Dynamic Productivity Decomposition with Allocative Efficiency[1]

Kaoru Hosono[2]
Miho Takizawa[3]

Abstract

We propose a novel approach to decomposing aggregate productivity growth that considers changes in allocative efficiency as well as technical efficiency, entry and exit, and variety. The allocative efficiency is measured in terms of the dispersion in revenue-based productivity (TFPR) while the technical efficiency depends only on producer-level quantity-level productivity (TFPQ). We apply our approach to an establishment-level dataset of manufacturing industries and a firm-level dataset of manufacturing and nonmanufacturing industries from Japan. Our results from both datasets show that the allocative efficiency among survivors declined in the banking crisis period of the latter half of the 1990s while the technical efficiency declined in the Global Financial Crisis period of the latter half of the 2000s. Our result of the allocative efficiency is in contrast with the results from the decomposition approach proposed by Foster, Haltiwanger, and Krizan (2001) that measures the reallocation effect in terms of the correlation between the change in output share and productivity. Our results from both datasets further show that almost throughout the sample period, both entering and exiting establishments/firms were more efficient than survivors, indicating a positive entry effect and a negative exit effect, respectively. The variety effect in the manufacturing industries tended to be negative since the early 1990s, while that in both manufacturing and nonmanufacturing industries tended to be positive.

Keyword: Productivity decomposition; Allocative efficiency, Japan.
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[2] Gakushuin University and RIETI, email: kaoru.hosono@gakushuin.ac.jp
[3] Gakushuin University, email: miho.takizawa@gakushuin.ac.jp

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1. Introduction

The growth in aggregate productivity is one of the central themes of economic development. To gain insights into its driving forces, existing studies define the aggregate productivity as a weighted average of productivity at the producer (firm or establishment) level and decompose it into several factors. Although exact decomposition is different across researchers, their basic idea is common in that aggregate productivity increases if (1) each surviving producers increase their productivity (within effect), (2) higher productivity surviving producers increase their market share (between effect or reallocation effect), (3) high productivity producers enter the market (entry effect), and/or (4) low productivity producers exit (exit effect). The intuition behind such decomposition is straightforward once the aggregate productivity is defined as the weighted average of producers' productivity.

However, such definition and decomposition of aggregate productivity is not necessarily pinned down by microeconomic analyses; if the value of marginal product is higher for some producers than others, then resource allocation from the latter to the former increases output given total inputs, indicating the improvement in allocative efficiency. This is true regardless of whether the former firms exhibit higher productivity or not.

The first aim of this study is to propose a novel approach to decomposing aggregate productivity growth that adequately captures changes in the allocative efficiency. We build a measure of the allocative efficiency following Hsieh and Klenow (2009), who show that it is measured by the dispersion in revenue-based productivity (TFPR) among producers. We extend their approach to consider the entering and exiting producers' efficiency following Melitz and Polanec (2015) and Hosono et al. (2016).

We further apply our approach to an establishment-level dataset from Japanese manufacturing over the period of 1986-2014. A number of studies try to uncover the sources for the stagnant aggregate TFP in the 1990s in Japan by decomposing aggregate TFP following Foster, Haltiwanger, and Krizan (2001) (FHK)'s decomposition approach (Fukao and Kwon, 2006; Fukao, Kim, and Kwon, 2009). Due to banks' non-performing loan problems, unprofitable firms were more likely to receive credit than profitable firms in the 1990s in Japan (Peek and Rosengren, 2005). This misallocation of credit was likely to result in the misallocation of capital and labor (Caballero, Hoshi, and Kashyap, 2008). Nonetheless, most of the studies applying FHK decomposition to Japanese firms or establishments find positive and large reallocation effects in the1990s. We thus compare the results between our approach and FHK's approach. While our allocative efficiency is measured in terms of the dispersion in TFPR, FHK's reallocation effect is measured in terms of the correlation between the change in output share on one hand and productivity and its change on the other.

We find that the allocative efficiency among survivors declined from a positive value in the bubble period (1987-1990) to zero in the banking crisis period (1996-2000), and turned to negative in the first half of the 2000s (2001-2005). This result is in contrast with the results from the decomposition approach proposed by FHK. We further find that almost throughout the sample period, both entering and exiting establishments were more efficient than survivors, indicating a positive entry effect and a negative exit effect, respectively.

The rest of this paper proceeds as follows. In Section2, we review related studies on productivity decomposition and allocative efficiency. Section 3 describes how we aggregate producer-level productivity to an industry-level and economy-wide productivity, and decompose it in a way that considers allocative efficiency as well as entry and exit. Section 4 describes the dataset we apply our approach to and present the decomposition results. We further compare our results from those using FHK's decomposition. Section 5 concludes with some possible extensions

2. Related Literature

This study is related to the literature on aggregate productivity decomposition. Baily, Hulten, and Campbell (1992) (BHC) and following studies assume that aggregate productivity is a share-weighted average of producer-level productivity. Let producer *i*'s log of productivity and share at period *t* denote a_{it} and s_{it}, respectively, and A_t denote the set of all producers that are active in period *t*. Then, log of aggregate productivity a_t is defined as

$$a_t = \sum_{i \in A_t} s_{it} \, a_{it} \tag{1}$$

BHC first use this definition to decompose the change in aggregate productivity. Griliches and Regev (1995) and FHK develop BHC's approach using a reference average productivity level. Let S_t denote the set of producers that survive from period *t-1* and *t*, E_t that enter in period *t*, and X_t that exit in period *t*. Then, FHK's decomposition is as follows:

$$\triangle a_t = \sum_{i \in S_t} s_{it-1} \triangle a_{it} + \sum_{i \in S_t} \Delta s_{it}(a_{it-1} - a_{t-1}) + \sum_{i \in S_t} \Delta s_{it} \triangle a_{it} + \sum_{i \in E_t} s_{it}(a_{it} - a_{t-1}) - \sum_{i \in X_t} s_{it-1}(a_{it-1} - a_{t-1}) \tag{2}$$

The first term represents the fixed share-weight average of productivity changes among surviving producers (within effect). The second term represents the fixed productivity-weighted sum of the change in shares among surviving producers (between-effect) while the third term represents the covariance effect. These two terms together represent the reallocation effect. The fourth and fifth terms represent the share-weighted average of entering producers' productivity (entry effect) and the share-weighted average of the exiting producers' productivity (exit effect), respectively.

Although decomposition (2) is intuitive, the reallocation effect does not necessarily reflect the allocative efficiency[4]. To illustrate, suppose that two producers operate, and producer i (i =*1* or *2*), produces output Y_i using input K_i. The production technology is represented by the production function $Y_i = A_i f(K_i)$, where A_i is the total factor productivity, $f'(K_i)$>0, and $f''(K_i)$<0. Without loss of generality, we assume that $A_1 > A_2$. Suppose further that the total amount of K is fixed. Then, total output is maximized when the marginal product of output is the same across the producers: $A_1 f'(K_1{}^*) = A_2 f'(K_2{}^*)$ (Figure 1). In Case A, the government taxes only the output of producer *1* in period *t-1*. Then, $K_{1t-1} < K_1{}^*$ and $K_{2t-1} > K_2{}^*$, indicating that the total output is smaller than the maximal level (Figure 2A). If the government abolishes the tax in period *t*, then $K_{1t} = K_1{}^*$ and $K_{2t} = K_2{}^*$, indicating that the allocation is efficient in the sense that the total amount is maximal. In this case, producer *1* increases its output share while producer *2* decreases it, indicating that the reallocation effect in (2) increases, which is consistent with the allocative efficiency. However, suppose in Case B that the government taxes only the output of producer 2 in period *t-1*. Then, $K_{1t-1} > K_1{}^*$ and $K_{2t-1} < K_2{}^*$ (Figure 2B). If the government abolishes the tax in period *t*, then the allocation improves. Nonetheless, because producer *1* decreases its output share and producer *2* increases it, the reallocation effect in (2) decreases, which is not consistent with the allocative efficiency. This inconsistency arises because aggregation formulae (1) does not take into consideration the decreasing marginal product of inputs. In fact, the problem is not limited to the decomposition. The aggregate productivity defined by (1) decreases in Case B, although the actual aggregate output increases given the aggregate input. The inconsistency between the reallocation effect and the

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[4] To the best of our knowledge, Petrin and Levinsohn (2012) is the first that point out the inconsistency between the reallocation effect and the allocative efficiency. The example here is similar to theirs

allocative efficiency is seen also in Olley and Pakes (1996) and Melitz and Polanec (2015) who extend BHC and FHK.

Petrin and Levinsohn (2012) (PL) resolves this problem by measuring the reallocation effect in terms of the difference between the value of marginal product of input and its price. They start by defining the growth rate of aggregate productivity (APG_{Gt}) as

$$APG = \sum_i dVA_i - \sum_i \sum_k W_{ik} dX_{ik} \qquad (3)$$

, where VA_i is producer i's value added, W_{ik} and and X_{ik} are its price and use for primary input *k*. After discretizing (3), they decompose APG as

$$APG_{Gt} = \sum_i \overline{D}_{it} \Delta a_{it} + \sum_i \overline{D}_{it} \sum_k (\varepsilon_{ik} - \bar{s}_{ikt}) \Delta lnX_{ikt} + \sum_i \overline{D}_{it} \sum_k (\varepsilon_{ij} - \bar{s}_{ijt}) \Delta lnM_{ijt} - \sum_i \overline{D}_{it} \Delta lnF_{it} \qquad (4)$$

where $\overline{D}_{it}$ the two-period average of the ratio of producer-level revenue to aggregate final demand, $\frac{P_i Q_i}{\sum_i VA_i}$ (Domar weight), ε_{ik} is the elasticity of input, and $\bar{s}_{ikt}$ is the two-period average of the revenue share of input, $\frac{W_{ik} X_{ik}}{P_i Q_i}$, ΔlnM_{ijt} is the change in intermediate input, and ΔlnF_{it} is the change in fixed cost. The first term is the technical efficiency (TE), which represents the contribution to APG from producers' generating more output holding input constant. The second and third terms together are the reallocation (RE), which relates the change in input allocation across producers to changes in final demand. Note that the weight used in RE is the difference in the elasticity and share of input,

$\varepsilon_{ik} - \bar{s}_{ikt}$, which represents the difference between the value of marginal product and the price of input : $P_i \frac{\partial Q_i}{\partial X_{ik}} - W_{ik}$. The fourth term is the fixed costs (FE).

The RE term in PL is meant to capture the allocative efficiency in terms of the difference in elasticity and share of input, as is the allocative efficiency measure of this study. However, because they take the input share given, RE can deviate from the allocative efficiency. Going back to the example of the two producers, suppose that the allocation is efficient in period t-1 (Figure 1).[5] In period t, producer *1*'s productivity rises, but the government taxes on its output so that its output does not change from period t-1 (Figure 2C). Then, RE in PL does not change at zero, although the allocative efficiency actually worsens. To remedy this problem, we need to take distortions such as taxes as given rather than input share. Furthermore, PL does not distinguish physical productivity (TFPQ) and revenue-based productivity (TFPR)[6]. If a producer faces higher taxes and/or other distortions than before, then it exhibits higher TFPR even when its physical productivity does not change. In this case, the TE term in PL increases although the actual producer-level productivity does not change.

Thus, this study contributes to the preceding studies in two ways. First, we measure the allocative efficiency based on the difference between the value of marginal product of input and its price, given producer-level distortion. Second, we distinguish TFPQ from TFPR. To the best of our knowledge, none of the preceding studies on aggregate productivity decomposition has these two properties except for the recent study by Osotimehin (2019). Her technical efficiency is a combination of weighted averages of the producer-level productivity changes while her allocative efficiency is a combination of weighted averages of the producer-level changes in distortions. One of the differences between her study and ours is that her technical efficiency measure depends on TFPR as she uses

[5] This example is based on the discussion of Osotimehin (2019, pp.182).
[6] For the distinction between TFPQ and TFPR, see, e.g., Foster, Haltiwanger, and Syverson (2008).

TFPR as a weight of producer-level TFPQ (see Equation (9) in Osotimehin, 2019). On the other hand, our technical efficiency measure depends only on producer-level TFPQ. In addition, she does not take into consideration the effect of variety expansion on aggregate productivity, while we do. The variety effect emerges if aggregate output increases with a larger variety of intermediate inputs produced keeping total amount inputs produced constant. The variety effect is potentially important given recent studies (Fattal Jaef, 2018; Yang 2016). Thus consideration for the variety effect is our third contribution to the literature. On the other hand, Osotimehin (2019) considers the allocative efficiency across sectors as well as that within sectors while we focus on the latter.

3. Decomposition

3.1 Illustration

We decompose the change in aggregate productivity into survivors' technical efficiency, their allocative efficiency, the entry and exit effects, and the variety effect. However, before formally showing them, we illustrate our decomposition into technical efficiency and allocative efficiency by focusing on survivors. Suppose, as in Figures 1 and 2, that there are two producers in periods *t-1* and *t*. Panel A of Figure 3 illustrates that in period *t-1*, producer 1 underuses *K* and producer 2 overuses *K* relative to the optimal allocation: $K_{1t-1} < K_{1t-1}{}^{*}$ and $K_{2t-1} > K_{2t-1}{}^{*}$, so that actual output is smaller than the optimal output by the area *C* . In period *t*, producer *1*'s productivity increases, but the allocation does not change. Consequently, the output increases by area *A*. However, if input *K* were allocated optimally both in periods *t-1* and *t*, then the output would increase by the sum of areas A and B. This hypothetical increase in output due to the productivity gain is our technical efficiency measure. On the other hand, output loss due to the misallocation of inputs increases by *B* (from *C* to *B*+*C*), which is exactly our allocative efficiency measure.

