | 0.034***<br>(0.001) | 0.064***<br>(0.001)  | 0.025***<br>(0.001)  | 0.047***<br>(0.001) | 0.071***<br>(0.001)  | 0.022***<br>(0.001)  |
| $t + 2$             | 0.008***<br>(0.001) | 0.065***<br>(0.001)  | 0.002*<br>(0.001)    | 0.027***<br>(0.001) | 0.078***<br>(0.001)  | 0.019***<br>(0.001)  | 0.043***<br>(0.001) | 0.092***<br>(0.001)  | 0.018***<br>(0.001)  |
| $t + 3$             | 0.004***<br>(0.001) | 0.085***<br>(0.001)  | -0.002**<br>(0.001)  | 0.018***<br>(0.001) | 0.094***<br>(0.001)  | 0.010***<br>(0.001)  | 0.036***<br>(0.001) | 0.116***<br>(0.001)  | 0.012***<br>(0.001)  |
| $t + 4$             | 0.009***<br>(0.001) | 0.092***<br>(0.001)  | 0.002<br>(0.001)     | 0.019***<br>(0.001) | 0.098***<br>(0.001)  | 0.011***<br>(0.001)  | 0.036***<br>(0.001) | 0.118***<br>(0.001)  | 0.012***<br>(0.001)  |
| Exit                |                     | -0.074***<br>(0.001) | -0.045***<br>(0.001) |                     | -0.051***<br>(0.001) | -0.022***<br>(0.001) |                     | -0.108***<br>(0.002) | -0.074***<br>(0.002) |
| Age                 |                     | -0.000***<br>(0.000) | -0.000***<br>(0.000) |                     | -0.000***<br>(0.000) | -0.000***<br>(0.000) |                     | -0.000***<br>(0.000) | -0.000***<br>(0.000) |
| Exporting           |                     | 0.011***<br>(0.001)  | 0.013***<br>(0.001)  |                     | -0.005***<br>(0.001) | -0.003***<br>(0.001) |                     | 0.032***<br>(0.001)  | 0.034***<br>(0.001)  |
| Region:             |                     |                      |                      |                     |                      |                      |                     |                      |                      |
| Costal              |                     | 0.012***<br>(0.001)  | 0.014***<br>(0.001)  |                     | 0.013***<br>(0.001)  | 0.015***<br>(0.001)  |                     | 0.046***<br>(0.001)  | 0.048***<br>(0.001)  |
| Western             |                     | -0.025***<br>(0.002) | -0.023***<br>(0.002) |                     | -0.033***<br>(0.002) | -0.031***<br>(0.002) |                     | -0.046***<br>(0.002) | -0.043***<br>(0.002) |
| Northeastern        |                     | 0.005***<br>(0.002)  | -0.002<br>(0.002)    |                     | 0.010***<br>(0.002)  | 0.002<br>(0.002)     |                     | -0.008***<br>(0.002) | -0.017***<br>(0.002) |

Table 5. (Continued)

| Dependent Variable: | OLS       |                     |                     | ACF       |                     |                     | BB        |                     |                     |
|---------------------|-----------|---------------------|---------------------|-----------|---------------------|---------------------|-----------|---------------------|---------------------|
|                     | (1)       | (2)                 | (3)                 | (4)       | (5)                 | (6)                 | (7)       | (8)                 | (9)                 |
| Productivity        |           |                     |                     |           |                     |                     |           |                     |                     |
| Ownership:          |           |                     |                     |           |                     |                     |           |                     |                     |
| COE                 |           | 0.100***<br>(0.002) | 0.103***<br>(0.002) |           | 0.101***<br>(0.002) | 0.104***<br>(0.002) |           | 0.267***<br>(0.002) | 0.270***<br>(0.002) |
| DPE                 |           | 0.175***<br>(0.002) | 0.088***<br>(0.002) |           | 0.170***<br>(0.002) | 0.086***<br>(0.002) |           | 0.362***<br>(0.002) | 0.259***<br>(0.002) |
| HMT                 |           | 0.161***<br>(0.002) | 0.105***<br>(0.002) |           | 0.153***<br>(0.002) | 0.100***<br>(0.002) |           | 0.321***<br>(0.002) | 0.256***<br>(0.002) |
| FIE                 |           | 0.216***<br>(0.002) | 0.146***<br>(0.002) |           | 0.206***<br>(0.002) | 0.139***<br>(0.002) |           | 0.404***<br>(0.002) | 0.322***<br>(0.002) |
| OTHER               |           | 0.153***<br>(0.002) | 0.094***<br>(0.002) |           | 0.142***<br>(0.002) | 0.086***<br>(0.002) |           | 0.312***<br>(0.002) | 0.242***<br>(0.002) |
| Industry dummy      | Y         | Y                   | Y                   | Y         | Y                   | Y                   | Y         | Y                   | Y                   |
| Year dummy          | Y         | N                   | Y                   | Y         | N                   | Y                   | Y         | N                   | Y                   |
| # of obs.           | 1,977,126 | 1,976,355           | 1,976,355           | 1,977,126 | 1,976,355           | 1,976,355           | 1,977,126 | 1,976,355           | 1,976,355           |
| R-squared           | 0.200     | 0.175               | 0.208               | 0.257     | 0.235               | 0.262               | 0.833     | 0.832               | 0.839               |

