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Kaoru Hosono
Miho Takizawa

Research Project on Central Bank Communication
702 Faculty of Economics, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
Tel: +81-3-5841-5595 E-mail: watlab@e.u-tokyo.ac.jp
http://www.centralbank.e.u-tokyo.ac.jp/en/

DYNAMIC PRODUCTIVITY DECOMPOSITION WITH ALLOCATIVE EFFICIENCY[1]

KAORU HOSONO[2]
Gakushuin University

MIHO TAKIZAWA[3]
Gakushuin University

Abstract

We propose a novel approach to decomposing aggregate productivity growth into changes in technical efficiency, allocative efficiency, and variety of goods as well as relative efficiency of entrants and exiters. We measure technical efficiency by the aggregate production possibility frontier and allocative efficiency by the distance from the frontier. Applying our approach to establishment- and firm-level datasets from Japan, we find that the allocative efficiency among survivors declined during the banking crisis period, while the technical efficiency declined during the Global Financial Crisis period. Furthermore, we find that both entrants and exiters were likely to be more efficient than survivors.

Keywords: Productivity decomposition, Allocative efficiency, Japan.

JEL classification: D24, O40, O47

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2 Corresponding author. Gakushuin University and RIETI, 1-5-1 Mejiro, Toshima-ku, Tokyo 171-8588, Japan. Tel: +81-3-5992-4909. Email: kaoru.hosono@gakushuin.ac.jp

3 Gakushuin University, 1-5-1 Mejiro, Toshima-ku, Tokyo 171-8588, Japan. Tel: +81-3-5992-2520. Email: miho.takizawa@gakushuin.ac.jp

I. INTRODUCTION

Growth in aggregate productivity is key to economic growth in both developing and developed economies. Past studies have proposed various methods of analysis to gain further insight into its driving forces. These include aggregating producer-level productivity to economy-wide productivity, and decomposing changes in aggregate productivity. This decomposition consists of changes in technology, allocation of resources across producers, and the relative productivity of entrants and survivors. However, as far as we know, no preceding study decomposes aggregate productivity into technical efficiency in terms of the aggregate production possibility frontier, and allocative efficiency in terms of distance from the frontier, although this decomposition is straightforward from a microeconomic view.

Considering this, this study first proposes a novel approach to decomposing aggregate productivity growth into changes in technical and allocative efficiency using the aggregate production possibility frontier as a reference point. Specifically, we expand on the method of Hsieh and Klenow (2009), which measures allocative efficiency by the dispersion in revenue-based productivity (TFPR) among producers to include a dynamic setting with productivity shocks, and entries and exits. Figure 1 illustrates our decomposition into technical efficiency and allocative efficiency. For simplicity, suppose that two producers operate in period $s = t - 1$ and t and no entry or exit exists. Producer i, (i =*1* or *2*) produces output Y_{is} using input K_{is}. The production technology is represented by the production function $Y_{is} = A_{is} f(K_{is})$, where A_{is} is producer *i*'s total factor productivity (TFP) in period s, $f'(K_{is})$>0, and $f''(K_{is})$<0. Without loss of generality, we assume that $A_{1t-1} > A_{2t-1}$. Suppose further that the total amount of K_s is fixed. Then, total output is maximized when the marginal product of capital is the same across producers: $A_{1s}f'(K_{1s}^*) = A_{2s}f'(K_{2s}^*)$. However, in period *t-1*, producer 1 underuses *K* and producer 2 overuses *K* relative to the optimal allocation due to some frictions: $K_{1t-1} < K_{1t-1}^*$ 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 due to some frictions. 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 contrary, output loss due to the misallocation of inputs increases by *B* (from *C* to *B*+*C*), which is exactly our allocative efficiency measure. In addition to the two intensive margins of the technical efficiency and the allocative efficiency as illustrated by Figure 1, we further consider the role of the three extensive margins in changes in aggregate productivity: changes in the efficiency of entrants relative to survivors (entry effect) and exiters (exit effect), and changes in the variety of goods (variety effect). Specifically, we consider the relative efficiency of entrants and exiters following Melitz and Polanec (2015) and Hosono et al. (2016).

The second aim of this study is to apply our approach to establishment- and firm-level panel datasets from Japan in order to see whether allocative efficiency fell during the Japanese banking crisis during the latter half of the 1990s. Several studies (Fukao and Kwon, 2006; Fukao, Kim, and Kwon, 2009) attempt to uncover the source of stagnant aggregate TFP during this period by decomposing aggregate TFP following the approach of Foster, Haltiwanger, and Krizan (2001) (FHK). Due to banks' non-performing loan problems, unprofitable firms were more likely to receive credit than profitable ones (Peek and Rosengren, 2005). This misallocation of credit likely resulted in the misallocation of capital and labor as well (Caballero, Hoshi, and Kashyap, 2008). Nonetheless, most of the studies applying FHK decomposition to Japanese firms or establishments find positive and large reallocation effects during this crisis period. We thus compare the results between our approach and FHK's approach. Their 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.

Applying our decomposition approach to a panel dataset of Japanese manufacturing establishments from the Census of Manufactures (CM), 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 into a negative value in the first half of the 2000s (2001-2005).[4] These results are in contrast with those reached through the decomposition

[4] For data as of 2011, we use the Economic Census for Business Activity 2012 conducted by the Statistics

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 variety effect tended to be negative except for the bubble period. We obtain similar results when we apply our approach to a firm-level panel dataset of Japanese manufacturing and non-manufacturing firms from the Basic Survey of Japanese Business Structure and Activities (BSJBSA).