To compare our decomposition with Osotimehin (2019), Panel B of Figure 3 illustrates her decomposition in the same situation. While we measure the technical efficiency and allocative efficiency using the optimal allocation as the reference point, she measures them using the previous period's allocation as the reference point. Specifically, her technical efficiency is the sum of the increase in output due to productivity gain given the allocation in period *t-1*, which is denoted by area *A*, and the effect of the change in inputs that is required to hold allocative efficiency constant after the change in firm-level productivity, which is denoted by area B_1: the difference between area *B* (our allocative efficiency measure) and period *t-1*'s output loss due to misallocation (B_2). Her allocative efficiency is - B_1. As such, her technical efficiency measure depends on the previous period's allocative efficiency. More specifically, her technical efficiency measure is lower and the negative (positive) value of her allocative efficiency measure is smaller (larger) as compared to our counterparts as the previous period's output loss due to misallocation (denoted by area *C*) is larger.

3.2 Producer-level productivity and distortions

To measure the value of marginal product for each producer and each input, we need a model that accounts for producers' profit maximization. We follow Hsieh and Klenow (2009).

Consider an economy with *S* sectors. In sector s and period *t*, there are N_{st} producers that produce differentiated intermediated goods in a monopolistically competitive market. Denote producer i's output by y_{it}. Sectoral good producers produce output in a competitive market by combining intermediated goods. Their production function is the CES with the elasticity of substitution $\eta_s > 1$:

$$Y_{st} = \left(\sum_{i=1}^{N_{st}} y_{it}^{\frac{\eta_s - 1}{\eta_s}} \right)^{\frac{\eta_s}{\eta_s - 1}} \tag{5}$$

Let P_{st} and p_{it} denote the prices of the sectoral good and producer *i*'s intermediate goods, respectively. Then, the sectoral goods producers' profit maximization leads to the demand for intermediate goods as

$$y_{it} = p_{it}{}^{-\eta_s} P_{st}{}^{\eta_s} Y_{st} \tag{6}$$

Intermediate goods producer *i*'s production function is the following constant-returns-to-scale Cobb-Douglas:

$$y_{it} = A_{it} K_{it}{}^{\alpha_s} L_{it}{}^{1-\alpha_s} \tag{7}$$

where A_{it}, K_{it}, and L_{it} denote productivity, capital, and labor.

Intermediate goods producer *i* faces distortions of τ_{Yit} on output and τ_{Kit} on capital, respectively. She maximizes her profit under the constraints (6) and (7) given rental rate R_t, wage rate W_t, and distortions τ_{Yit} and τ_{Kit}:

$$(1-\tau_{Yit}) p_{it} y_{it} - (1+\tau_{Kit}) R_t K_{it} - W_t L_{it} \tag{8}$$

The first-order conditions lead to

$$ln(1+\tau_{Kit}) = ln\left(\frac{\alpha_s}{1-\alpha_s}\right) + ln\left(\frac{W_t L_{it}}{R_t K_{it}}\right) \tag{9}$$

$$ln(1-\tau_{Yit}) = \ln(m_s) + ln\left(\frac{W_t L_{it}}{p_{it} y_{it}}\right) - ln(1-\alpha_s) \tag{10}$$

$$ln(A_{it}) = \ln(\kappa_{st}) + \ln(m_s) + ln(p_{it}y_{it}) - \alpha ln(K_{it}) - (1-\alpha_s)ln(L_{it}) \qquad (11)$$

where m_s is the markup ratio, $m_s = \frac{\eta_s}{\eta_s - 1}$, and $\kappa_{st} = (P_{st}{}^{\eta_s} Y_{st})^{\frac{-1}{\eta_s - 1}}$. We can recover producer-level distortions and productivity from Equations (9)-(11) given the sectoral variable κ_{st}. Note that Equation (10) shows that the distortion on output can be captured partly by the difference between revenue share and elasticity of input as in PL, but we adjust for markup as well.

3.3 Sectoral aggregation

We define producer-level revenue-based productivity as $TFPR_{it} = p_{it}A_{it}$. Then, we obtain

$$TFPR_{it} = m_s \left(\frac{(1+\tau_{Kit})R_t}{\alpha_s}\right)^{\alpha_s} \left(\frac{W_t}{(1-\tau_{Yit})(1-\alpha_s)}\right)^{1-\alpha_s} \qquad (12)$$

Using Equation (12), we obtain the sectoral TFP, defined by $A_{st} = \frac{Y_{st}}{\left(\sum_{i=1}^{N_{st}} K_{it}\right)^{\alpha_s} \left(\sum_{i=1}^{N_{st}} L_{it}\right)^{1-\alpha_s}}$, as

$$A_{st} = \left[\sum_{i=1}^{N_{st}} \left(A_{it} \frac{\overline{TFPR}_{st}}{TFPR_{it}}\right)^{\eta_s - 1}\right]^{\frac{1}{\eta_s - 1}} \qquad (13)$$

where $\overline{TFPR}_{st} = m_s \left(\frac{R}{\alpha_s} \frac{1}{\sum_{i=1}^{N_{st}} \frac{1-\tau_{Yit}}{1+\tau_{Kit}} \frac{p_{it}y_{it}}{P_{st}Y_{st}}}\right)^{\alpha_s} \left(\frac{W}{(1-\alpha_s)} \frac{1}{\sum_{i=1}^{N_{st}} (1-\tau_{Yit}) \frac{p_{it}y_{it}}{P_{st}Y_{st}}}\right)^{1-\alpha_s}$. [7] Without distortions, $TFPR_{it}$ is identical across producers. To the extent it disperses across producers, allocative efficiency is worse.

[7] For the derivation of Equation (13), see Hsieh and Klenow (2009) or Hosono and Takizawa (2015).

Note that our sectoral output measure based on the CES function (5) is different from the aggregate output measure used in the System of National Accounts (SNA), where sectoral output is the simple sum of value added: $Y_{st} = \sum_{i=1}^{N_{st}} p_{it} y_{it}$. While we assume imperfect substitutes among different products, SNA assumes perfect substitutes among them after controlling for the quantity represented by the price. Due to such difference in aggregation, our measure of sectoral (and hence aggregate) TFP is different from the sectoral (and aggregate) TFP that is based on SNA (e.g., the Japan Industrial Productivity Database (JIP)).

3.4 Sectoral decomposition

We first decompose the sectoral TFP growth into the efficiency improvement of survivors and the relative efficiency of entering and exiting producers. Let C_{st} denote the set of producers that survive from period *t* to *t+1*. Then, the aggregate productivity for those survivors is

$$A_{st}^{C_{st}} = \left[\sum_{i \in C_{st}} \left(A_{it} \frac{\overline{TFPR}_{st}}{TFPR_{it}} \right)^{\eta_s - 1} \right]^{\frac{1}{\eta_s - 1}} \quad (14)$$

Using Equation (14), we can decompose the sectoral TFP growth as follows:[8]

$$ln\left(\frac{A_{s,t+1}}{A_{st}}\right) = ln\left(\frac{A_{s,t+1}^{C_{st}}}{A_{st}^{C_{st}}}\right) + ln\left(\frac{A_{s,t+1}}{A_{s,t+1}^{C_t}}\right) - ln\left(\frac{A_{st}}{A_{st}^{C_{st}}}\right) \quad (15)$$

The first term represents the efficiency improvement for surviving producers, while the second and the third terms represent the relative efficiency of entering and exiting producers.

[8] This decomposition follows Melitz and Polanec (2002) and Hosono et al. (2016).

Next, we distinguish the average TFP and the variety effect. We define the average TFPs for all the producers and for the survivors as follows

$$\bar{A}_{st} = \left(\frac{1}{N_{st}}\right)^{\frac{1}{\eta_s - 1}} A_{st} \qquad (16)$$

$$\overline{A_{st}^{C_t}} = \left(\frac{1}{N_{st}^{C_{st}}}\right)^{\frac{1}{\eta_s - 1}} A_{st}^{C_t} \qquad (17)$$

where $N_{st}^{C_t}$ is the number of survivors. Using Equations (16) and (17), we can decompose the sectoral TFP growth into the average efficiency improvement of survivors, the average efficiency of entering and exiting producers, and the variety effect as follows:

$$ln\left(\frac{A_{s,t+1}}{A_{st}}\right) = ln\left(\frac{\overline{A_{s,t+1}^{C_{st}}}}{\overline{A_{st}^{C_{st}}}}\right) + ln\left(\frac{\overline{A_{s,t+1}}}{\overline{A_{s,t+1}^{C_{st}}}}\right) - ln\left(\frac{\overline{A_{st}}}{\overline{A_{st}^{C_{st}}}}\right) + \frac{1}{\eta_s - 1} ln\left(\frac{N_{s,t+1}}{N_{st}}\right) \qquad (18)$$

We further decompose the first term for survivors into the changes in productivity and allocative efficiency. Let $\overline{H_{st}^{C_t}}$ denote the hypothetical average TFP that would be achieved without any distortions on survivors:

$$\overline{H_{st}^{C_{st}}} = \left(\frac{1}{N_{st}^{C_{st}}}\right)^{\frac{1}{\eta_s - 1}} \left[\sum_{i \in C_{st}} {A_{it}}^{\eta_s - 1}\right]^{\frac{1}{\eta_s - 1}} \qquad (19)$$

Then we define the ratio of the actual and hypothetical average productivity for survivors by $\overline{D_t^{C_{st}}} = \frac{\overline{A_t^{C_{st}}}}{\overline{H_t^{C_{st}}}}$. The higher $\overline{D_t^{C_t}}$ indicates the better allocation among survivors. Using this definition, we obtain the following decomposition:

$$ln\left(\frac{A_{s,t+1}}{A_{st}}\right) = \underbrace{ln\left(\frac{\overline{H_{s,t+1}^{C_{st}}}}{\overline{H_{st}^{C_{st}}}}\right)}_{\substack{\text{Technical}\\ \text{Efficiency}\\ \text{(TE)}}} + \underbrace{\ln\left(\frac{\overline{D_{t+1}^{C_{st}}}}{\overline{D_{t}^{C_{st}}}}\right)}_{\substack{\text{Allocative}\\ \text{Efficiency}\\ \text{(AE)}}} + \underbrace{ln\left(\frac{\overline{A_{s,t+1}}}{\overline{A_{s,t+1}^{C_{st}}}}\right)}_{\text{Entry effect}} - \underbrace{ln\left(\frac{\overline{A_{st}}}{\overline{A_{st}^{C_{st}}}}\right)}_{\text{Exit effect}} + \underbrace{\frac{1}{\eta_s - 1}\ln\left(\frac{N_{s,t+1}}{N_{st}}\right)}_{\text{Variety effect}} \quad (20)$$

The first term represents the productivity improvement effect (technical efficiency: TE) of survivors while the second term represents the improvement in allocative efficiency (allocative efficiency: AE) among survivors. We refer to the sum of the third term (entry effect) and the fourth term (exit effect) as the net entry effect below.

Our allocative efficiency measure should be regarded as the measure in the static sense because we take the distortions as given, following Hsieh and Klenow (2009). In fact, distortions reflect various factors that causes deviation from marginal revenue and marginal cost of inputs. They include not only taxes and regulations, but also adjustment cost of dynamic inputs (Asker, Collard-Wexler, and De Loecker, 2014), financial frictions (Banerjee and Moll 2010; Midrigan and Xu 2014; Moll 2014), and markups (Peters, 2018) that are endogenous in dynamic settings. To measure the allocative efficiency from the dynamic viewpoint would require a more structural model and hence be more model-dependent.[9]

3.5 Aggregation

A representative firm produces final goods Y in a competitive market by combining the sectoral goods using a Cobb-Douglas production technology:

$$Y_t = \prod_s {Y_{st}}^{\theta_s}, \qquad where \sum_s \theta_s = 1 \qquad (21)$$

[9] Lentz and Mortensen (2008) and Murao and Nirei (2011) use an endogenous growth model to decompose aggregate productivity growth.

Then, the change in aggregate productivity can be represented by the weighted average of the sector-level change in productivities (see Appendix A for proof):

$$ln\left(\frac{A_{t+1}}{A_t}\right) = \sum_s \theta_s ln\left(\frac{A_{st+1}}{A_{st}}\right) \tag{22}$$

, where θ_s can be represented by $\theta_s = \frac{P_{st}Y_{st}}{P_tY_t}$.

We decompose the aggregate productivity growth by taking the weighted average of each sectoral component.

4. Data

4.1 Data sources

We mainly use two data sources to conduct our analysis. The data we use for our main analysis are the establishment-level data underlying the *Census of Manufactures* published by the Ministry of Economy, Trade and Industry (METI). In years ending with 0, 3, 5, and 8, the Census covers all establishments located in Japan (excluding those belonging to the government) and falling into the manufacturing sector.[10] In other years, the Census covers establishments with four or more employees. Since we need data on fixed tangible assets to construct establishment-level TFPQ, we use only those establishments for which such data are available. The Census reports fixed tangible assets for establishments with 10 employees or more for 1986-2000 and 2005, and for those with 30 employees or more for 2001-2004 and 2006-2013. For 2014, we use the Economic Census for Business Frame conducted by the Statistics Bureau (SB) of Japan that covers establishments with 10 employees or more. To keep consistency over time, we restrict our sample to the establishments with 30 employees or more. The greatest merit of the Census is its long time horizon and the wide coverage of establishments in the manufacturing sector. On the other hand, an obvious shortcoming of the Census

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[10] Although the data are at the establishment level and not the firm level, most of the establishments are owned by single-establishment firms. In 2008, for example, 84.4% of the establishments (222,145 out of 263,061 establishments) were owned by single-establishment firms.

is that it excludes establishments in non-manufacturing industries.

Another micro-level data source we use is the Basic Survey of Japanese Business Structure and Activities (BSJBSA) published by the METI. The main purpose of this annual survey is to gauge quantitatively the activities of Japanese enterprises, including capital investment, exports, foreign direct investment, and investment in R&D. To this end, the survey covers the universe of enterprises in Japan with more than 50 employees and with paid-up capital of over 30 million yen. The sample covers firms both in manufacturing and non-manufacturing industries. The sample period is from 1995 to 2015.