Notes: 1. Robust standard errors are reported in parentheses. The stars, \*, \*\* and \*\*\* indicate the significance level at 10%, 5% and 1%, respectively.

2. For the definition of OLS, ACF and BB, please refer to Figure 1.

3. COE stands for collective owned enterprises, DPE for domestic private-owned enterprises, HMT for HongKong, Macau or Taiwan owned enterprises, FIE for foreign-invested enterprises, OTHER for other ownership types.

4. The baseline group for region is Central and the baseline group for ownership is SOE.

Second, in line with Table 3 of Brandt *et al.* (2012), we also find positive association between new entry and productivity in columns 4 and 7 of Table 5 for ACF and BB. Consistent with Table 4 of Ding *et al.* (2016), using Haltiwanger (1997) decomposition, Table 6 also shows that around two-thirds of productivity growth comes from new entering firms. However, as shown in columns 6 and 9 of Table 5, after controlling for year dummies and other variables the impact of new entry becomes much smaller using ACF and BB estimates, even ignorable using OLS. This indicates that entry is not random and the new entrants that drive China's productivity growth could be those foreign and private firms established in coastal regions in late years.

Third, consistent with Brandt *et al.* (2012) and Ding *et al.* (2016), firm exit is negatively associated with productivity. On average exiting firms are less productive than continuing firms by 7.4% based on the BB estimate in column 9 of Table 5, implying that the exit of low-productivity firms is an important source of the productivity growth of the Chinese manufacturing sector. The firm exit is accompanied with market competition and resource reallocation from low-productivity firms and industries to high-productivity firms and industries.

Fourth, Table 5 also reports the effect of exporting on firm productivity based on the three estimates of productivity. The results based on ACF estimates in columns 5 and 6 suggest a small but negative exporting effect on productivity after controlling for regional and ownership characteristics, while the coefficients of exporting variable based on BB estimates in columns 8 and 9 are positive. Thus, one should be cautious to claim that Chinese exporters are more productive than non-exporters in general. This point is confirmed in the regression by industry in Table 7 containing the results on three industries of textile, raw chemical materials and chemical products, and electronic and telecommunications equipment. The exporting effect on firm productivity is consistently negative based on the three estimates for the industry of electronic and telecommunications equipment in columns 7–9, while it is consistently positive in the textile industry in

Table 6. Haltiwanger Decomposition: All Industries

| Estimates | Productivity Growth<br>over 1998–2007 (%) | Within<br>Firm | Between<br>Firm | Cross<br>Firm | Exitors | Enterers                     |
|-----------|---|----------------|-----------------|---------------|---------|------------------------------|
|           | (1)                                       | (2)            | (3)             | (4)           | (5)     | (6)                          |
| OLS       | 28.0                                      | 9.1            | −1.5            | 0.4           | −0.9    | <b>19.1</b><br><b>(68.2)</b> |
| ACF       | 29.0                                      | 8.3            | −0.8            | 0.1           | −0.7    | <b>20.8</b><br><b>(71.7)</b> |
| BB        | 56.2                                      | 11.8           | −1.2            | 3.6           | −5.7    | <b>36.4</b><br><b>(64.7)</b> |

Notes: 1. For the decomposition method, please refer to Haltiwanger (1997).

2. The numbers in parentheses are the contribution of new entering firms to productivity growth over a 10-year period of 1998–2007.