The rest of this paper proceeds as follows. In Section II, we review related studies on aggregate productivity decomposition and their application to Japan. Section III describes how we aggregate producer-level productivity to industry-level productivity, decompose it into technical efficiency, allocative efficiency, entry effect, exit effect, and variety effect, and aggregate industry-level productivity to economy-wide productivity. Section IV describes the datasets to which we have applied our approach and outlines the decomposition results. We further compare our decomposition results to those using FHK's decomposition approach, applied to the same data. Section V concludes with some possible extensions.

II. RELATED LITERATURE

Bureau of Japan and the Ministry of Economy, Trade and Industry instead of the Census of Manufactures. However, we refer to these two datasets to the CM for simplicity below.

This study is related to the literature on aggregate productivity decomposition. Baily, Hulten, and Campbell (1992) (BHC), Griliches and Regev (1995), and FHK define aggregate productivity as a share-weighted average of producer-level productivity and decompose its changes into changes in producer-level productivity, and changes in output or input shares.[5]

Although such decomposition is intuitive, the reallocation effect does not necessarily reflect the improvement in allocative efficiency in terms of the deviation from the optimal allocation of resources.[6] Suppose, for example, that a high-productivity producer receives a subsidy and consequently overuses labor as compared to the optimal allocation. The marginal product of labor for this producer is lower than the wage. If the subsidy is abolished, and hence the producer decreases labor and the other producers hire the released labor, then the allocation of labor becomes optimal, and aggregate output increases. However, the reallocation effect of FHK worsens because the high-productivity firm's share decreases. This inconsistency arises because they do not incorporate decreasing marginal product of inputs into the formula. This is also seen in Olley and Pakes (1996) and Melitz and Polanec (2015), who have expanded on both BHC and FHK's decomposition approaches.

Recent studies solve such problems by extending Solow's (1957) growth accounting to a framework with producer heterogeneity and allocative frictions (Basu and Fernald, 2002;

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5 Griliches and Regev (1995) and FHK develop BHC's approach using a reference average productivity level.

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

Petrin and Levinsohn, 2012; Osotimehin 2019; Baqaee and Farhi, 2019). While these studies share similarities to our own, their suggested approaches to decomposition into technical efficiency and allocative efficiency are different.

First, Petrin and Levinsohn (2012) (PL) define aggregate productivity growth (APG) as the change in aggregate final demand minus the change in the aggregate expenditures on labor and capital. They then measure the reallocation effect in terms of the difference between the value of marginal product of input and its price, or equivalently, the difference in the output elasticity and share of input, which is the allocative efficiency measure in this study. However, because they take the input share given, their reallocation effect can deviate from the allocative efficiency of this study. In Figure 1, for example, PL's reallocation effect is zero because no reallocation of input occurs.[7] It should also be noted that when PL applies their framework to actual data, they do not distinguish physical productivity (TFPQ) and revenue-based productivity (TFPR).[8] Baqaee and Farrhi (2019) follow PL's decomposition approach. Osotimehin (2019) measures technical efficiency as a combination of weighted averages of the producer-level productivity changes, and allocative efficiency as a combination of weighted averages of the producer-level changes in distortions. Although our decomposition shares these

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7 This example is similar to Osotimehin's (2019, pp.182) discussion.

8 PL acknowledges that deflating nominal gross output by a four-digit industry price index leads to bias in the technical efficiency term. For the distinction between TFPQ and TFPR, see, e.g., Foster, Haltiwanger, and Syverson (2008).

features, she measures technical efficiency using the previous period's allocation as the reference point. Therefore, her technical efficiency depends on the previous period's allocative efficiency, while our technical efficiency does not.

This study contributes to the preceding studies on aggregate productivity decomposition in two ways. First, we measure the technical efficiency as the change in the aggregate production possibility frontier and the allocative efficiency as a distance from the frontier. Specifically, we measure the allocative efficiency based on the difference between the value of marginal product of input and its price, given producer-level distortions. None of the preceding studies proposes such decomposition, although we believe that our decomposition is straightforward from a microeconomic perspective. Second, in addition to the technical and the allocative efficiency, we explicitly consider the roles of the three extensive margins in aggregate productivity: the efficiency of entrants relative to that of survivors (entry effect); the efficiency of exiting producers relative to that of survivors (exit effect); and the change in the variety of products (variety effect). Baqaee and Farhi (2019) do not explicitly consider these extensive margins. While Osotimehin (2019) considers the entry and exit effects, she does not account for the effect of variety expansion on aggregate productivity. The variety effect emerges if aggregate output increases with a larger variety of intermediate inputs produced, keeping the total amount of inputs produced constant. Recent studies find the importance of the variety effect (Fattal-Jaef 2018; Yang 2016). Our results from Japanese establishment- and firm-level datasets reveal that each of the three extensive margins account for a non-negligible part of aggregate TFP growth.

This also relates to a number of studies that apply extant decomposition methods to micro datasets of Japan and try to uncover the source of the stagnant aggregate TFP during the 1990s. Fukao, Kim, and Kwon (2009) apply FHK decomposition to the data from the CM for the period of 1981-2003 and find that the reallocation effects were positive and accelerating in the 1980s and 1990s. They also find that the exit effect in terms of FHK was negative, attributing it to the productive firms' relocation of establishments to abroad, especially in Asia, through foreign direct investment. Nishimura, Nakajima, and Kiyota (2005) apply the Griliches-Regev approach to the firm-level dataset from the BSJBSA for the banking crisis period of 1994-1998, and find negative exit effects, suggesting a malfunctioning of the natural selection mechanism. Fukao and Kwon (2006) apply FHK decomposition to the manufacturing firms contained in the BSJBSA for the period of 1994-2001 and find that the reallocation effect was positive. Kwon, Narita, and Narita (2015) apply PL's decomposition to the CM for the period of 1981-2000, and show that in the 1990s, while technical efficiency was positive and relatively large (1.8%), the reallocation effect and the net entry effect were negative and relatively small (-0.4% and -0.1%, respectively).