4.2 Variables

Data from the Census

We use Census data for the period from 1986 to 2014.[11] Information from the Census that we use is an establishment's labor compensation (excluding non-wage compensation), value added, the number of workers and capital stock as well as what industry (at the four-digit level) it belongs to[12].

Data from the BSJBSA

We use BSJBSAs data for the period from 1995 to 2015. Information from the BSJBSA that we use is a firm's output and input data (i.e., sales, the cost of sales and selling, and the general and administrative expenses, the number of workers and tangible capital stock) and the industry classification at the three-digit level which the firm belongs to[13].

We reclassify establishments from the Census into 52 manufacturing industries based on the

[11] Although data for 2015 are available from the 2016 Economic Census for Business Activity, we could not connect them with data for 2014 from the Census of Manufactures 2014.
[12] See the appendix A for details.
[13] See the appendix B for details

Japan Industrial Productivity (JIP) Database 2015, published by the Research Institute of Economy, Trade and Industry (RIETI), to use the industry-level labor shares of the JIP Database as described below. We also reclassify firms from the BSJBSA into 39 manufacturing and 26 non-manufacturing industries based on the JIP Database 2015.

We set the rental price of capital to R = 0.1, based on our assumption that the interest rate is 4% and the depreciation rate is 6%. For the baseline specification, we set the elasticity of substitution between products, η_s, to 3 for all the industries based on Hsieh and Klenow (2009) and Osotimehin (2019). Alternatively, we set η_s based on Broda and Weinstein (2006). Specifically, we reclassify the JIP industry classifications to the Rauch (1999)'s three goods categories, i.e., commodity goods, reference-priced goods, and differentiated goods (see Table A1) and set η_s to 3.5, 2.9, and 2.1 for each category. These values are taken from the median value of each category for 1990-2001 estimated by Broda and Weinstein (2006).

We set α_s as one minus the industry-level labor share, meaning that we assume that in each industry rents from mark-ups are divided pro rata into payments to labor and capital. Industry-level labor shares are taken from the JIP Database.

To obtain κ_s, we measure P_{st} by the sectoral deflator from the JIP database, and compute Y_{st} as the simple sum of value added divided by the sectoral deflator.

We identify survivors as the plants that continue to appear in the dataset.[14]

To exclude outliers, we trim the 1% tails of TFPQ and TFPR. For the analysis using the Census, the number of establishments per observation year varies from 34,608 to 57,626 during the period we focus on. The number of total establishment-year observations in our dataset is 1,386,336. For the analysis using the BSBSA, the number of firms per observation year varies from 21,512 to 28,662

[14] If some firms switch their industries and continue to operate, we define them as survivors. This definition is slightly different from the definition in Section 3.4, where survivors are defined as the producers that operate in the same sector. We choose our definition to assure that the sum of the decomposed components is equal to the aggregate TFP.

during the period we focus on. The number of total firm-year observations in our dataset is 585,208. See Appendices B and C for more details on how we constructed our dataset.

5. Empirical Results

5.1 Establishments in manufacturing industries

A. Baseline Results

We first show the results from the establishment-level dataset from the Census of Manufacturing over the period of 1987-2014, assuming that $\eta = 3$ across sectors. As we mentioned in Section 3.2, our measure of aggregate TFP can be different from the JIP database due to the difference in the aggregation of output and in the data covered. That being said, we compare the 5-year average of the year-on-year change in our aggregate productivity measure and that in the JIP database in Figure 4.[15] Our aggregate TFP growth measure is more volatile than the JIP. However, both the long-run average (1.3% for our measure and 1.5% for the JIP) and the cyclical pattern is similar, although our aggregate TFP growth in the late 1980s is substantially lower than the JIP counterpart.

Table 1 shows the descriptive statistics of aggregate TFP growth and its components for the 28 years of 1987-2014. The average aggregate TFP growth rate is 1.3%. The TE for survivors is relatively large (3.8%), but more than offset by the AE for survivors (-0.7%), the net entry effect (-1.1%), and the variety effect (-0.8%). The net entry effect is the sum of the positive entry effect (4.2%) and the negative exit effect (-8.0%). The TE for survivors is more volatile than the aggregate TFP growth while the AE for survivors and the variety effect are relatively stable.

Table 2 and Figure 5 show the averages of the decomposition of the year-to-year changes in aggregate TFP for each of the 5-year sub-periods (except for the first sub-period of 1987-90 and the last one of 2011-14).They show that TE for survivors turned from negative in the bubble period

[15] For the JIP data, we connect the data for 1987-1994 from the JIP 2015 database and the data for 1995-2014 from the JIP 2018 database.

(1987-1990) to positive in the first half of the 1990s and accelerated afterwards until the Global Financial Crisis (GFC) period (2006-2010), when it turned to negative again. Then it picked up in the early 2010s (2011-2014). On the other hand, AE for survivors continued to fall from 0.5% in the bubble period (1987-1990) to zero in the banking crisis period (1996-2000). It further declined to -2.8% in the first half of the 2000s. It fluctuated between positive and negative values afterwards.. The entry effect was positive for all the sub-periods, indicating that entrants were more efficient than incumbents either in terms of technical efficiency or allocative efficiency. On the other hand, the exit effect was negative for all the sub-periods, indicating that exiting establishments were more efficient than the rest (survivors and entrants). The variety effect turns from positive in the bubble period to negative afterwards, indicating that the number of establishments decreased after the 1990s.

Table 3 shows the correlation matrix among the aggregate TFP growth and its components. The aggregate TFP growth is positively correlated with the TE for survivors (with the correlation coefficient of 0.759) while it is negatively correlated with the AE for survivors (-0.306), though not significantly. The TE and AE for survivors are negatively correlated with each other (-0.695). Adjustment costs of inputs might hinder smooth movement of inputs across establishments when only a part of establishments are hit by positive productivity shocks. The TE for survivors is also negatively correlated with the entry effect (-0.861), the exit effect (-0.882), and the variety effect (-0.222).

Table 4 shows the dynamic correlation of the growth rate of aggregate output defined by equation (21) with the aggregate TFP growth and its components. The aggregate TFP growth is not significantly correlated with the lagged, contemporaneous, or leading aggregate output growth. The TE for survivors is positively correlated with one-year ahead of aggregate output growth. The contemporaneous correlation with output growth and AE is negative and significant. This result is consistent with Osotimehin (2019), who find that her measure of the within-sector allocative efficiency is countercyclical using a dataset of French manufacturing and service firms.

B. Different elasticity of substitution across sectors

Next, we examine how our baseline results change if we relax the assumption that the demand elasticity (η), and hence markup are the same across industries. Specifically, we apply a different elasticity of substitution to the three categories of the goods based on Rauch (1999)'s classification: 3.5 for commodity goods, 2.9 for reference-priced goods, and 2.1 for differentiated goods. [16] In Figure 6, the line labelled "Rauch" shows the year-by-year change in aggregate productivity. It is a little more volatile than the baseline aggregation ($\eta = 3$).

Table 5 and Figure 7 show the averages of the decomposition of the year-to-year changes in aggregate TFP for the same sub-periods as in Table 2 and Figure 5. Figure 8 compares the baseline result and the result from Rauch classification of demand elasticity for each of the sub-period averages of aggregate TFP growth and its components. It shows that the movement of each component is similar between these two results.

Table 6 shows summary statistics of the decomposition for each industry and the four sub-periods of 1987-1990, 1991-2000, 2001-2010, and 2011-2014. Note that Table 5 shows weighted averages of aggregate TFP growth and its components (see equation (22)) while the mean values in Table 6 are simple averages. Nonetheless, the median and mean values of AE effects are very small (0.1% and 0.3%, respectively) in the 1990s. Table A2 reports the decomposition of TFP growth for each industry for each sub-period.

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[16] These values are taken from the median value of each category for 1972-1988 and 1990-2001 estimated by Broda and Weinstein (2006). They estimate elasticities of substitution among goods using the U.S. trade data (the Tariff System of the U.S.A. (TSUSA) seven-digit for 1972-1988 Harmonized Tariff System (HTS) ten-digit for 1990-2001. Using their estimates, we implicitly assume that elasticities of substitution among goods produced in Japan are the same as those among US imports. Table A1 shows the correspondence between JIP industry classification and Rauch's three categories of goods.

C. Comparison with other decomposition methods

We conduct FHK decomposition using the same establishment data that we use to conduct our baseline decomposition. Figure 6 compares the year-on-year change in aggregate TFP of the baseline result (with $\eta = 3$) and the aggregation used in FHK (output-weighted average). While the average rates of increase in aggregate TFP are almost the same between the two (1.3% for the baseline and 1.2% for the FHK), the FHK series is less volatile than the baseline result (the standard errors are 6.2% for the baseline and 5.4% for the FHK). The cyclical pattern is also different between the two.

Table 7 and Figure 9 show FHK decomposition for the 5-year sub-periods. They show that the FHK reallocation effect is positive and sizable and account for a major part of the aggregate TFP growth rate for all the sub-periods. In the banking crisis period (1996-2000) and the first half of the 2000s, the reallocation effect was 2.1%, while the AE for survivors of our decomposition shows 0.0% and -2.8% for the corresponding period. While the between effect is negative for all the sub-periods, the covariance effect is positive and outweighs the negative between effect for all the sub-periods. As we have mentioned in Section2, the positive correlation between the productivity growth rate and the share growth does not necessarily indicate the improvement in allocative efficiency.

The FHK entry effect is positive for some sub-periods and negative for the other sub periods, which is different from our entry effect. This is due to the difference in the measurement of productivity; they use TFPR while we use TFPQ. On the other hand, the FHK exit effect is consistently negative for all the sub-periods, which is consistent with our exit effect, although the measurement of TFP is different.

Fukao, Kim, and Kwon (2009) apply FHK decomposition to the Census for the period of 1981-2003 to find positive and accelerating reallocation effects in the 1980s and 2000s, although the within effects account for a major part of the TFP growth rates in both decades.

Kwon, Narita, and Narita (2015) apply PL's decomposition to the Census for the period of 1981-

2000. Table 8 compares the 10-year averages of their results and our baseline results. Both studies show that in the 1990s, while the technical efficiency was relatively high (1.8% for Kwon et al. and 1.4% for our baseline result), the reallocation effect of Kwon et al. and the allocative efficiency were relatively low (-0.4% for Kwon et al. and 0.2% for our baseline result). Both studies also show that the net entry effect is relatively low, although the sign is different (-0.1% for Kwon et al. and 0.2% for our baseline result).

5.2 Firms in the manufacturing and non-manufacturing industries

In this subsection, we present the results from the firm-level dataset from the BSJBSA over the period of 1994-2015, assuming that $\eta = 3$ across sectors. Table 9 and Figure 10 show the averages of the decomposition of the year-to-year changes in aggregate TFP for the 5-year sub-periods (except for the 6-year sub-period of 1995-2000). The TE for survivors was positive for all the sub-periods and relatively high except for the GFC period of 2006-2010. The AE for survivors was negative for the banking crisis period (1995-2000) and the first half of the 2000s. The entry effect is consistently positive, possibly because the BSJBSA cover large firms relative to the establishments covered by the CM. The exit effect and the net entry effect are consistently negative, which is consistent with the result from the CM. The variety effect is positive (except for the first half of the 2000s when it is zero) due to an increase in the number of firms that enter into non-manufacturing industries.

We further show the results from the manufacturing firms that are contained in the BSJBSA. Table 10 and Figure 11 show the averages of the decomposition for the same sub-periods as in Table 9. The results from manufacturing firms are similar to those from all firms including non-manufacturing firms, although the AE for survivors in the first half of the 2000s is not negative (0.1%). This may be because the AE for survivors in nonmanufacturing industries worsened significantly in this period. On the other hand, the AE for 1995-2000 is negative and sizable (-6.5%) while the AE for 1996-2000 from the CM was zero. Because the BSJBSA cover relatively large firms, these results may suggest that misallocation was severer among large firms. The exit effect is also negative and large. The variety effect is negative from the first half of the 2000s unlike the result from all firms in the BSJBSA. Nishimura, Nakajima, and Kiyota (2005) apply the Griliches- Regev approach to the BSJBSA dataset for the banking crisis period of 1994-1998, and find negative entry and exit effects, although their sample includes non-manufacturing firms as well as manufacturing firms. On the other hand, Fukao and Kwon (2006) apply FHK decomposition to the manufacturing firms contained in the BSJBSA dataset for the period of 1994-2001 to find that the weighted average of all the manufacturing industries indicate that the within, reallocation and net entry effects are all positive (1.2%, 0.3%, and 0.6%, respectively).

6. Conclusion

We have proposed a novel approach to decomposing aggregate productivity growth that considers changes in the allocative efficiency as well as technical efficiency, entry and exit, and variety. The allocative efficiency is measured in terms of the dispersion in revenue-based productivity (TFPR) while the technical efficiency depends only on producer-level quantity-level productivity (TFPQ). , we find that the allocative efficiency declined in the banking crisis period (1996-2000) while the technical efficiency declined in the Global Financial Crisis period (2005-2010). Our result of the allocative efficiency is in contrast with the results from the decomposition approach proposed by Foster, Haltiwanger, and Krizan (2001). Our result suggests that the allocative efficiency matters for aggregate TFP in the medium to long run.

Some extensions to improve the aggregate TFP growth are left for future research. First, it may be desirable to relax the common demand elasticity across all or multiple sectors and to estimate it for each industry. Extensions to improve each decomposed effect are also left for the future research. Second, to capture the variety effect more accurately, it is useful to relax our assumption that each establishment produces a single product. Thirdly, to improve the allocative efficiency measure, it is desirable to consider distortions across sectors. Furthermore, from the dynamic viewpoint, a dynamic model that incorporates adjustment costs and fixed costs might be helpful..

It is interesting to analyze the driving factors of each component. To do so, it may be useful to focus on some specific shocks such as financial shocks, export shocks, and natural disasters. It may also useful to exploit variations in each component across industries and regions.