3. For the definition of OLS, ACF and BB, please refer to Figure 1.



Table 7. Determinants of Productivity: Three Industries

| Dependent Variable: | Textile              |                      |                      | Raw Chemical Materials |                      |                      | Electronic and Telecom |                      |                      |
|---------------------|----------------------|----------------------|----------------------|------------------------|----------------------|----------------------|------------------------|----------------------|----------------------|
|                     | OLS<br>(1)           | ACF<br>(2)           | BB<br>(3)            | OLS<br>(4)             | ACF<br>(5)           | BB<br>(6)            | OLS<br>(7)             | ACF<br>(8)           | BB<br>(9)            |
| Productivity        |                      |                      |                      |                        |                      |                      |                        |                      |                      |
| Entry ( $t_0$ )     | -0.009***<br>(0.003) | 0.016***<br>(0.003)  | 0.122***<br>(0.003)  | -0.001<br>(0.003)      | 0.019***<br>(0.003)  | 0.055***<br>(0.003)  | 0.007<br>(0.006)       | 0.070***<br>(0.006)  | 0.018***<br>(0.006)  |
| $t + 1$             | -0.001<br>(0.003)    | 0.009***<br>(0.003)  | 0.104***<br>(0.003)  | 0.008**<br>(0.004)     | 0.016***<br>(0.004)  | 0.065***<br>(0.004)  | 0.012**<br>(0.006)     | 0.065***<br>(0.006)  | 0.035***<br>(0.006)  |
| $t + 2$             | 0.004<br>(0.003)     | 0.009***<br>(0.003)  | 0.086***<br>(0.003)  | 0.009**<br>(0.004)     | 0.015***<br>(0.004)  | 0.059***<br>(0.004)  | -0.002<br>(0.006)      | 0.041***<br>(0.006)  | 0.016**<br>(0.006)   |
| $t + 3$             | -0.001<br>(0.003)    | 0.001<br>(0.003)     | 0.062***<br>(0.003)  | 0<br>(0.004)           | 0.003<br>(0.004)     | 0.042***<br>(0.004)  | -0.004<br>(0.006)      | 0.028***<br>(0.006)  | 0.010<br>(0.007)     |
| $t + 4$             | 0.007**<br>(0.004)   | 0.008**<br>(0.004)   | 0.049***<br>(0.004)  | 0.012**<br>(0.005)     | 0.014***<br>(0.005)  | 0.045***<br>(0.005)  | -0.009<br>(0.008)      | 0.014*<br>(0.008)    | 0.011<br>(0.009)     |
| Exit                | -0.031***<br>(0.004) | 0.000<br>(0.005)     | 0.002<br>(0.005)     | -0.052***<br>(0.006)   | -0.025***<br>(0.006) | -0.030***<br>(0.006) | -0.027***<br>(0.009)   | -0.035***<br>(0.010) | -0.089***<br>(0.010) |
| Age                 | 0.000<br>(0.000)     | 0.000<br>(0.000)     | -0.000***<br>(0.000) | 0.000<br>(0.000)       | 0.000<br>(0.000)     | -0.000***<br>(0.000) | 0.000<br>(0.000)       | 0.000<br>(0.000)     | -0.000**<br>(0.000)  |
| Exporting           | 0.028***<br>(0.002)  | 0.011***<br>(0.002)  | 0.019***<br>(0.002)  | 0.020***<br>(0.002)    | 0.001<br>(0.002)     | -0.036***<br>(0.002) | -0.036***<br>(0.004)   | -0.054***<br>(0.004) | -0.027***<br>(0.005) |
| Region:             |                      |                      |                      |                        |                      |                      |                        |                      |                      |
| Costal              | 0.014***<br>(0.004)  | -0.009**<br>(0.004)  | 0.030***<br>(0.004)  | 0.000<br>(0.003)       | -0.021***<br>(0.003) | 0.066***<br>(0.003)  | 0.094***<br>(0.010)    | 0.132***<br>(0.010)  | 0.153***<br>(0.011)  |
| Western             | -0.046***<br>(0.008) | -0.033***<br>(0.009) | -0.093***<br>(0.009) | -0.030***<br>(0.005)   | -0.025***<br>(0.005) | -0.040***<br>(0.005) | 0.051***<br>(0.014)    | 0.031**<br>(0.015)   | 0.046***<br>(0.016)  |
| Northeastern        | -0.062***<br>(0.009) | -0.048***<br>(0.009) | -0.082***<br>(0.009) | -0.014**<br>(0.006)    | -(0.008)<br>(0.006)  | 0.011*<br>(0.006)    | 0.054***<br>(0.015)    | 0.042***<br>(0.016)  | 0.050***<br>(0.017)  |