This study contributes to these preceding studies on Japan in two ways. First, this study first applies our approach to Japanese micro data. Moreover, to investigate the difference in our results and the preceding studies, we apply FHK to the same establishment-level data from the CM. The differences in decomposition yield a striking change in the results for FHK's reallocation effect and our allocation efficiency. Second, because our datasets cover a relatively long period (29 years in 1986-2014 for the CM and 21 years in 1995-2015 for the BSJBSA), we can and do trace a long trend of the decomposed factors of aggregate TFP growth and examine the comovement of each component with aggregate TFP and output growth.

III. DECOMPOSITION

Producer-Level Productivity and Distortions

To measure the value of marginal product for each producer and each input and aggregate producer-level TFP to sectoral and economy-wide productivity, 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 $\eta_s > 1$:

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

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

$$y_{it} = p_{it}^{-\eta_s} P_{st}^{\eta_s} Y_{st} . \quad (2)$$

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

$$y_{it} = A_{it} K_{it}^{\alpha_s} L_{it}^{1-\alpha_s}, \quad (3)$$

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

Intermediate goods producer i faces distortions of τ_{Yit} on output and τ_{Kit} on capital, respectively. She/he maximizes her/his profit (Π_{it}) under the constraints (2) and (3), given rental rate R_t, wage rate W_t, and distortions τ_{Yit} and τ_{Kit}:

$$\Pi_{it} = (1-\tau_{Yit})p_{it}y_{it} - (1+\tau_{Kit})R_t K_{it} - W_t L_{it} \ . \quad (4)$$

The first-order conditions lead to

$$ln(1+\tau_{Kit}) = ln\left(\frac{\alpha_s}{1-\alpha_s}\right) + ln\left(\frac{W_t L_{it}}{R_t K_{it}}\right) \quad (5)$$

$$ln(1-\tau_{Yit}) = \ln(m_s) + ln\left(\frac{W_t L_{it}}{p_{it}y_{it}}\right) - ln(1-\alpha_s) \quad (6)$$

$$ln(A_{it}) = \ln(\kappa_{st}) + m_s ln(p_{it}y_{it}) - \alpha_s ln\,(K_{it}) - (1-\alpha_s)\,ln(L_{it}), \quad (7)$$

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 TFPQ from Equations (5)-(7) given the sectoral variable κ_{st}. Equation (6) 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.

Sectoral Aggregation

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

$$TFPR_{it} = m_s \left(\frac{(1+\tau_{Kit})R_t}{\alpha_s}\right)^{\alpha_s} \left(\frac{W_t}{(1-\tau_{Yit})(1-\alpha_s)}\right)^{1-\alpha_s} . \quad (8)$$

Using Equation (8), 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

$$A_{st}=\left[\sum_{i=1}^{N_{st}}\left(A_{it}\frac{\overline{TFPR}_{st}}{TFPR_{it}}\right)^{\eta_s-1}\right]^{\frac{1}{\eta_s-1}}, \qquad (9)$$

where $\overline{TFPR}_{st}=m_s\left(\frac{R}{\alpha_s}\frac{1}{\sum_{i=1}^{N_{st}}\frac{1-\tau_{Yit}}{1+\tau_{Kit}}\frac{p_{it}y_{it}}{P_{st}Y_{st}}}\right)^{\alpha_s}\left(\frac{W}{(1-\alpha_s)}\frac{1}{\sum_{i=1}^{N_{st}}(1-\tau_{Yit})\frac{p_{it}y_{it}}{P_{st}Y_{st}}}\right)^{1-\alpha_s}$.[9] [10]

Without distortions, $TFPR_{it}$ is identical across producers. To the extent that it disperses across producers, allocative efficiency is worse.

Sectoral Decomposition

We first decompose the sectoral TFP growth into the efficiency improvement of survivors and the three extensive margins: the relative efficiency of entering and exiting producers and change in the variety of goods. We define the average TFPs for all the producers and for the producers that survive from period *t* to *t+1* as

$$\bar{A}_{st}=\left(\frac{1}{N_{st}}\right)^{\frac{1}{\eta_s-1}}A_{st}, \qquad (10)$$

and

9 For the derivation of Equation (9), see Hsieh and Klenow (2009) or Hosono and Takizawa (2015).

10 Our measure of sectoral (and hence aggregate) TFP is different from the sectoral (and aggregate) TFP that isbased on the System of National Accounts (SNA) (e.g., the Japan Industrial Productivity Database (JIP)), because our sectoral output measure based on the CES function (1) is different from the aggregate output measure used in SNA. In SNA, 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 quality represented by the price.