Appendices

A. Aggregation

In this Appendix, we prove (22) for the continuous time model. The sectoral output can be represented by

$$Y_s = A_s {K_s}^{\alpha_s} {L_s}^{1-\alpha_s} \tag{A1}$$

Substituting (A1) into (21) yields

$$Y = \prod_s \left(A_s {K_s}^{\alpha_s} {L_s}^{1-\alpha_s}\right)^{\theta_s} \tag{A2}$$

By definition,

$$ln(A) = dln(Y) - \varepsilon_L dln(L) - \varepsilon_K dln(K) \tag{A3}$$

, where $\varepsilon_L = \frac{dln(Y)}{dln(L)}$ and $\varepsilon_K = \frac{dln(Y)}{dln(K)}$

Using (21) and (A1), we obtain

$$\varepsilon_L = \sum_s \frac{\partial \ln(Y)}{\partial \ln(Y_s)} \frac{\partial \ln(Y_s)}{\partial \ln(L_s)} \frac{\partial \ln(L_s)}{\partial \ln(L)} = \sum_s \theta_s (1-\alpha_s) \frac{\partial \ln(L_s)}{\partial \ln(L)} \tag{A4}$$

Similarly,

$$\varepsilon_K = \sum_s \theta_s \alpha_s \frac{\partial \ln(K_s)}{\partial \ln(K)} \tag{A5}$$

Substituting (A4) and (A5) into (A3), we obtain

$$\mathrm{d}ln(A) = dln(Y) - \sum_s \theta_s (1-\alpha_s) \frac{\partial \ln(L_s)}{\partial \ln(L)} dln(L) - \sum_s \theta_s \alpha_s \frac{\partial \ln(K_s)}{\partial \ln(K)} dln(K) \tag{A6}$$

On the other hand, from (A2),

$$\begin{aligned} dln(Y) &= \sum_s \theta_s dln(A_s) + \sum_s \theta_s (1-\alpha_s)\, dln(L_s) + \sum_s \theta_s \alpha_s\, dln(K_s) \\ &= \sum_s \theta_s dln(A_s) + \sum_s \theta_s (1-\alpha_s) \frac{\partial \ln(L_s)}{\partial \ln(L)} dln(L) + \sum_s \theta_s \alpha_s \frac{\partial \ln(K_s)}{\partial \ln(K)} dln(K) \end{aligned} \tag{A7}$$

Substituting (A7) into (A6), we obtain

$$\mathrm{d}ln(A) = \sum_s \theta_s dln(A_s) \tag{A8}$$

The discrete time version of (A8) leads to (22). From the final goods producer maximization, we obtain $\theta_s = \frac{P_{st} Y_{st}}{P_t Y_t}$.

B. Data from the Census

We basically follow Hosono and Takizawa (2015) to construct the data of output and factor inputs at the establishment level. Gross output is measured as the sum of shipments, revenues from repairing and fixing services, and revenues from performing subcontracted work. Gross out-put is deflated by the output deflator taken from the Japan Industrial Productivity (JIP) Database 2015 and converted to values in constant prices of 2000.

Intermediate input is defined as the sum of raw materials, fuel, electricity and subcontracting expenses for consigned production used by the establishment. Using the intermediate goods deflator taken from the JIP Database, intermediate input is converted to values in constant prices of 2000. Value Added is defined as the difference between gross output and intermediate input.

Capital input is measured as real capital stock, defined as follows:

Capital Input (K_{sit}) = Nominal book value of tangible fixed assets from the Census of Manufactures × Book-to-market value ratio for each industry (γ_{st}).

The book-to-market value ratio for each industry (γ_{st}) is calculated using the industry-level data of real capital stock (K_{st}^{JIP}) taken from the JIP Database as follows:

$$\frac{Y_{st}^{JIP}}{K_{st}^{JIP}} = \frac{\sum_{i \in s} Y_{sit}^{CM}}{\sum_{i \in s} BVK_{sit}^{CM} \times \gamma_{st}}.$$

$\sum_{i \in s} Y_{sit}^{CM}$ is the sum of establishments' value added (i is the index of an establishment), and $\sum_{i \in s} BVK_{sit}^{CM}$ is the sum of the nominal book value of tangible fixed assets of industry s in the Census of Manufactures.

Labor input is the number of employees.

C. Data from the BSBSJA

We follow Hosono et. al (2016) to construct the data of output and factor inputs using BSBSJA. We first use each firm's total sales as the nominal gross output. As for wholesale and retail industries, the nominal gross output is measured as each firm's total sales minus total purchases of goods. Then, this nominal gross output is deflated by the output deflator taken from the JIP database to convert it into values in constant prices (i.e., real gross output) based on the year 2000.

The nominal intermediate input is defined as the sum of the cost of sales and selling, and the general and administrative expenses less wages and depreciation. Using the intermediate deflator in the JIP database, this nominal intermediate input is converted into values in constant prices (i.e., real intermediate input) for the year 2000. The real value added is defined as the difference between the real gross output and the real intermediate input.

The data for capital stock is constructed as follows.

Capital Input (K_{sit}) = Nominal book value of tangible fixed assets from the BSBSJA × Book-to-market value ratio for each industry (α_{st}). We calculate the book-to-market value ratio for each industry (α_{st}) by using the data of real capital stock (K_{st}^{JIP}) and real value added (Y_{st}^{JIP}) at each data point taken from the JIP database as follows:

$$\frac{Y_{st}^{JIP}}{K_{st}^{JIP}} = \frac{\sum_i Y_{sit}^{\text{BSJBSA}}}{\sum_i BVK_{sit}^{\text{BSJBSA}} * \alpha_{st}}$$

where $\sum_i Y_{sit}^{\text{BSJBSA}}$ is the sum of the firms' value added (i is the index of a firm), and $\sum_i BVK_{sit}^{\text{BSJBSA}}$ is the sum of the nominal book value of tangible fixed assets of industry s in BSJBSA.

As a labor input, we use each firm's total number of workers.

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Table 1. Descriptive statistics of aggregate TFP growth and its components: baseline result.

Variables	Mean	Median	SD
TFP	1.3%	1.3%	6.2%
TE for survivors	3.8%	7.4%	22.7%
AE for survivors	-0.7%	-0.6%	5.6%
Entry effect	7.2%	4.2%	8.8%
Exit effect	-8.3%	-8.0%	7.1%
Variety effect	-0.8%	-0.6%	1.5%
(Net entry effect)	-1.1%	-3.7%	14.4%

Note. Descriptive statistics for the 28 sample years of 1987-2014.

Table 2. Sub-period averages of aggregate TFP growth and its components: baseline result.

Period	TFP	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect	(Net entry effect)
1987-1990	0.7%	-0.7%	0.5%	9.3%	-9.0%	0.6%	0.3%
1991-1995	0.7%	0.6%	0.4%	5.1%	-5.0%	-0.5%	0.1%
1996-2000	1.5%	2.2%	0.0%	6.7%	-6.4%	-1.0%	0.3%
2001-2005	3.7%	12.0%	-2.8%	5.2%	-9.6%	-1.2%	-4.3%
2006-2010	0.5%	-5.5%	4.0%	10.6%	-7.9%	-0.7%	2.7%
2011-2014	0.4%	15.8%	-7.2%	6.4%	-12.8%	-1.9%	-6.4%
1987-2014	1.3%	3.8%	-0.7%	7.2%	-8.3%	-0.8%	-1.1%

Table 3. Correlation matrix of aggregate TFP growth and its components: baseline result.

	TFP	TE for survivors	AE for surivors	Entry effect	Exit effect	Variety effect	(Net entry effect)
TFP	1.000						
TE for survivors	0.759 ***	1.000					
AE for surivors	-0.306	-0.695 ***	1.000				
Entry effect	-0.590 ***	-0.861 ***	0.409 **	1.000			
Exit effect	-0.592 ***	-0.882 ***	0.625 ***	0.637 ***	1.000		
Variety effect	0.024	-0.222 ***	0.166	0.220	0.118	1.000	
(Net entry effect)	-0.652 ***	-0.960 ***	0.559 ***	0.925 ***	0.883 ***	0.192	1.000

Note. *** and ** denote the significance levels of 1% and 5%, respectively.

Table 4. Dynamic correlation with aggregate output growth and aggregate TFP and its components: baseline result.

	Output (t-1)	Ouput (t)	Output (t+1)
TFP (t)	-0.126	-0.255	0.215
TE for survivors (t)	-0.398 **	-0.009	0.328 *
AE for surivors (t)	0.100	-0.338 *	-0.183
Entry effect (t)	0.471 **	0.084	-0.373 *
Exit effect (t)	0.450 **	-0.101	-0.296
Variety effect (t)	0.249	0.336 *	0.161
(Net entry effect (t))	0.512 **	0.002	-0.374 *

** and * denote the significance levels of 5% and 10%, respectively.

Table 5. Sub-period averages of aggregate TFP growth and its components: Different demand elasticity based on Rauch classification of goods

Period	TFP	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect	(Net entry effect)
1987-1990	-1.0%	-2.1%	0.0%	11.0%	-10.6%	0.6%	0.4%
1991-1995	0.7%	-0.3%	1.0%	5.1%	-4.8%	-0.5%	0.3%
1996-2000	2.7%	3.8%	0.4%	6.2%	-6.7%	-1.0%	-0.5%
2001-2005	8.3%	16.9%	0.3%	4.8%	-12.4%	-1.2%	-7.6%
2006-2010	-0.7%	-1.2%	1.6%	11.0%	-11.5%	-0.6%	-0.5%
2011-2014	5.3%	20.6%	-3.0%	11.6%	-22.1%	-1.8%	-10.4%
1987-2014	2.6%	6.1%	0.2%	8.1%	-11.0%	-0.8%	-2.9%

Note. $\eta = 3.5$ for commodity goods, $\eta = 2.9$ for reference-priced goods, and $\eta = 2.1$ for differentiated goods.

Table 6. Decomposition of industry-level TFP growth of manufacturing establishments: Summary statistics

Variables	N	Mean	Median	SD
1987-1990				
TFP	51	1.8%	0.5%	13.0%
TE for survivors	51	3.6%	1.2%	14.0%
AE for survivors	51	0.8%	0.2%	7.3%
Entry effect	52	14.6%	6.3%	48.3%
Exit effect	51	-11.1%	-7.6%	12.8%
Variety effect	51	0.5%	0.6%	2.6%
1991-2000				
TFP	52	2.8%	0.3%	8.6%
TE for survivors	52	3.8%	2.2%	11.1%
AE for survivors	52	0.1%	0.3%	6.0%
Entry effect	52	5.4%	3.5%	12.2%
Exit effect	52	-5.4%	-2.5%	10.7%
Variety effect	52	-1.0%	-0.8%	2.2%
2001-2010				
TFP	52	-1.4%	-0.3%	14.8%
TE for survivors	52	-2.9%	-2.1%	22.0%
AE for survivors	52	1.8%	1.2%	6.3%
Entry effect	52	9.1%	7.5%	12.4%
Exit effect	52	-7.9%	-5.9%	9.2%
Variety effect	52	-1.6%	-1.2%	2.8%
2011-2014				
TFP	52	8.4%	9.8%	14.2%
TE for survivors	52	18.0%	19.2%	19.5%
AE for survivors	52	-3.1%	-2.2%	7.4%
Entry effect	52	9.0%	3.9%	21.1%
Exit effect	52	-11.7%	-9.9%	17.6%
Variety effect	52	-3.8%	-1.9%	5.6%

Note. Summary statistics from the decomposition of 52 JIP-classified manufacturing industries for each sub-period. $\eta = 3.5$ for commodity goods, $\eta = 2.9$ for reference-priced goods, and $\eta = 2.1$ for differentiated goods.

Table 7. Sub-period averages of aggregate TFP growth and its components: FHK.

Period	TFP	Within	Reallocation	(Between)	(Covariance)	Entry	Exit	(Net Entry)
1987-1990	4.2%	0.0%	1.8%	-1.3%	3.1%	0.7%	-0.3%	0.5%
1991-1995	1.0%	-0.1%	2.1%	-1.2%	3.3%	-1.3%	-0.2%	-1.5%
1996-2000	2.0%	-1.9%	2.1%	-1.6%	3.7%	-1.1%	-0.2%	-1.3%
2001-2005	-0.6%	0.6%	1.8%	-2.4%	4.2%	-0.4%	-1.7%	-2.1%
2006-2010	-2.2%	-4.5%	2.9%	-4.2%	7.1%	0.7%	-1.7%	-1.0%
2011-2014	3.8%	3.2%	3.7%	-2.6%	6.3%	0.5%	-1.9%	-1.4%
1987-2014	1.2%	-0.6%	2.4%	-2.3%	4.6%	-0.2%	-1.0%	-1.2%

Table 8. Comparison of Kwon et al. (2015) and the baseline result

Kwon et al. (2015)			Baseline result		
	1980s	1990s		1990s	2000s
APG	3.9%	1.4%	TFP	1.1%	2.1%
TE	3.9%	1.8%	TE for survivors	1.4%	3.3%
RE	-0.2%	-0.4%	AE for survivors	0.2%	0.6%
NE	0.3%	-0.1%	Net entry effect	0.2%	-0.8%
			Variety effect	-0.7%	-0.9%

Note. The columns under "Kwon et al. (2015)" reproduce their decomposition (Table 4, pp. 715) following Petrin and Levinson (2012). APG, TE, RE, and NE denote aggregate productivity growth, technical efficiency, reallocation efficiency, and net entry. The columns under "Baseline result" show each of the 10-year averages of our baseline decomposition results.