Table 7. (Continued)

| Dependent Variable: | Textile             |                     |                     | Raw Chemical Materials |                     |                     | Electronic and Telecom |                     |                     |
|---------------------|---------------------|---------------------|---------------------|------------------------|---------------------|---------------------|------------------------|---------------------|---------------------|
|                     | OLS<br>(1)          | ACF<br>(2)          | BB<br>(3)           | OLS<br>(4)             | ACF<br>(5)          | BB<br>(6)           | OLS<br>(7)             | ACF<br>(8)          | BB<br>(9)           |
| Productivity        |                     |                     |                     |                        |                     |                     |                        |                     |                     |
| Ownership:          |                     |                     |                     |                        |                     |                     |                        |                     |                     |
| COE                 | 0.124***<br>(0.009) | 0.059***<br>(0.009) | 0.303***<br>(0.009) | 0.087***<br>(0.006)    | 0.041***<br>(0.006) | 0.203***<br>(0.006) | 0.121***<br>(0.015)    | 0.262***<br>(0.015) | 0.358***<br>(0.016) |
| DPE                 | 0.118***<br>(0.009) | 0.048***<br>(0.009) | 0.309***<br>(0.009) | 0.076***<br>(0.005)    | 0.031***<br>(0.005) | 0.194***<br>(0.005) | 0.120***<br>(0.013)    | 0.273***<br>(0.013) | 0.393***<br>(0.013) |
| HMT                 | 0.143***<br>(0.009) | 0.083***<br>(0.009) | 0.249***<br>(0.009) | 0.108***<br>(0.006)    | 0.061***<br>(0.006) | 0.236***<br>(0.006) | 0.137***<br>(0.013)    | 0.229***<br>(0.013) | 0.356***<br>(0.013) |
| FIE                 | 0.166***<br>(0.009) | 0.103***<br>(0.009) | 0.302***<br>(0.009) | 0.150***<br>(0.006)    | 0.097***<br>(0.007) | 0.284***<br>(0.006) | 0.210***<br>(0.013)    | 0.286***<br>(0.013) | 0.472***<br>(0.013) |
| OTHER               | 0.134***<br>(0.009) | 0.066***<br>(0.009) | 0.256***<br>(0.009) | 0.077***<br>(0.005)    | 0.032***<br>(0.005) | 0.149***<br>(0.005) | 0.200***<br>(0.013)    | 0.307***<br>(0.013) | 0.443***<br>(0.014) |
| Year dummy          | Y                   | Y                   | Y                   | Y                      | Y                   | Y                   | Y                      | Y                   | Y                   |
| # of obs.           | 170,646             | 170,646             | 170,646             | 144,101                | 144,101             | 144,101             | 65,461                 | 65,461              | 65,461              |
| R-squared           | 0.061               | 0.030               | 0.130               | 0.034                  | 0.016               | 0.097               | 0.208                  | 0.228               | 0.245               |

Notes: 1. Robust standard errors are reported in parentheses. The stars, \*, \*\* and \*\*\* indicate the significance level at 10%, 5% and 1%, respectively.