$$\overline{A_{st}^{C_{st}}} = \left(\frac{1}{N_{st}^{C_{st}}}\right)^{\frac{1}{\eta_s - 1}} A_{st}^{C_{st}} \ , \tag{11}$$

respectively, where C_{st} denotes the set of survivors, $N_{st}^{C_{st}}$ denotes their number, and $A_{st}^{C_{st}}$ denotes their aggregate productivity: $A_{st}^{C_{st}} = \left[\sum_{i \in C_{st}} \left(A_{it} \frac{\overline{TFPR_{st}}}{TFPR_{it}}\right)^{\eta_s - 1}\right]^{\frac{1}{\eta_s - 1}}$. Using Equations (10) and (11) and the identity $ln\left(\frac{A_{s,t+1}}{A_{st}}\right) = ln\left(\frac{A_{s,t+1}^{C_{st}}}{A_{st}^{C_{st}}}\right) + ln\left(\frac{A_{s,t+1}}{A_{s,t+1}^{C_t}}\right) - ln\left(\frac{A_{st}}{A_{st}^{C_{st}}}\right)$, we can decompose the sectoral TFP growth as follows:[11]

$$ln\left(\frac{A_{s,t+1}}{A_{st}}\right) = ln\left(\frac{\overline{A_{s,t+1}^{C_{st}}}}{\overline{A_{st}^{C_{st}}}}\right) + ln\left(\frac{\overline{A_{s,t+1}}}{\overline{A_{s,t+1}^{C_{st}}}}\right) - ln\left(\frac{\overline{A_{st}}}{\overline{A_{st}^{C_{st}}}}\right) + \frac{1}{\eta_s - 1} ln\left(\frac{N_{s,t+1}}{N_{st}}\right) \ . \tag{12}$$

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

$$\overline{H_{st}^{C_{st}}} = \left(\frac{1}{N_{st}^{C_{st}}}\right)^{\frac{1}{\eta_s - 1}} \left[\sum_{i \in C_{st}} {A_{it}}^{\eta_s - 1}\right]^{\frac{1}{\eta_s - 1}} . \tag{13}$$

Then we define the ratio of the actual and hypothetical average productivity for survivors

11 Melitz and Polanec (2002) and Hosono et al. (2016) use this identity to isolate the relative efficiency of entrants and exiters.

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:

$$ln\left(\frac{A_{s,t+1}}{A_{st}}\right) = \underbrace{ln\left(\frac{\overline{H_{s,t+1}^{C_{st}}}}{\overline{H_{st}^{C_{st}}}}\right)}_{\substack{\text{Technical}\\\text{Efficiency}\\\text{(TE)}}} + \underbrace{\ln\left(\frac{\overline{D_{t+1}^{C_{st}}}}{\overline{D_t^{C_{st}}}}\right)}_{\substack{\text{Allocative}\\\text{Efficiency}\\\text{(AE)}}} + \underbrace{ln\left(\frac{\overline{A_{s,t+1}}}{\overline{A_{s,t+1}^{C_{st}}}}\right)}_{\substack{\text{Entry}\\\text{Effect}}} \underbrace{- ln\left(\frac{\overline{A_{st}}}{\overline{A_{st}^{C_{st}}}}\right)}_{\substack{\text{Exit}\\\text{Effect}}} + \underbrace{\frac{1}{\eta_s - 1}\ln\left(\frac{N_{s,t+1}}{N_{st}}\right)}_{\substack{\text{Variety}\\\text{Effect}}}. \tag{14}$$

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 cause deviations from marginal revenue and marginal cost of inputs. They include not only taxes and regulations, but also adjustment costs 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. Measuring the allocative efficiency from the dynamic viewpoint would require a more structural model and hence be more model-dependent.[12]

Our entry and exit effects are different from FHK's counterparts because we measure TFPQ while they measure TFPR. Moreover, we do not take entrants' and exiters' shares as given while FHK do. Therefore, our entry effect is high if the technical efficiency of entrants is high relative to that of survivors and/or if the allocative efficiency among entrants is high relative to that of survivors. Similarly, our exit effect is high if the technical efficiency of exiters is low relative to that of survivors and/or if the allocative efficiency among exiters is low relative to that of survivors. Thus, we can decompose each of the entry and exit effects into the two components. Let $\overline{H_{st}}$ denote the hypothetical average TFP that would be achieved without any distortions on *all* producers in sector *s*: and define $\overline{D_{st}} = \frac{\overline{A_{st}}}{H_{s,t}}$. Then, the entry and exit effects can be further decomposed into the relative technical efficiency of entrants and exiters and the relative allocative efficiency of them as

$$\underbrace{ln\left(\frac{\overline{A_{s,t+1}}}{\overline{A^{C_{st}}_{s,t+1}}}\right)}_{\text{Entry Effect}} = \underbrace{log\left(\frac{\overline{H_{st+1}}}{\overline{H^{C}_{st+1}}}\right)}_{\text{TE for Entrants}} + \underbrace{log\left(\frac{\overline{D_{st+1}}}{\overline{D^{C}_{st+1}}}\right)}_{\text{AE for entrants}} \tag{15}$$

$$\underbrace{-ln\left(\frac{\overline{A_{s,t}}}{\overline{A^{C_{st}}_{s,t}}}\right)}_{\text{Exit Effect}} = \underbrace{-log\left(\frac{\overline{H_{st}}}{\overline{H^{C}_{st}}}\right)}_{\text{TE for Exitors}} \underbrace{- log\left(\frac{\overline{D_{st}}}{\overline{D^{C}_{st}}}\right)}_{\text{AE for Exitors}} . \tag{16}$$

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

Economy-wide Aggregation

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

$$Y_t = \prod_s Y_{st}{}^{\theta_{st}}, \qquad where \ \sum_s \theta_{st} = 1. \tag{17}$$

Then, the change in aggregate productivity can be represented by the weighted average of the sector-level change in productivities:

$$ln\left(\frac{A_{t+1}}{A_t}\right) = \sum_s \theta_{st} ln\left(\frac{A_{st+1}}{A_{st}}\right), \tag{18}$$

where θ_{st} can be represented by $\theta_{st} = \frac{P_{st}Y_{st}}{P_tY_t}$.[13]

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

IV. DATA

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 in the CM conducted by the Ministry of Economy, Trade and Industry (METI). In years ending with 0, 3, 5, and 8, the CM covers all establishments that are located in Japan (excluding those belonging to the government) and fall

[13] See subsection named Economy-wide aggregation in Appendices for proof.

into the manufacturing sector.[14] In other years, the CM covered 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 CM 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 of Japan and the Ministry of Economy, Trade and Industry, which covers establishments with 10 employees or more. To maintain consistency over time, we restrict our sample to the establishments with 30 employees or more. The most significant benefit of the CM is its long time horizon and its wide coverage of establishments in the manufacturing sector. However, an obvious shortcoming of the CM is that it excludes establishments in non-manufacturing industries.