Table 9. Decomposition of aggregate TFP growth of manufacturing and nonmanufacturing firms in BSJBSA

Period	TFP	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect	(Net entry effect)
1995-2000	5.0%	6.0%	-3.0%	3.6%	-2.3%	0.8%	1.3%
2001-2005	6.9%	13.6%	-5.2%	4.4%	-5.9%	0.0%	-1.5%
2006-2010	6.8%	4.1%	4.0%	7.9%	-9.5%	0.4%	-1.7%
2011-2015	2.6%	9.2%	0.5%	3.8%	-11.0%	0.1%	-7.2%
1995-2015	5.3%	8.1%	-1.1%	4.8%	-7.0%	0.4%	-2.1%

Note. $\eta = 3$

Table 10. Decomposition of aggregate TFP growth of manufacturing firms in BSJBSA

Period	TFP	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect	(Net entry effect)
1995-2000	2.9%	8.2%	-6.9%	6.0%	-4.5%	0.1%	1.6%
2001-2005	14.8%	26.4%	0.1%	1.1%	-12.6%	-0.3%	-11.4%
2006-2010	5.0%	12.6%	2.1%	7.4%	-17.0%	-0.1%	-9.6%
2011-2015	2.0%	14.0%	-0.9%	4.9%	-15.6%	-0.3%	-10.7%
1995-2015	6.0%	14.9%	-1.7%	4.9%	-12.0%	-0.1%	-7.1%

Figure 1. Efficient allocation

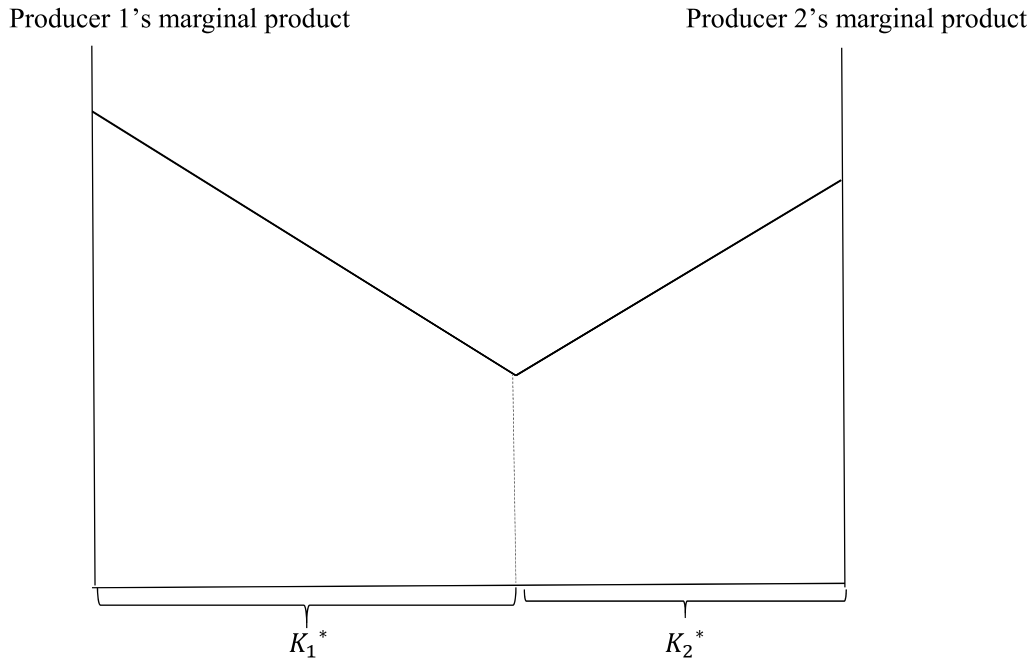


Figure 2A. Inefficient allocation: example 1.

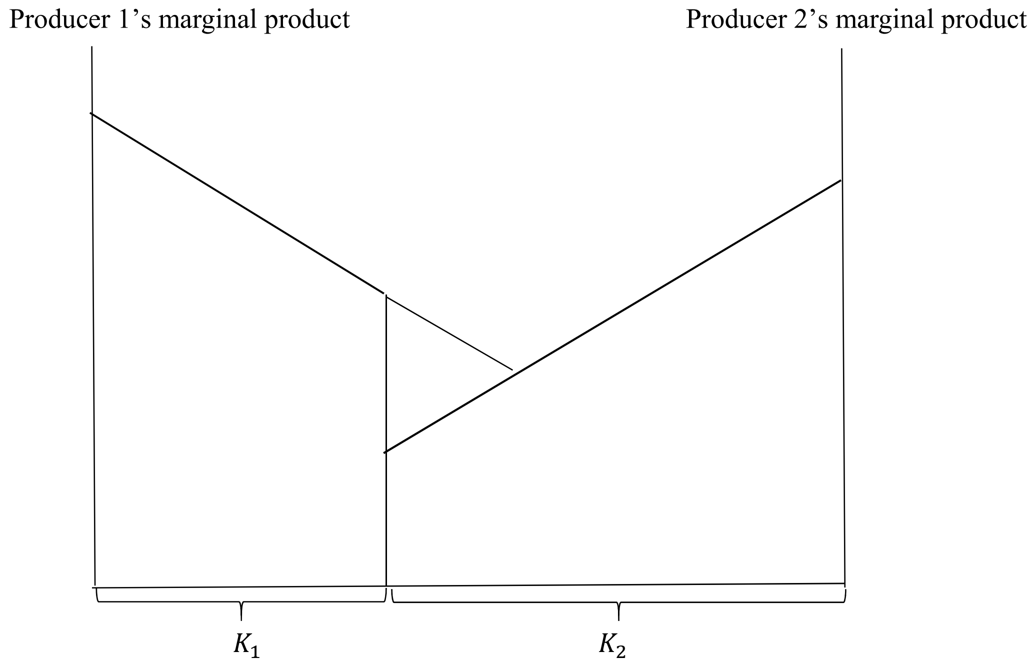


Figure 2B. Inefficient allocation: example 2.

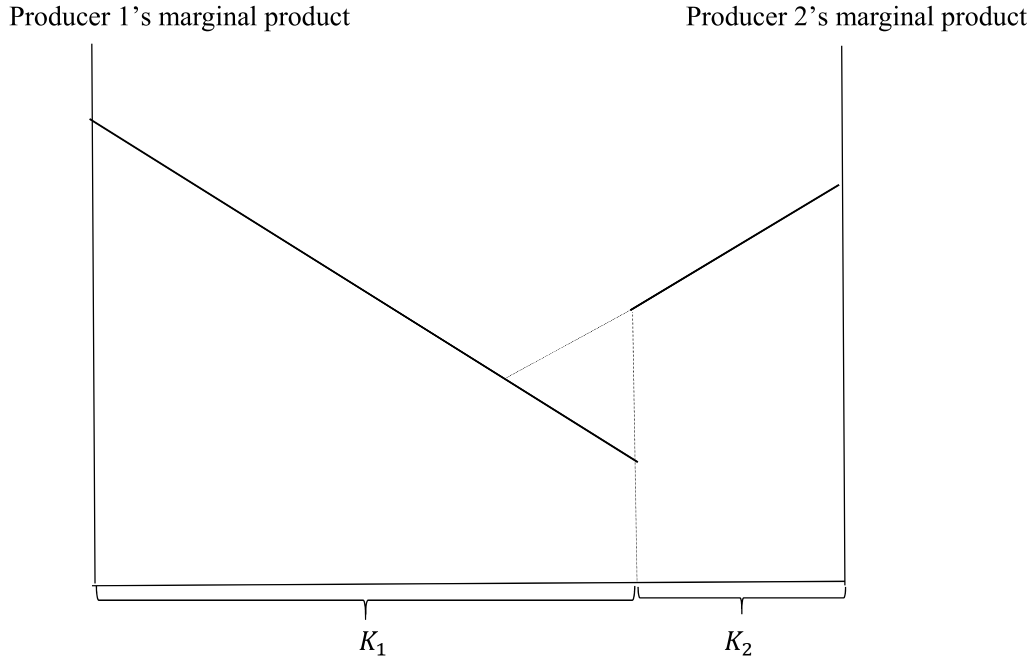


Figure 2C. Inefficient allocation: example 3.

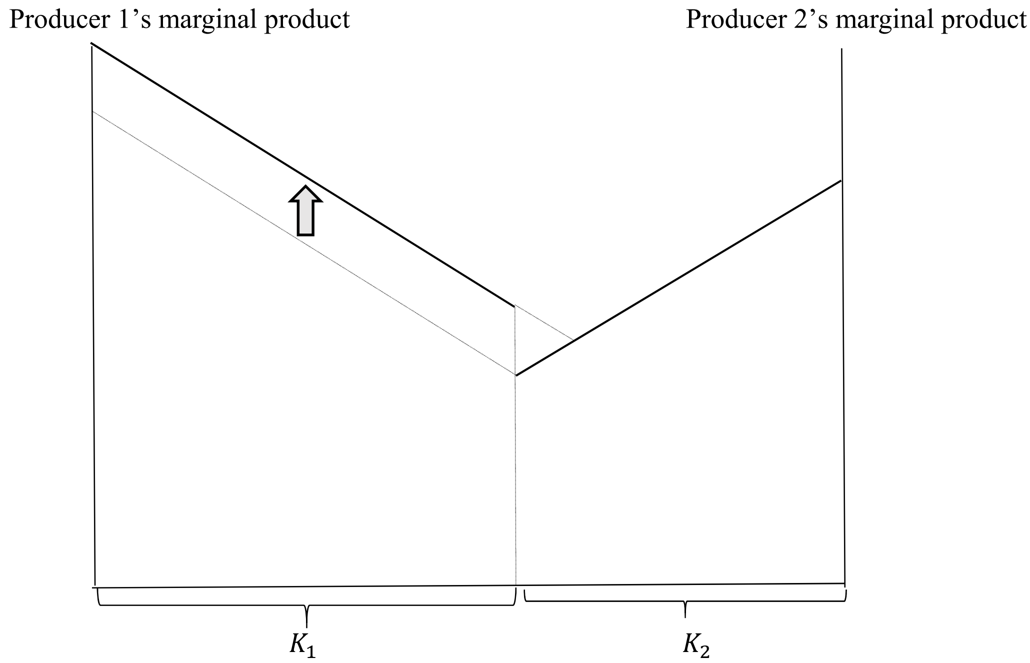
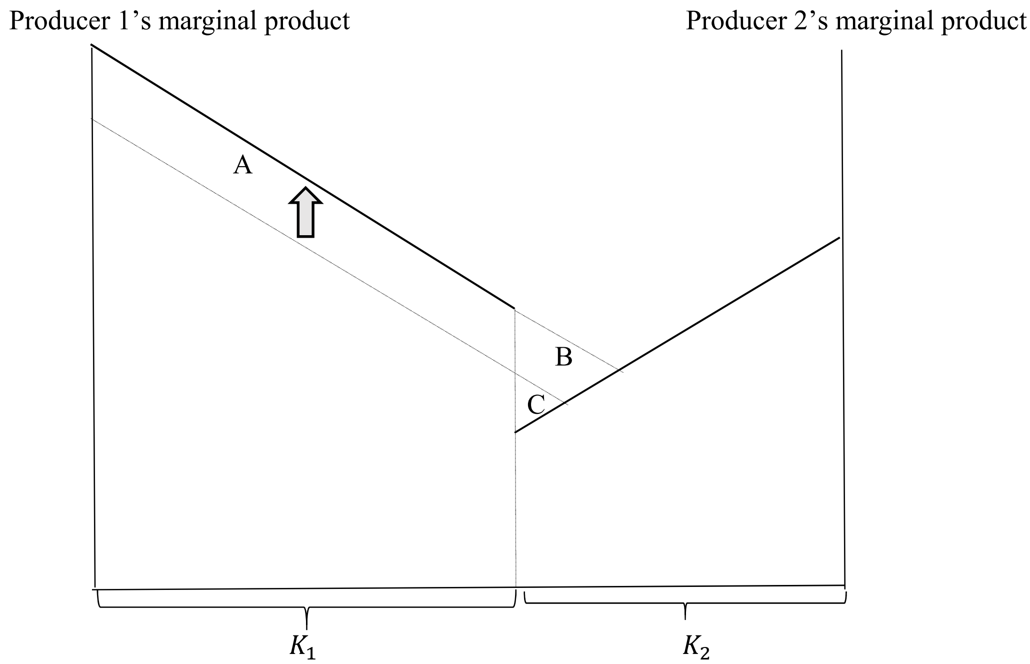


Figure 3. Technical efficiency (TE) and allocative efficiency (AE)

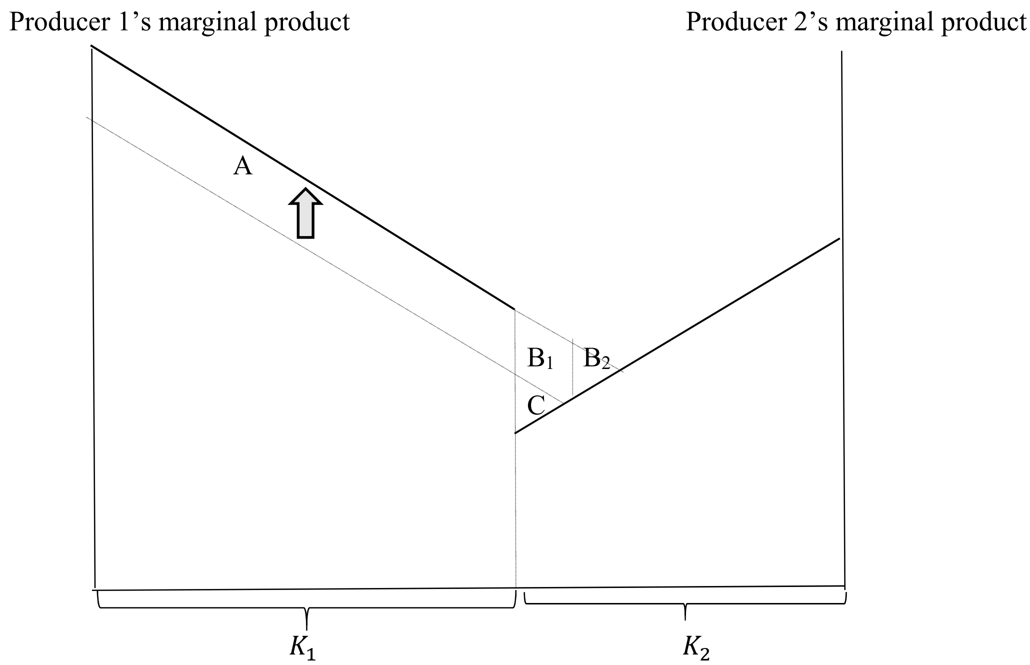
A. Our decomposition



TE: A+B

AE: -B

B. Osotimehin (2019)'s decomposition



TE: A+B_1 (B_1=B- B_2, B_2=C,)

AE: -B_1

Figure 4. Comparison of aggregate TFP growth between the baseline result and the JIP database.