2. For the definition of OLS, ACF and BB, please refer to Figure 1.

3. For the definition of COE, DPE, HMT, FIE and OTHER, please refer to Table 5.

4. The baseline group for region is Central and the baseline group for ownership is SOE.

Table 8. Robustness Checks

| Dependent Variable: Productivity | ACF                  |                      |                      | BB_DIF               |
|----------------------------------|----------------------|----------------------|----------------------|----------------------|
|                                  | 1st<br>(1)           | 2nd<br>(3)           | 3rd<br>(3)           | (4)                  |
| Entry ( $t_0$ )                  | 0.011***<br>(0.001)  | 0.017***<br>(0.001)  | 0.021***<br>(0.001)  | 0.001<br>(0.001)     |
| Exit                             | -0.032***<br>(0.001) | -0.028***<br>(0.002) | -0.024***<br>(0.001) | -0.089***<br>(0.002) |
| Age                              | -0.000***<br>(0.000) | -0.000***<br>(0.000) | -0.000***<br>(0.000) | -0.000***<br>(0.000) |
| Exporting                        | 0.003***<br>(0.001)  | -0.008***<br>(0.001) | -0.005***<br>(0.001) | -0.025***<br>(0.001) |
| Region:                          |                      |                      |                      |                      |
| Costal                           | 0.018***<br>(0.001)  | 0.026***<br>(0.001)  | 0.019***<br>(0.001)  | 0.121***<br>(0.001)  |
| Western                          | -0.027***<br>(0.002) | -0.040***<br>(0.002) | -0.034***<br>(0.002) | -0.075***<br>(0.002) |
| Northeastern                     | 0.004**<br>(0.002)   | 0.004**<br>(0.002)   | 0.002<br>(0.002)     | 0.008***<br>(0.002)  |
| Ownership:                       |                      |                      |                      |                      |
| COE                              | 0.081***<br>(0.002)  | 0.125***<br>(0.002)  | 0.126***<br>(0.002)  | 0.460***<br>(0.002)  |
| DPE                              | 0.067***<br>(0.002)  | 0.114***<br>(0.002)  | 0.113***<br>(0.002)  | 0.472***<br>(0.002)  |
| HMT                              | 0.085***<br>(0.002)  | 0.127***<br>(0.002)  | 0.124***<br>(0.002)  | 0.432***<br>(0.002)  |
| FIE                              | 0.115***<br>(0.002)  | 0.175***<br>(0.002)  | 0.169***<br>(0.002)  | 0.544***<br>(0.002)  |
| OTHER                            | 0.068***<br>(0.002)  | 0.110***<br>(0.002)  | 0.109***<br>(0.002)  | 0.415***<br>(0.002)  |
| Industry dummy                   | Y                    | Y                    | Y                    | Y                    |
| Year dummy                       | Y                    | Y                    | Y                    | Y                    |
| # of obs.                        | 1,976,355            | 1,976,355            | 1,976,355            | 1,976,355            |
| R-squared                        | 0.437                | 0.731                | 0.337                | 0.582                |

Notes: 1. Robust standard errors are reported in parentheses. The stars, \*, \*\* and \*\*\* indicate the significance level at 10%, 5% and 1%, respectively.

2. 1st, 2nd and 3rd represent productivity processes in ACF approach that are of linear form, 2nd and 3rd order polynomials, respectively.

3. BB\_DIF refers to productivity estimate obtained by first-difference GMM in Blundell and Bond (2000).

4. For the definition of COE, DPE, HMT, FIE and OTHER, please refer to Table 5.

5. The baseline group for region is Central and the baseline group for ownership is SOE.

columns 1–3. This finding is consistent with Ding *et al.* (2016), who find positive exporting effect in only 9 out of 26 industries. This is also in line with Lu's (2010) argument that exporters are not necessarily more productive than non-exporters. It could be industry specific.

It is worth noting that OLS, ACF and BB deliver conflicting evidences on the firm exit effect in textile industry and exporting effect in raw chemical materials.

#### **4.4. Robustness checks**

Table 8 presents robustness checks using the data pooling all industries. The ACF results reported in column 6 of Table 5 are based on 4th order polynomials for the productivity process. Here, columns 1–3 of Table 8 give the similar regression results to Table 5 including only one entry dummy with a productivity process in the ACF estimation that is of linear form, 2nd and 3rd order polynomials, respectively. Compared with the column 6 of Table 5, these three columns present very similar results.

Column 4 of Table 8 replaces the system GMM (or BB) with the first-difference GMM estimates. Compared with column 9 of Table 5, the first-difference GMM estimates deliver similar effects of location and ownership on productivity, but different sign on exporting effect. This confirms the robustness of location and ownership effects, and the uncertainty of exporting effect, as discussed in the previous subsection.

### **5. Conclusion**

This paper aims to understand China's high-speed economic growth from the view of TFP growth. Different from the analyses based on aggregate-level data, we estimate the aggregate productivity growth by employing a large data set of Chinese manufacturing firms during 1998–2007 and the state-of-art estimation methods of firm-level production function. In addition, we also quantify how much China's productivity growth can be explained by the resource reallocation from low-productivity firms to high-productivity ones.