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

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

Variables

Data from the CM. We use the CM for the period from 1986 to 2014.[15] We use the following information from them: an establishment's labor compensation (excluding non-wage compensation), value added, the number of workers and capital stock, and what industry (at the four-digit level) it belongs to.[16]

Data from the BSJBSA. We use BSJBSA's data for the period from 1995 to 2015. We use the following information from the BSJBSA: 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 that the firm belongs to.[17]

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

15 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.

16 See subsection Data from the CM in Appendices for details.

17 See subsection Data from the BSJBSA in Appendices for details.

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).[18]

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 assume that each producer (establishment for the CM and firm for the BSJBSA) produces a single product and does not consider multiple-product producers due to data limitation. We identify survivors as the producers that appear in the dataset for the two consecutive years.[19] To exclude outliers, we trim the 1% tails of TFPQ and TFPR. For the analysis using the CM, 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

[18] Alternatively, we set different η_s for Rauch's (1999) three goods categories: commodity goods, reference-priced goods, and differentiated goods. The results are qualitatively similar to the results from the common η_s across sectors. See subsection Different Elasticity of Substitution across Sectors in Appendices.

19 If some firms switch their industries and continue to operate, we define them as survivors. This definition is slightly different from the definition under the subsection Sectoral Aggregation in Section III, where survivors are defined as the producers that operate in the same sector. We change our definition here to assure that the sum of the decomposed components is equal to the economy-wide aggregate TFP.

firms per observation year varies from 21,512 to 28,662 during the period we focus on. The number of total firm-year observations in our dataset is 585,208.

One caveat is that we do not adjust for capital utilization or hours worked due to data limitation, so that our technical efficiency may capture the variations in them.

V. EMPIRICAL RESULTS

Establishments in Manufacturing Industries

Our Decomposition. We first present the results from the establishment-level dataset from the CM over the period of 1987-2014. Table 1 shows the descriptive statistics of the year-on-year change in aggregate TFP and its components for the 28 years of 1987-2014.[20] The average aggregate TFP growth rate is 1.3%. The TE for survivors is relatively large (3.8%), but partly 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 aggregate TFP growth, while the AE for survivors and the variety effect are relatively stable. Further decomposition of entry effects into the relative TE and AE for entrants show that both are positive (2.8% for the TE and 4.3% for the AE). On the contrary, the relative TE and AE for exiters are both negative (-4.2% for the TE and -4.0% for the AE).

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[20] Figure A1 in Appendices shows year-on-year changes in aggregate TFP and its components for the baseline results.

Table 2 illustrates the averages of the year-on-year changes in aggregate TFP and its components for each of the 5-year sub-periods (except for the 4 years of the first sub-period of 1987-90 and the last one of 2011-14). We refer the sub-period of 1987-1990 to the bubble period, that of 1996-2000 to the banking crisis period, and that of 2006-2010 to the Global Financial Crisis period below.[21] It shows that the TE for survivors turned from negative in the bubble period to positive in the first half of the 1990s and subsequently accelerated until the Global Financial Crisis period, when it turned negative again. It then picked up in the early 2010s (2011-2014). In contrast, the AE for survivors continued to fall from 0.5% in the bubble period to zero in the banking crisis period. It further declined to -2.8% in the first half of the 2000s. It fluctuated between positive and negative values afterwards. The entry effect and its components were positive for all the sub-periods, indicating that entrants were more efficient than incumbents both in terms of technical and allocative efficiency. On the contrary, the exit effect and its components were negative for all the sub-periods, indicating that exiting establishments were more efficient than survivors both in terms of technical and allocative efficiency. It is interesting that the absolute values of the relative TE for exiters tended to increase from the 1990s while those of the relative AE tended to decrease. The variety effect turned from positive in the bubble period to negative afterwards, indicating that the number of

[21] When we present the results from the BSJBSA in the subsection Firms in the Manufacturing and Non-Manufacturing Industries, we refer the period of 1995-2000 to the banking crisis period, although it is slightly different from the definition here.

establishments decreased after the 1990s.

How can we interpret these decomposition results? The negative TE for survivors during the Global Financial Crisis seems to be consistent with the view that Japanese firms were hit by the crisis through the decline in export demands (Hosono, Takizawa, and Tsuru, 2016), because such a demand shock is likely to cause a decline in measured TE through the decline in capital utilization rates and hours worked. The decline in AE for survivors and the negative exit effect during the banking crisis period seem to be consistent with the zombie lending (Caballero, Hoshi, and Kashyap, 2008, and Nishimura, Nakajima, and Kiyota, 2005, among others). The negative TE for exiters for the whole period is not consistent with the natural selection mechanism through which the market eliminates inefficient firms (Jovanovic, 1982, Hopenhayn, 1992, and Caballero and Hammour, 1994, among others). However, it is consistent with the view that Japanese firms relocated production units to abroad (Fukao, Kim, and Kwon, 2009).