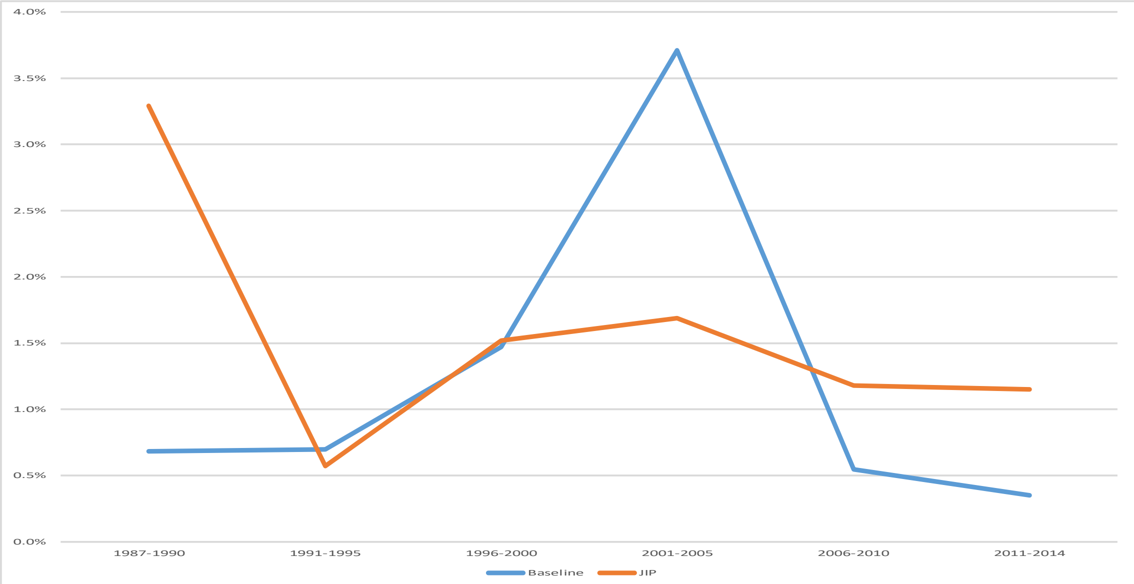


Figure 5. Sub-period averages of aggregate TFP growth and its components: baseline result

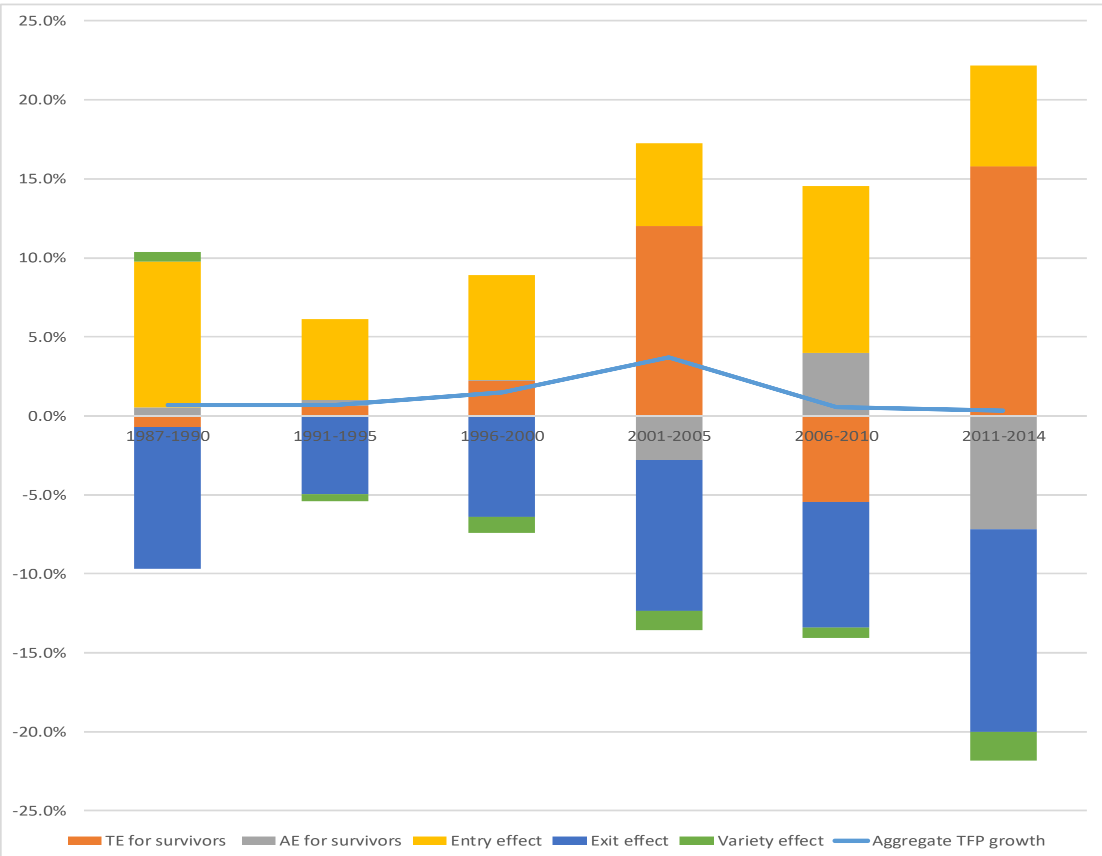
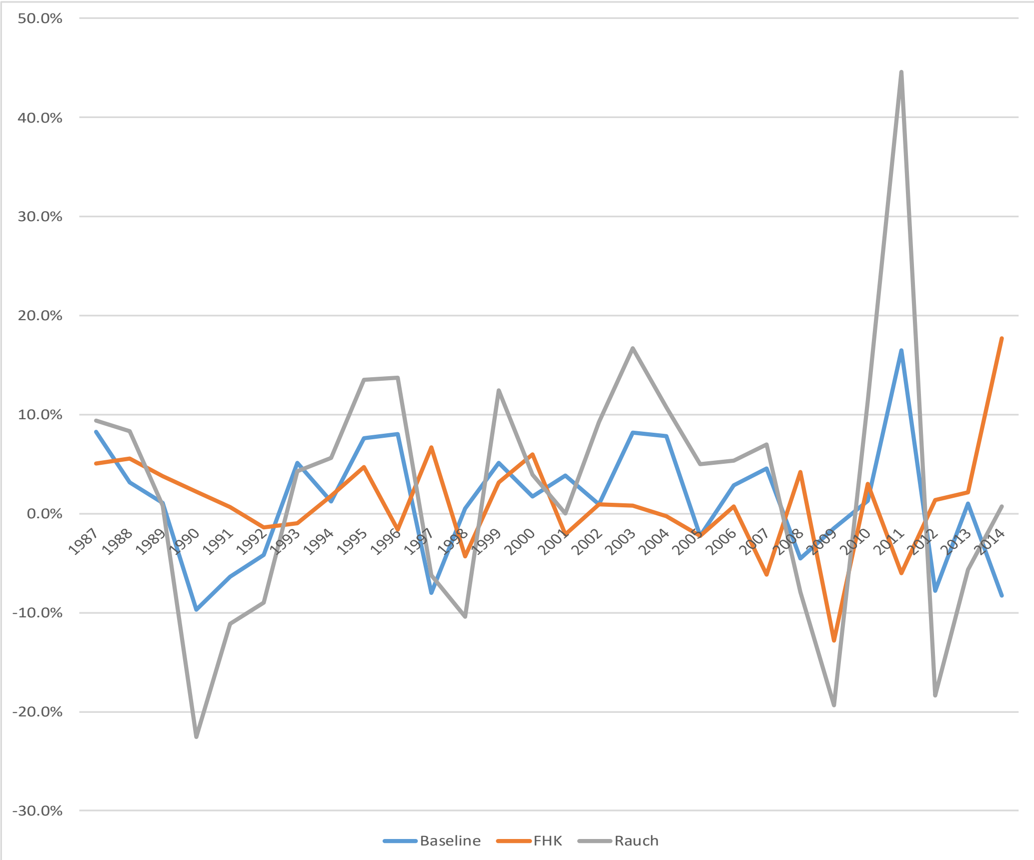


Figure 6. Aggregate TFP growth of manufacturing establishments: Alternative aggregation methods



Note. Baseline denotes our baseline result with $\eta = 3$. Rauch denotes the result for three sectors each with different η. FHK denotes Foster, Haltiwanger, and Krizan (2001)'s method.

Figure 7. Sub-period averages of aggregate TFP growth and its components: Different demand elasticities based on Rauch classification of goods

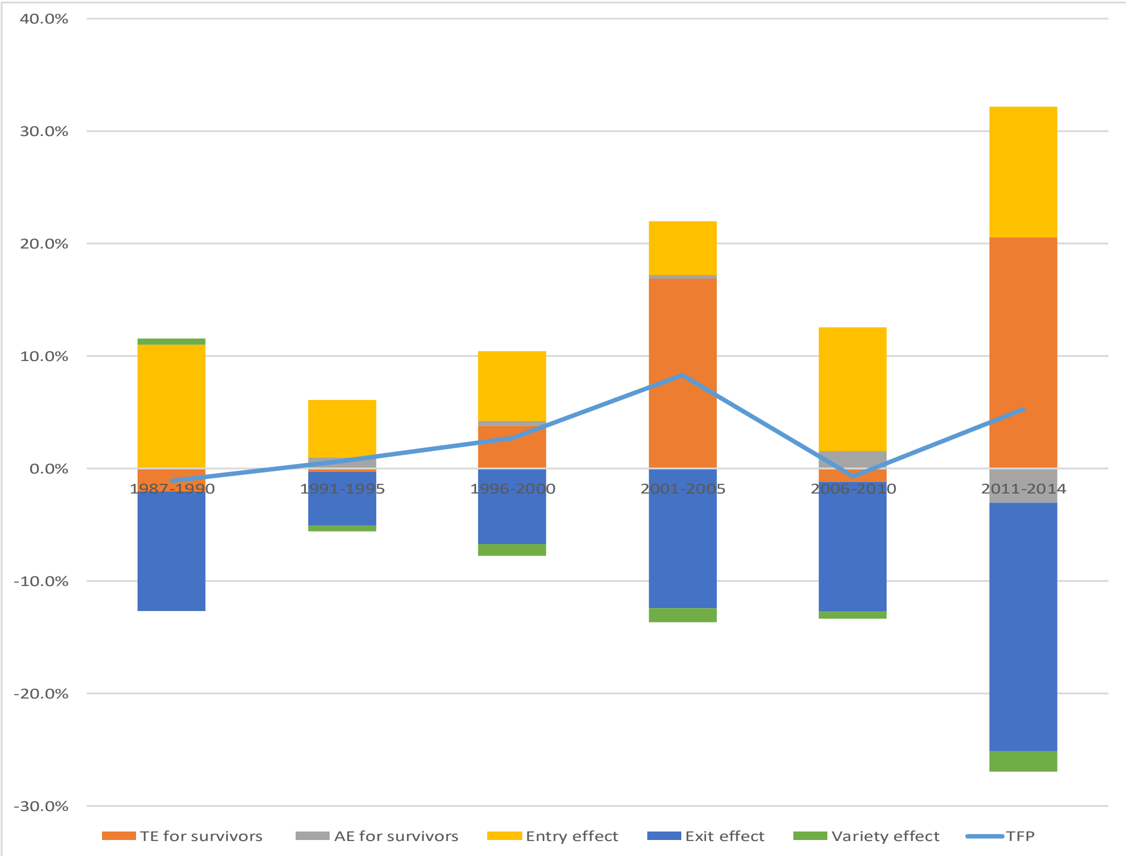


Figure 8. Comparison between the baseline result and the result from Rauch classification of demand elasticity

Note. _B and _R denote the baseline result and the result from Rauch classification of demand elasticity, respectively.