Using revenue-measured firm-level production function estimates, we find that the average annual TFP growth rate of Chinese manufacturing is comparable to Zhu's (2012) estimate using growth accounting during 1998–2007. In addition, the firm-level evidence shows that the contribution of resource reallocation to TFP growth seems only appear in early years of the sample period. In this sense, the importance of resource reallocation to China's economic growth cannot be overemphasized nowadays without further reforms in factor markets and financial systems.

We also empirically compare OLS, ACF and BB methods in the large data set of Chinese manufacturing firms. It seems that these three methods work equally well in estimating productivity growth, and quantifying the contribution of resource reallocation to productivity growth. However, they may lead to conflicting results when estimating the exporting effect on productivity and in by-industry analyses.

### **Acknowledgments**

The authors would like to thank Tan Kong Yam and the participants of Singapore Economic Review Conference 2015, The 28th CESA Annual Conference at James Cook University, Cairns, for their constructive comments and suggestions. Financial support from the MOE AcRF Tier 1 Grant M4011314 (RG75/14) at Nanyang Technological University is gratefully acknowledged.

**References**

- Akerberg, D, K Caves and G Frazer (2006). Structural identification of production functions. Working paper, UCLA.
- Akerberg, D, K Caves and G Frazer (2015). Identification properties of recent production function estimators. *Econometrica*, 83, 2411–2451.
- Bond, S and M Söderbom (2005). Adjustment costs and the identification of Cobb–Douglas production functions, Working Paper, The Institute for Fiscal Studies, Britain.
- Brandt, L, J Van Biesebroeck and Y Zhang (2012). Creative accounting or creative destruction? firm-level productivity growth in Chinese manufacturing. *Journal of Development Economics*, 97(2), 339–351.
- Brandt, L and X Zhu (2010). Accounting for China's Growth. Mimeo, University of Toronto.
- Blundell, R and S Bond (2000). GMM estimation with persistent panel data: An application to production functions. *Econometric Reviews*, 19(3), 321–340.
- Ding, S, A Guariglia and R Harris (2016). The determinants of productivity in Chinese large and medium-sized industrial firms, 1998–2007. *Journal of Productivity Analysis*, 45(2), 131–155.
- Haltiwanger, J (1997). Measuring and analyzing aggregate fluctuations: The importance of building from microeconomic evidence. *Federal Reserve Bank St. Louis Review*, 79(3), 55–77.
- Jefferson, GH, TG Rawski and Y Zhang (2008). Productivity growth and convergence across China's industrial economy. *Journal of Chinese Economic and Business Studies*, 6(2), 121–140.
- Jin, H, Y Qian and BR Weingast (2005). Regional decentralization and fiscal incentives: Federalism, Chinese style. *Journal of Public Economics*, 89(9), 1719–1742.
- Levinsohn, J and A Petrin (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, 70, 317–342.
- Li, X, X Liu and Y Wang (2015). A model of China's state capitalism, Working paper, HKUST.
- Lu, D (2010). Exceptional exporter performance? evidence from Chinese manufacturing firms. University of Chicago, Mimeograph.
- Naughton, B (2007). *The Chinese Economy: Transitions and Growth*, MIT Press, Cambridge MA, USA.
- Olley, GS and A Pakes (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, 64(6), 1263–1297.
- Pavcnik, N (2002). Trade liberalization, exit, and productivity improvements: Evidence from Chilean plants. *Review of Economic Studies*, 69(1), 245–276.
- Song, Z, K Storesletten and F Zilibotti (2011). Growing like China. *American Economic Review*, 101(1), 196–233.
- The Growth Report: Strategies for Sustained Growth and Inclusive Development (2008). The International Bank for Reconstruction and Development/The World Bank.
- Young, A (2003). Gold into base metals: Productivity growth in the People's Republic of China during the reform period. *Journal of Political Economy*, 111(1), 1220–1261.
- Yu, M (2015). Processing trade, tariff reductions and firm productivity: Evidence from Chinese firms. *Economic Journal*, 125(585), 943–988.
- Zheng, J, A Bigsten and A Hu (2009). Can China's growth be sustained? A productivity perspective. *World Development*, 37(4), 874–888.
- Zhu, X (2012). Understanding China's growth: Past, present, and future. *Journal of Economic Perspectives*, 26(4), 103–124.