As we mentioned in Section III, under Sectoral Aggregation, 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 with that in the JIP Database (Column (12) of

Table 2).[22] Both the sample-period average and the cyclical pattern are similar, although our aggregate TFP growth measure is more volatile than the JIP, and, especially, our aggregate TFP growth in the bubble period is substantially lower than the JIP's counterpart.

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 a 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 some 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 (17) 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. A positive TE may be contemporaneously offset at least partially by a negative AE due to adjustment costs. The negative contemporaneous correlation between output growth and AE

22 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.

is consistent with this view. It is also consistent with Osotimehin (2019), who found, using a dataset of French manufacturing and service firms, that her measure of the within-sector allocative efficiency is countercyclical.

Comparison with FHK. We conduct FHK decomposition using the same establishment data that we used to conduct our decomposition.[23] We find that the average rates of increase in aggregate TFP are almost the same between the two (1.3% for our decomposition and 1.2% for the FHK), although the FHK series is less volatile than ours (the standard errors are 6.2% for the baseline and 5.4% for the FHK).[24]

Table 5 shows FHK decomposition for the 5-year sub-periods. It shows that the FHK reallocation effect is positive and sizable, and accounts for a major part of the aggregate TFP growth rate for all the sub-periods. The reallocation effect was 2.1% both in the banking crisis period and the first half of the 2000s, while the AE for survivors of our decomposition shows 0.0% and -2.8% for the corresponding periods. The FHK's reallocation effect is composed of the between effect (the fixed productivity-weighted sum of the change in shares among surviving producers) and the covariance effect (the sum of the multiples of the changes in shares and productivity of producers). 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

[23] See subsection named FHK's decomposition in Appendices for their decomposition.
[24] Figure A2 in Appendices shows the aggregate TFP growths for the FHK decomposition.

sub-periods. As we mentioned in Section II, the positive correlation between the productivity growth rate and the share growth does not necessarily indicate an improvement in allocative efficiency in terms of our measure.

The FHK entry effect is positive for some sub-periods, which is different from our entry effect. On the contrary, the FHK exit effect is consistently negative for all the sub-periods, which is consistent with our exit effect. However, the magnitude is larger for our method than for FHK's, possibly because our exit effect captures the relative AE for exiters, as well the relative TE for them.

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. Table 6 shows the averages of the decomposition of the year-on-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 and relatively high for all the sub-period except for the Global Financial Crisis period. The AE for survivors was negative for the banking crisis period (1995-2000) and the first half of the 2000s. The entry effect was consistently positive, possibly because the BSJBSA cover large firms relative to the establishments covered by the CM. However, the relative TE for entrants was negative for the banking crisis period and the first half of the 2000s while the relative AE for entrants was consistently positive. The exit effect and its components were consistently negative, which is consistent with the results from the CM. The net entry effect was negative except for the banking crisis period when the exit effect was negative but small. The variety effect was positive (except for the first half of the 2000s, when it was zero) due to an increase in the number of firms that enter into non-manufacturing industries.[25]

VI. CONCLUSION

We have proposed a novel approach to decomposing aggregate productivity growth into changes in technical efficiency and allocative efficiency as well as the three extensive margins: the relative efficiency of entrants and exiters and changes in the variety of goods. We measure technical efficiency by the aggregate production possibility frontier, and allocative efficiency by the distance from the frontier. 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 results for allocative efficiency are consistent with the zombie lending view, and in contrast

[25] We show the results from manufacturing firms and non-manufacturing firms, separately, that are contained in the BSJBSA in subsections Results from manufacturing firms in the BSJBSA and Results from non-manufacturing firms in the BSJBSA, respectively, in Appendices.

with the results of the decomposition proposed by FHK. Our results suggest that allocative efficiency matters for aggregate TFP in the medium to long run.

We measure the producer-level productivity following Hsieh and Klenow (2009) in order to focus on proposing a new decomposition of aggregate productivity growth and its application to Japan. However, it may be desirable to estimate producer-level productivity by estimating demand elasticity for each narrowly-defined industry. It may also be useful to extend our model by incorporating multi-product producers and dynamic factor adjustment costs.

To analyze the driving factors of each component of aggregate productivity growth, it may be useful to focus on some specific shocks such as financial shocks, export shocks, and natural disasters by exploiting variations in each component across industries and regions. These are all left for future work.

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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%
TE for entrants	2.8%	1.4%	4.5%
AE for entrants	4.3%	3.2%	4.5%
Exit effect	-8.3%	-8.0%	7.1%
TE for exitors	-4.2%	-4.0%	5.3%
AE for exitors	-4.0%	-3.5%	2.6%
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	(1) TFP	(2) TE for survivors	(3) AE for survivors	(4) Entry effect	(5) TE for entrants	(6) AE for entrants	(7) Exit effect	(8) TE for exitors	(9) AE for exitors	(10) Variety effect	(11) (Net entry effect)	(12) (TFP from JIP)
1987-1990	0.7%	-0.7%	0.5%	9.3%	3.4%	5.8%	-9.0%	-4.3%	-4.7%	0.6%	0.3%	3.3%
1991-1995	0.7%	0.6%	0.4%	5.1%	1.0%	4.1%	-5.0%	-0.7%	-4.3%	-0.5%	0.1%	0.6%
1996-2000	1.5%	2.2%	0.0%	6.7%	2.5%	4.2%	-6.4%	-2.3%	-4.1%	-1.0%	0.3%	1.5%
2001-2005	3.7%	12.0%	-2.8%	5.2%	1.7%	3.6%	-9.6%	-5.3%	-4.2%	-1.2%	-4.3%	1.7%
2006-2010	0.5%	-5.5%	4.0%	10.6%	5.5%	5.2%	-7.9%	-4.7%	-3.3%	-0.7%	2.7%	1.2%
2011-2014	0.4%	15.8%	-7.2%	6.4%	3.0%	3.4%	-12.8%	-9.2%	-3.6%	-1.9%	-6.4%	1.2%
1987-2014	1.3%	3.8%	-0.7%	7.2%	2.8%	4.3%	-8.3%	-4.2%	-4.0%	-0.8%	-1.1%	1.5%

Notes. Column (12) shows the TFP growth of manufacturing industries from the JIP database 2015 (for 1987-1994) and the JIP database 2018 (for 1995-2014).