Figure 9. Sub-period averages of aggregate TFP growth and its components: FHK

Figure 10. Sub-period averages of aggregate TFP growth and its components: manufacturing and nonmanufacturing firms in BSJBSA

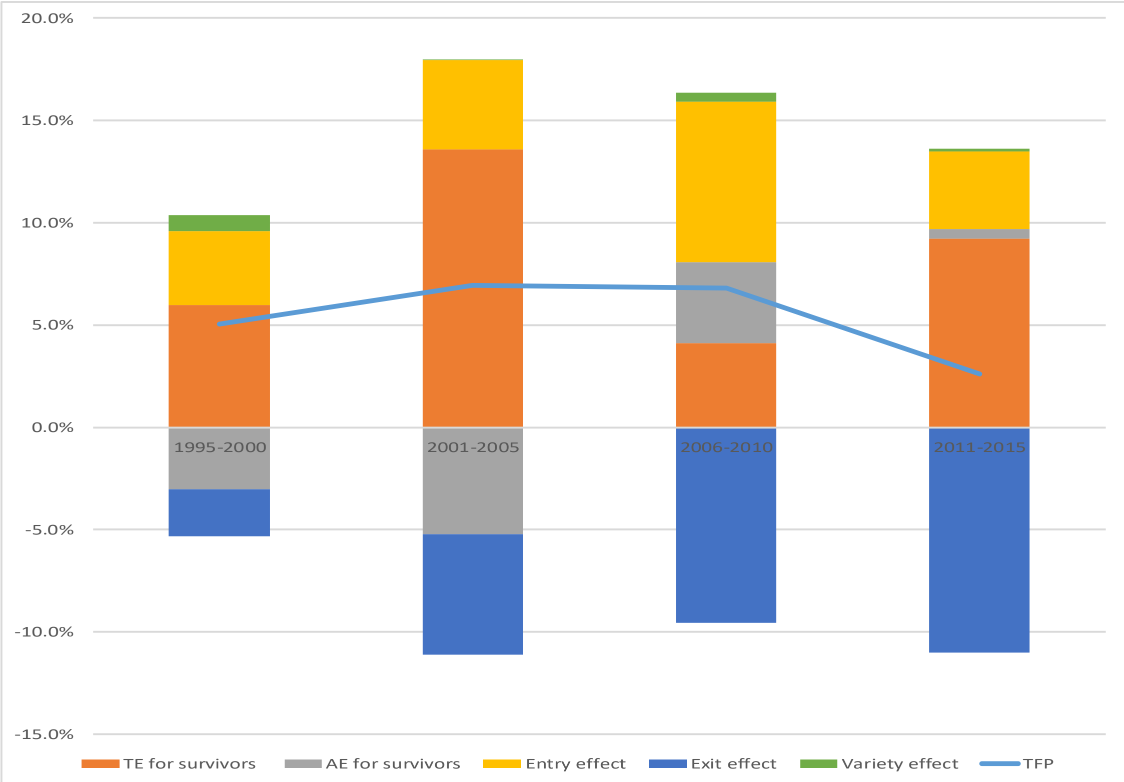


Figure 11. Sub-period averages of aggregate TFP growth and its components: manufacturing firms in BSJBSA

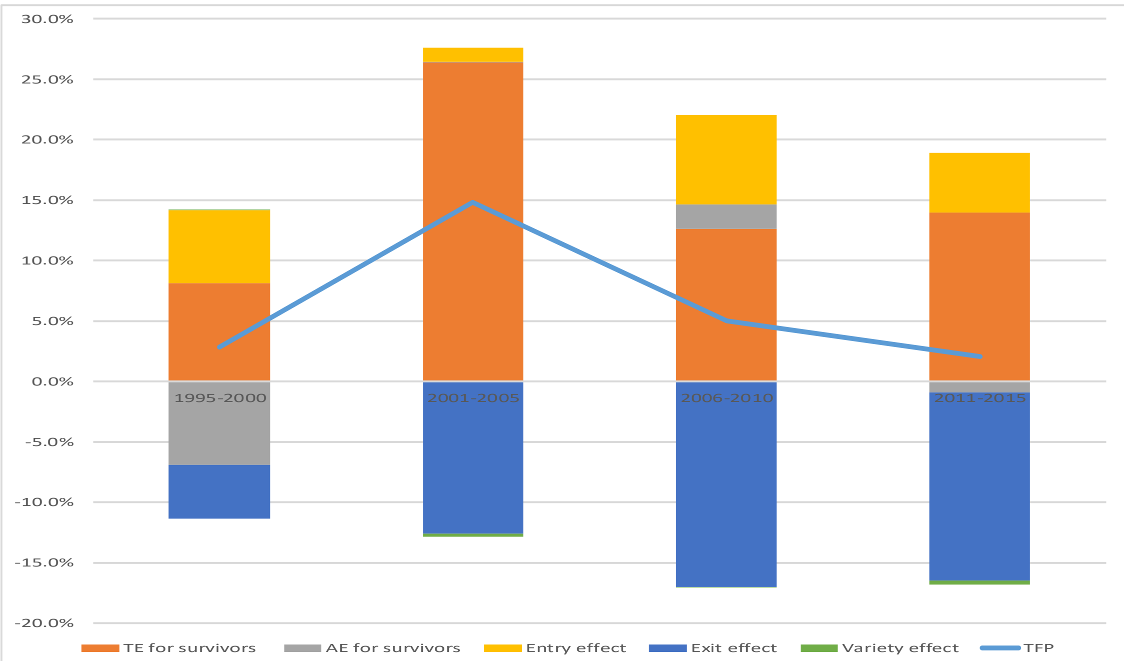


Table A1. JIP industry classification and Rauch classification

JIP Classification No.	Industry	Rauch Classification
8	Livestock products	Ref.
9	Seafood products	Dif.
10	Flour and grain mill products	Homo.
11	Miscellaneous foods and related products	Dif.
12	Prepared animal foods and organic fertilizers	Homo.
13	Beverages	Dif.
14	Tobacco	Ref.
15	Textile products	Dif.
16	Lumber and wood products	Ref.
17	Furniture and fixtures	Dif.
18	Pulp, paper, and coated and glazed paper	Dif.
19	Paper products	Dif.
20	Printing, plate making for printing and bookbinding	Dif.
21	Leather and leather products	Dif.
22	Rubber products	Homo.
23	Chemical fertilizers	Homo.
24	Basic inorganic chemicals	Dif.
25	Basic organic chemicals	Dif.
26	Organic chemicals	Dif.
27	Chemical fibers	Dif.
28	Miscellaneous chemical products	Dif.
29	Pharmaceutical products	Dif.
30	Petroleum products	Homo.
31	Coal products	Homo.
32	Glass and its products	Dif.
33	Cement and its products	Homo.
34	Pottery	Dif.
35	Miscellaneous ceramic, stone and clay products	Dif.
36	Pig iron and crude steel	Homo.
37	Miscellaneous iron and steel	Dif.
38	Smelting and refining of non-ferrous metals	Ref.
39	Non-ferrous metal products	Dif.
40	Fabricated constructional and architectural metal produc	Dif.
41	Miscellaneous fabricated metal products	Dif.
42	General industry machinery	Dif.
43	Special industry machinery	Dif.
44	Miscellaneous machinery	Dif.
45	Office and service industry machines	Dif.
46	Electrical generating, transmission, distribution and indus	Dif.
47	Household electric appliances	Dif.
48	Electronic data processing machines, digital and analog c	Dif.
49	Communication equipment	Dif.
50	Electronic equipment and electric measuring instruments	Dif.
51	Semiconductor devices and integrated circuits	Dif.
52	Electronic parts	Dif.
53	Miscellaneous electrical machinery equipment	Dif.
54	Motor vehicles	Dif.
55	Motor vehicle parts and accessories	Dif.
56	Other transportation equipment	Dif.
57	Precision machinery & equipment	Dif.
58	Plastic products	Dif.
59	Miscellaneous manufacturing industries	Dif.

Note. Homo., Ref., and Dif. denote commodity goods, reference-priced goods, and differentiated goods, respectively.

Table A2. Decomposition of industry-level TFP growth of manufacturing establishments: Result from different elasticity of substitution

	Aggregate TFP growth	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect
8 Livestock products						
1987-90	0.5%	-0.6%	1.3%	8.8%	-9.1%	0.1%
1991-00	-1.7%	-5.1%	0.0%	8.6%	-4.9%	-0.3%
2001-10	8.0%	-0.3%	1.5%	9.8%	-9.3%	6.3%
2011-14	6.9%	15.6%	-4.2%	10.5%	-16.1%	1.2%
9 Seafood products						
1987-90	-2.9%	-0.1%	0.2%	8.1%	-13.6%	2.6%
1991-00	14.3%	19.2%	-3.7%	2.2%	-4.6%	1.2%
2001-10	0.4%	-3.2%	1.2%	3.3%	0.6%	-1.5%
2011-14	-7.4%	-3.4%	-2.7%	0.4%	1.2%	-2.9%
10 Flour and grain mill products						
1987-90	1.3%	0.8%	10.4%	6.6%	-15.3%	-1.2%
1991-00	-0.3%	1.6%	-11.5%	10.6%	-0.7%	-0.3%
2001-10	1.5%	-17.6%	35.9%	6.8%	-24.1%	0.3%
2011-14	-14.0%	-5.9%	-23.6%	128.1%	-112.5%	-0.2%
11 Miscellaneous foods and related products						
1987-90	-4.1%	-1.8%	-0.8%	6.3%	-9.7%	1.8%
1991-00	-2.2%	1.2%	2.2%	-4.1%	-2.2%	0.7%
2001-10	-0.2%	2.9%	1.1%	-1.7%	-2.4%	-0.1%
2011-14	10.9%	22.0%	3.4%	-13.5%	-0.4%	-0.6%
12 Prepared animal foods and organic fertilizers						
1987-90	-3.1%	-21.5%	3.7%	21.6%	-5.8%	-1.0%
1991-00	0.0%	-7.3%	6.6%	-0.2%	1.5%	-0.6%
2001-10	-2.7%	-2.0%	-1.6%	-1.8%	4.8%	-2.1%
2011-14	-4.4%	-1.7%	-3.8%	3.9%	-2.6%	-0.3%
13 Beverages						
1987-90	-10.0%	-18.5%	2.7%	18.9%	-14.8%	1.7%
1991-00	-5.0%	-8.3%	0.8%	3.7%	-0.1%	-1.0%
2001-10	5.9%	5.8%	3.0%	10.4%	-12.6%	-0.7%
2011-14	-3.6%	6.6%	-5.2%	0.0%	-4.4%	-0.7%
14 Tobacco						
1987-90	9.5%	12.8%	8.3%	8.3%	-14.4%	-5.5%
1991-00	6.0%	2.4%	0.7%	18.2%	-13.7%	-1.7%
2001-10	-42.2%	-41.7%	-3.2%	6.5%	-1.7%	-2.1%
2011-14	-35.8%	-29.4%	-6.5%	0.0%	9.1%	-9.1%
15 Textile products						
1987-90	-5.7%	-2.6%	-0.4%	0.9%	-3.5%	-0.1%
1991-00	-3.0%	-2.9%	1.4%	0.4%	3.8%	-5.7%
2001-10	-1.6%	1.2%	4.3%	0.3%	-0.9%	-6.5%
2011-14	7.6%	21.7%	-6.7%	2.0%	4.4%	-13.9%
16 Lumber and wood products						
1987-90	-5.9%	-10.1%	0.8%	7.4%	-4.4%	0.4%
1991-00	-2.4%	-2.8%	1.1%	3.7%	-2.3%	-2.2%
2001-10	-3.6%	-10.1%	3.6%	11.5%	-6.6%	-2.0%
2011-14	3.7%	0.8%	-5.0%	7.0%	0.5%	0.3%
17 Furniture and fixtures						
1987-90	-5.5%	-4.7%	1.5%	6.3%	-9.2%	0.6%
1991-00	-3.6%	-6.9%	1.3%	7.2%	-1.6%	-3.5%
2001-10	-5.0%	-5.9%	0.1%	9.3%	-3.8%	-4.7%
2011-14	15.4%	19.6%	-1.5%	6.2%	-8.6%	-0.3%

	Aggregate TFP growth	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect
18 Pulp, paper, and coated and glazed paper						
1987-90	-4.4%	0.8%	-5.1%	5.8%	-5.2%	-0.8%
1991-00	0.1%	-1.5%	0.1%	4.9%	-2.4%	-1.0%
2001-10	-9.3%	-13.8%	2.2%	9.1%	-4.1%	-2.7%
2011-14	14.9%	18.7%	-2.0%	9.9%	-9.9%	-1.8%
19 Paper products						
1987-90	-3.6%	-2.2%	-1.3%	6.7%	-7.5%	0.8%
1991-00	-1.5%	-0.7%	-0.2%	0.6%	-0.7%	-0.6%
2001-10	-0.7%	-1.0%	-0.3%	3.7%	-1.9%	-1.2%
2011-14	4.4%	19.5%	-2.3%	-4.5%	-6.4%	-1.9%
20 Printing, plate making for printing and bookbinding						
1987-90	0.5%	1.2%	2.0%	3.7%	-8.2%	1.8%
1991-00	-1.2%	-5.0%	0.4%	5.8%	-2.1%	-0.1%
2001-10	4.2%	2.7%	0.3%	9.0%	-6.0%	-1.8%
2011-14	1.0%	12.9%	-0.8%	9.9%	-15.6%	-5.4%
21 Leather and leather products						
1987-90	-13.5%	-20.8%	-1.7%	10.5%	-4.1%	2.6%
1991-00	-4.0%	-2.9%	2.4%	4.0%	-2.1%	-5.4%
2001-10	-6.8%	-4.2%	1.2%	3.4%	-2.4%	-4.8%
2011-14	5.8%	9.5%	-0.2%	4.1%	-4.3%	-3.4%
22 Rubber products						
1987-90	8.0%	7.5%	-0.8%	8.8%	-8.0%	0.6%
1991-00	-0.2%	-3.1%	1.2%	4.0%	-1.5%	-0.8%
2001-10	1.9%	2.5%	2.0%	2.9%	-4.9%	-0.6%
2011-14	-3.3%	5.9%	-3.1%	-1.5%	-4.1%	-0.5%
23 Chemical fertilizers						
1987-90	-13.2%	12.1%	37.7%	-0.9%	-60.3%	-1.8%
1991-00	-16.1%	15.9%	4.3%	-0.9%	-34.5%	-0.8%
2001-10	10.5%	-4.4%	9.4%	7.3%	-1.3%	-0.6%
2011-14	18.5%	28.7%	19.5%	-4.8%	-25.4%	0.5%
24 Basic inorganic chemicals						
1987-90	-18.3%	-14.4%	-1.5%	-0.2%	-0.7%	-1.5%
1991-00	6.8%	3.3%	-2.1%	3.9%	1.0%	0.7%
2001-10	-10.6%	-12.3%	0.8%	-2.3%	2.9%	0.3%
2011-14	18.7%	16.9%	1.8%	3.0%	-2.3%	-0.8%
25 Basic organic chemicals						
1987-90	3.4%	24.9%	-15.4%	22.7%	-36.9%	8.1%
1991-00	8.7%	28.7%	30.6%	2.6%	-46.9%	-6.3%
2001-10	-16.7%	-54.6%	-10.1%	56.7%	-13.0%	4.3%
2011-14	1.1%	3.6%	9.2%	9.9%	-26.8%	5.1%
26 Organic chemicals						
1987-90	3.5%	-8.4%	-0.5%	23.9%	-11.9%	0.4%
1991-00	-4.3%	6.7%	-2.4%	1.5%	-9.7%	-0.4%
2001-10	-18.7%	-16.0%	3.2%	-9.0%	3.1%	-0.1%
2011-14	13.6%	25.4%	-21.9%	3.9%	6.4%	-0.3%
27 Chemical fibers						
1987-90	11.4%	15.6%	-5.1%	0.8%	-0.2%	0.4%
1991-00	13.5%	11.3%	-1.7%	3.4%	2.1%	-1.5%
2001-10	-44.7%	-48.3%	-5.9%	8.7%	3.7%	-2.8%
2011-14	19.5%	7.6%	0.0%	55.9%	-43.4%	-0.6%