TABLE 3

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

	TFP	TE for survivors	AE for surivors	Entry effect	TE for entrants	AE for entrants	Exit effect	TE for exitors	AE for exitors	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							
TE for entrants	-0.649 ***	-0.893 ***	0.486 ***	0.969 ***	1.000						
AE for entrants	-0.492 ***	-0.773 ***	0.306	0.968 ***	0.875 ***	1.000					
Exit effect	-0.592 ***	-0.882 ***	0.625 ***	0.637 ***	0.680 ***	0.554 ***	1.000				
TE for exitors	-0.580 ***	-0.842 ***	0.677 ***	0.550 ***	0.579 ***	0.486 ***	0.956 ***	1.000			
AE for exitors	-0.447 **	-0.710 ***	0.342 *	0.633 ***	0.690 ***	0.534 ***	0.804 ***	0.594 ***	1.000		
Variety effect	0.024	-0.222	0.166	0.220	0.163	0.264	0.118	0.093	0.134	1.000	
(Net entry effect)	-0.652 ***	-0.960 ***	0.559 ***	0.925 ***	0.926 ***	0.864 ***	0.883 ***	0.808 ***	0.783 ***	0.192	1.000

Note. ***, **, and * denote the significance levels of 1%, 5%, and 10%, respectively.

TABLE 4

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

	output(t-1)	output(t)	output(t+1)
TFP	-0.126	-0.255	0.215
TE for survivors	-0.398 **	-0.009	0.328 *
AE for surivors	0.100	-0.338 *	-0.183
Entry effect	0.471 **	0.084	-0.373 *
TE for entrants	0.444 **	0.093	-0.328 *
AE for entrants	0.469 **	0.070	-0.396 **
Exit effect	0.450 **	-0.101	-0.296
TE for exitors	0.287	-0.053	-0.323
AE for exitors	0.651 ***	-0.169	-0.157
Variety effect	0.249	0.336 *	0.161
(Net entry effect)	0.512 ***	0.002 *	-0.374 *

Note. ***, **, and * denote the significance levels of 1%, 5%, and 10%, respectively.

TABLE 5

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 6

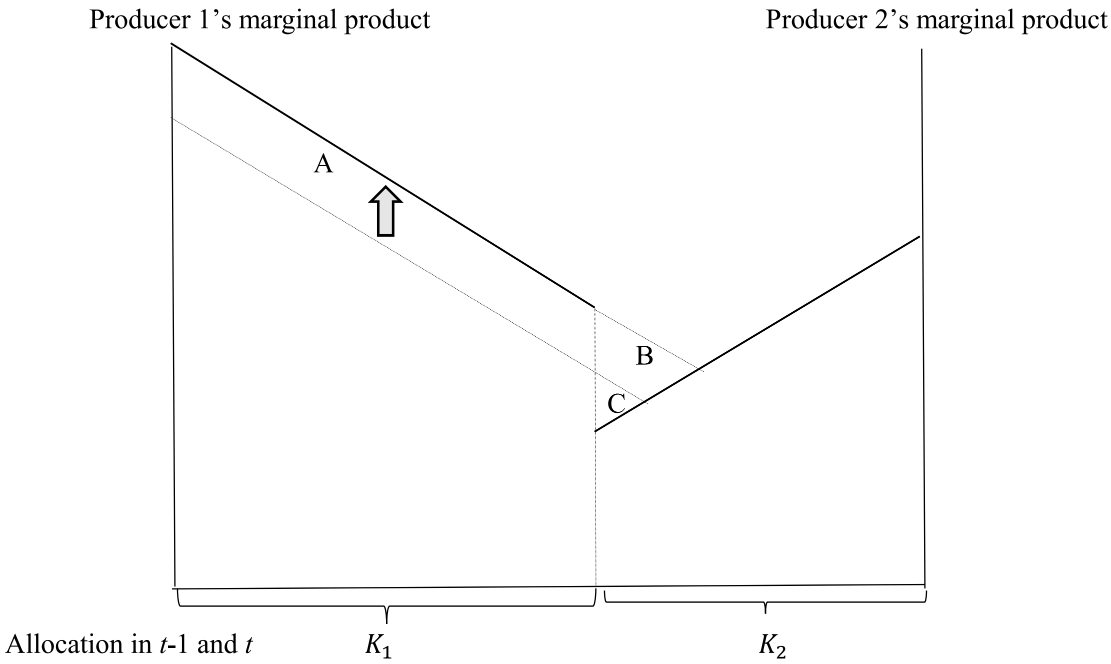
Decomposition of aggregate TFP growth of manufacturing and nonmanufacturing firms in BSJBSA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Period	TFP	TE for survivors	AE for survivors	Entry effect	TE for entrants	AE for entrants	Exit effect	TE for exitors	AE for exitors	Variety effect	(Net entry effect)
1995-2000	5.0%	6.0%	-3.0%	3.6%	-4.5%	8.1%	-2.3%	1.7%	-4.0%	0.8%	1.3%
2001-2005	6.9%	13.6%	-5.2%	4.4%	-0.3%	4.7%	-5.9%	-5.3%	-0.6%	0.0%	-1.5%
2006-2010	6.8%	4.1%	4.0%	7.9%	2.9%	5.0%	-9.5%	-6.4%	-3.2%	0.4%	-1.7%
2011-2015	2.6%	9.2%	0.5%	3.8%	0.6%	3.2%	-11.0%	-6.2%	-4.8%	0.1%	-7.2%
1995-2015	5.3%	8.1%	-1.1%	4.8%	-0.5%	5.4%	-7.0%	-3.8%	-3.2%	0.4%	-2.1%