	Aggregate TFP growth	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect
28 Miscellaneous chemical products						
1987-90	4.5%	16.3%	0.9%	16.6%	-30.9%	1.7%
1991-00	0.1%	6.6%	0.4%	3.3%	-10.5%	0.3%
2001-10	1.5%	-3.4%	1.4%	13.2%	-9.5%	0.0%
2011-14	8.9%	23.2%	-2.1%	2.0%	-12.5%	-1.7%
29 Pharmaceutical products						
1987-90	8.8%	3.8%	-2.2%	35.6%	-29.9%	1.4%
1991-00	4.1%	2.0%	0.5%	5.3%	-3.7%	0.1%
2001-10	1.1%	6.1%	2.1%	9.2%	-15.6%	-0.7%
2011-14	6.0%	19.9%	-3.7%	2.7%	-12.3%	-0.6%
30 Petroleum products						
1987-90	-12.5%	0.2%	-8.5%	16.0%	-20.6%	0.4%
1991-00	-12.2%	-18.2%	5.6%	-1.1%	2.3%	-0.9%
2001-10	-14.2%	-11.1%	12.0%	32.6%	-46.8%	-0.9%
2011-14	-5.0%	12.9%	-14.9%	-6.9%	2.4%	1.4%
31 Coal products						
1987-90	-30.6%	7.7%	-3.4%	3.0%	-34.6%	-3.2%
1991-00	10.4%	-0.3%	-12.0%	20.3%	2.5%	-0.2%
2001-10	-21.3%	-52.6%	-9.7%	61.1%	-21.0%	0.9%
2011-14	22.9%	57.4%	-6.3%	3.0%	-26.0%	-5.1%
32 Glass and its products						
1987-90	13.0%	15.3%	6.4%	3.2%	-14.2%	2.3%
1991-00	6.6%	4.5%	-1.5%	5.2%	-1.6%	0.0%
2001-10	0.6%	0.2%	-2.0%	6.5%	-2.4%	-1.8%
2011-14	22.5%	34.6%	2.8%	10.5%	-18.5%	-6.9%
33 Cement and its products						
1987-90	0.0%	3.4%	3.2%	10.7%	-16.8%	-0.5%
1991-00	-0.3%	0.4%	-0.1%	5.7%	-5.0%	-1.2%
2001-10	-2.9%	-9.0%	3.8%	9.0%	-3.9%	-2.7%
2011-14	2.8%	18.7%	-3.7%	3.5%	-14.8%	-0.9%
34 Pottery						
1987-90	11.5%	14.9%	3.1%	2.3%	-7.6%	-1.2%
1991-00	4.4%	9.3%	-0.5%	5.6%	-5.5%	-4.5%
2001-10	5.2%	5.9%	0.8%	9.1%	-6.5%	-4.2%
2011-14	13.7%	23.3%	-1.4%	6.1%	-5.9%	-8.4%
35 Miscellaneous ceramic, stone and clay products						
1987-90	9.1%	7.7%	2.6%	6.3%	-7.3%	-0.2%
1991-00	0.4%	3.6%	0.3%	2.7%	-3.5%	-2.7%
2001-10	-9.0%	-12.6%	-0.9%	12.1%	-5.8%	-1.8%
2011-14	12.3%	16.0%	-1.0%	3.7%	-5.1%	-1.3%
36 Pig iron and crude steel						
1987-90	15.9%	10.3%	5.1%	0.3%	0.9%	-0.6%
1991-00	6.7%	10.6%	-0.3%	6.6%	-9.3%	-0.9%
2001-10	-32.3%	-41.6%	9.3%	7.7%	-7.8%	0.2%
2011-14	68.8%	76.3%	-18.8%	12.4%	0.0%	-1.0%
37 Miscellaneous iron and steel						
1987-90	-4.2%	-10.4%	-17.9%	21.3%	2.2%	0.6%
1991-00	-6.6%	3.9%	-9.5%	2.9%	-2.5%	-1.4%
2001-10	-1.9%	-12.6%	8.6%	4.8%	-2.3%	-0.3%
2011-14	-12.5%	16.8%	-10.9%	-4.6%	-11.7%	-2.1%

	Aggregate TFP growth	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect
38 Smelting and refining of non-ferrous metals						
1987-90	9.6%	-10.3%	3.7%	6.6%	8.1%	1.5%
1991-00	2.9%	-3.4%	-15.8%	25.2%	-3.5%	0.5%
2001-10	4.0%	-7.6%	3.5%	17.2%	-9.5%	0.5%
2011-14	-18.9%	-55.0%	-11.5%	49.4%	2.1%	-3.9%
39 Non-ferrous metal products						
1987-90	6.2%	5.0%	-0.2%	0.8%	0.0%	0.5%
1991-00	-0.9%	-1.0%	-0.3%	-1.2%	1.9%	-0.4%
2001-10	-4.5%	-10.8%	3.0%	7.2%	-3.7%	-0.4%
2011-14	16.2%	29.9%	-5.0%	3.7%	-9.8%	-2.6%
40 Fabricated constructional and architectural metal products						
1987-90	-11.1%	-11.2%	-1.4%	9.8%	-11.3%	2.9%
1991-00	9.4%	11.9%	0.3%	6.7%	-8.8%	-0.7%
2001-10	-9.1%	-17.7%	-0.4%	15.4%	-4.3%	-2.0%
2011-14	-2.4%	-0.3%	-11.4%	6.2%	4.6%	-1.6%
41 Miscellaneous fabricated metal products						
1987-90	-3.4%	-2.5%	-0.1%	-0.3%	-2.3%	1.8%
1991-00	0.2%	4.6%	-0.6%	1.2%	-4.2%	-0.9%
2001-10	-1.7%	4.2%	0.6%	-2.2%	-3.5%	-0.8%
2011-14	3.8%	22.8%	-1.5%	-10.7%	0.4%	-7.2%
42 General industry machinery						
1987-90	0.8%	6.3%	2.3%	6.3%	-15.4%	1.3%
1991-00	-1.6%	-1.0%	0.1%	4.0%	-4.0%	-0.7%
2001-10	3.2%	3.8%	0.7%	8.3%	-8.4%	-1.2%
2011-14	9.4%	20.9%	-1.8%	3.5%	-12.3%	-0.8%
43 Special industry machinery						
1987-90	2.4%	6.6%	0.1%	0.0%	-6.0%	1.8%
1991-00	1.1%	4.9%	-0.5%	-3.0%	0.6%	-0.9%
2001-10	2.7%	11.6%	1.9%	-1.2%	-9.4%	-0.2%
2011-14	6.8%	31.9%	-3.5%	-8.3%	-12.9%	-0.4%
44 Miscellaneous machinery						
1987-90	-4.8%	-9.5%	-0.2%	11.1%	-6.7%	0.5%
1991-00	-4.7%	-7.7%	1.2%	2.0%	-0.5%	0.3%
2001-10	-0.6%	-2.1%	-0.6%	6.4%	-3.2%	-1.1%
2011-14	7.2%	9.0%	-2.9%	1.0%	2.5%	-2.4%
45 Office and service industry machines						
1987-90	3.2%	11.6%	1.3%	19.1%	-32.6%	3.7%
1991-00	7.8%	12.4%	0.1%	11.4%	-14.4%	-1.8%
2001-10	6.1%	3.1%	-1.6%	16.2%	-8.3%	-3.2%
2011-14	2.8%	1.0%	2.7%	14.2%	-9.7%	-5.3%
46 Electrical generating, transmission, distribution and industrial apparatus						
1987-90	-9.2%	-12.3%	3.1%	-0.4%	-0.9%	1.2%
1991-00	4.9%	3.4%	5.9%	0.0%	-2.5%	-2.0%
2001-10	-4.9%	-2.2%	-4.4%	12.2%	-3.9%	-6.6%
2011-14	14.0%	23.0%	-0.4%	8.3%	-14.7%	-2.2%
47 Household electric appliances						
1987-90	42.4%	46.1%	1.6%	-9.5%	4.1%	0.2%
1991-00	8.3%	14.4%	-4.9%	2.2%	2.5%	-5.9%
2001-10	42.7%	68.0%	4.7%	5.4%	-26.5%	-9.0%
2011-14	5.2%	15.0%	10.3%	19.3%	-29.2%	-10.3%

	Aggregate TFP growth	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect
48 Electronic data processing machines, digital and analog computer equipment and accessories						
1987-90	#DIV/0!	#DIV/0!	#DIV/0!	350.2%	#DIV/0!	#DIV/0!
1991-00	10.5%	-24.3%	6.0%	80.0%	-50.7%	-0.4%
2001-10	40.0%	63.3%	5.9%	12.0%	-30.3%	-10.9%
2011-14	16.9%	28.7%	-1.9%	30.9%	-11.9%	-28.9%
49 Communication equipment						
1987-90	42.0%	26.1%	3.9%	4.0%	6.9%	1.0%
1991-00	27.7%	27.4%	1.7%	2.6%	-6.4%	2.4%
2001-10	8.7%	9.6%	4.1%	17.4%	-20.9%	-1.5%
2011-14	27.0%	53.3%	2.7%	10.6%	-22.4%	-17.2%
50 Electronic equipment and electric measuring instruments						
1987-90	-16.6%	-16.7%	-3.6%	4.2%	-3.4%	2.9%
1991-00	2.9%	0.1%	0.3%	10.0%	-5.2%	-2.4%
2001-10	-5.7%	-10.7%	-0.1%	22.5%	-14.8%	-2.6%
2011-14	13.9%	10.7%	-15.7%	32.8%	-13.3%	-0.6%
51 Semiconductor devices and integrated circuits						
1987-90	26.2%	21.0%	-2.3%	33.0%	-27.4%	1.9%
1991-00	33.9%	27.5%	0.7%	-4.8%	2.8%	7.7%
2001-10	11.0%	15.5%	-0.7%	12.2%	-12.9%	-3.2%
2011-14	14.0%	33.3%	-5.4%	13.2%	-14.6%	-12.6%
52 Electronic parts						
1987-90	22.0%	35.2%	-5.7%	0.3%	-13.0%	5.2%
1991-00	21.4%	40.7%	-2.9%	-7.7%	-8.7%	0.0%
2001-10	20.9%	40.4%	1.3%	-6.3%	-10.7%	-3.9%
2011-14	18.4%	47.0%	2.2%	-3.1%	-12.6%	-15.1%
53 Miscellaneous electrical machinery equipment						
1987-90	-3.7%	-7.0%	2.1%	5.9%	-7.6%	2.9%
1991-00	-1.8%	0.0%	-0.8%	6.6%	-6.0%	-1.5%
2001-10	6.0%	7.3%	2.5%	3.8%	-7.6%	-0.1%
2011-14	11.3%	28.8%	-5.1%	11.4%	-20.8%	-2.9%
54 Motor vehicles						
1987-90	2.7%	13.3%	5.8%	14.3%	-27.8%	-3.0%
1991-00	3.8%	3.5%	1.0%	9.2%	-10.7%	0.8%
2001-10	2.9%	3.9%	1.1%	3.2%	-7.7%	2.4%
2011-14	16.8%	26.2%	2.4%	19.1%	-24.5%	-6.4%
55 Motor vehicle parts and accessories						
1987-90	-0.5%	7.8%	-3.0%	-2.0%	-4.2%	0.8%
1991-00	0.2%	4.8%	0.9%	-5.9%	0.7%	-0.3%
2001-10	10.8%	16.0%	0.7%	-3.6%	-2.9%	0.5%
2011-14	10.1%	29.4%	-3.4%	-4.8%	-7.9%	-3.1%
56 Other transportation equipment						
1987-90	8.8%	-2.8%	1.4%	15.6%	-1.1%	-4.3%
1991-00	3.2%	-1.5%	-1.8%	11.1%	-3.2%	-1.5%
2001-10	0.7%	-1.0%	-2.3%	8.1%	-6.1%	2.0%
2011-14	15.0%	23.6%	4.7%	7.2%	-14.9%	-5.6%
57 Precision machinery & equipment						
1987-90	0.5%	1.0%	-1.5%	5.5%	-2.4%	-2.1%
1991-00	-3.8%	-1.3%	0.4%	-0.7%	0.3%	-2.5%
2001-10	1.7%	2.9%	-1.2%	5.9%	-4.2%	-1.7%
2011-14	14.6%	17.5%	0.3%	-0.2%	0.0%	-3.0%

	Aggregate TFP growth	TE for survivors	AE for survivors	Entry effect	Exit effect	Variety effect
58 Plastic products						
1987-90	4.4%	13.5%	-3.1%	-9.2%	0.0%	3.1%
1991-00	3.5%	6.4%	2.7%	-2.7%	-3.5%	0.6%
2001-10	-0.4%	4.7%	0.2%	-4.1%	-0.9%	-0.2%
2011-14	10.6%	25.3%	-2.0%	-2.4%	-9.0%	-1.4%
59 Miscellaneous manufacturing industries						
1987-90	8.0%	20.9%	10.1%	4.2%	-19.3%	-7.9%
1991-00	1.7%	7.0%	-0.7%	-2.0%	0.4%	-3.0%
2001-10	-4.4%	-2.8%	2.6%	5.7%	-7.2%	-2.8%
2011-14	10.5%	18.9%	1.7%	4.4%	-13.2%	-1.3%