Note. $\eta = 3$

FIGURE 1

Technical efficiency (TE) and allocative efficiency (AE)



TE: A+B

AE: -B

APPENDICES

Economy-wide aggregation

In this Appendix, we prove (18) 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 (17) 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 (17) and (A1), we obtain

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

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),

$$dln(Y) = \sum_s \theta_s dln(A_s) + \sum_s \theta_s (1-\alpha_s)\, dln(L_s) + \sum_s \theta_s \alpha_s\, dln(K_s)$$
$$= \sum_s \theta_s dln(A_s) + \sum_s \theta_s (1-\alpha_s) \frac{\partial \ln(L_s)}{\partial \ln(L)} dln(L)$$
$$+ \sum_s \theta_s \alpha_s \frac{\partial \ln(K_s)}{\partial \ln(K)} dln(K). \qquad (A7)$$

Substituting (A7) into (A6), we obtain

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

The discrete time version of (A8) leads to (18). From the final goods producer maximization, we obtain $\theta_{st} = \frac{P_{st}Y_{st}}{P_t Y_t}$.

Data from the CM

We basically follow Hosono and Takizawa (2015) to construct the data for 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 output 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:

$$Y_{st}^{JIP}/K_{st}^{JIP} = \sum_{i\in s} Y_{sit}^{CM} / \left(\sum_{i\in s} BVK_{sit}^{CM} \times \gamma_{st}\right).$$

$\sum_{i\in s} Y_{sit}^{CM}$ 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.

Data from the BSBSJA

We follow Hosono et. al (2016) to construct the data for 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:

$$Y_{st}^{JIP}/K_{st}^{JIP} = \sum_i Y_{sit}^{\mathrm{BSJBSA}} \bigg/ \left(\sum_i BVK_{sit}^{\mathrm{BSJBSA}} * \alpha_{st} \right)$$

where $\sum_i Y_{sit}^{\mathrm{BSJBSA}}$ is the sum of the firms' value added (i is the index of a firm), and $\sum_i BVK_{sit}^{\mathrm{BSJBSA}}$ 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.

Different Elasticity of Substitution across Sectors

We show the results from applying a different elasticity of substitution to the three categories of the goods based on Rauch's (1999) classification. Specifically, we reclassify the JIP industry classifications to Rauch's three goods categories: commodity goods, reference-priced goods, and differentiated goods, 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). 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, and the 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 U.S. imports. See Table A1 for the correspondence between the JIP industry classification and Rauch's classification.

Table A2 shows the averages of the decomposition of the year-on-year changes in aggregate TFP for the same sub-periods as in Table 2. It shows that the movement of each component is similar to the baseline result. Table A3 shows the descriptive statistics of industry-level TFP growth and its components for each of the 5-year sub-periods. Table A4 shows the industry-level TFP growth and its components for each industry. Figure A2 shows the aggregate TFP growths for different demand elasticities.

FHK's decomposition

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

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

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:

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

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.

Results from manufacturing firms in the BSJBSA

We show the results from the manufacturing firms that are contained in the BSJBSA. Table A5 presents the averages of the decomposition for the same sub-periods shown in Table 6. The results from manufacturing firms are qualitatively similar to those from all firms in the BSJBSA, although the TFP growth and the TE for survivors tended to be larger while the AE for survivors and the variety effect tended to be lower than the results from all firms. Interestingly, the AE for 1995-2000 was 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 severe among such firms. The exit effect was also negative and large.

Results from non-manufacturing firms in the BSJBSA

We show the results from the non-manufacturing firms that are contained in the BSJBSA. Table A6 presents the averages of the decomposition for the same sub-periods shown in Table 6. The results from non-manufacturing firms are qualitatively similar to those from all firms, although the TFP growth and the TE for survivors tended to be smaller while the AE for survivors and the variety effect tended to be larger than the results from all firms. The AE for survivors in the banking crisis period is slightly negative (-0.1%).

TABLE A1

The JIP industry classification and Rauch's 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

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Period	TFP	TE for survivors	AE for survivors	Entry effect	TE for entrants	AE for entrants	Exit effect	TE for exitors	AE for exitors	Variety effect	(Net entry effect)
1987-1990	-1.0%	-2.1%	0.0%	11.0%	5.5%	5.5%	-10.6%	-5.6%	-5.1%	0.6%	0.4%
1991-1995	0.7%	-0.3%	1.0%	5.1%	2.5%	2.6%	-4.8%	-1.6%	-3.2%	-0.5%	0.3%
1996-2000	2.7%	3.8%	0.4%	6.2%	3.4%	2.7%	-6.7%	-3.7%	-3.0%	-1.0%	-0.5%
2001-2005	8.3%	16.9%	0.3%	4.8%	2.6%	2.1%	-12.4%	-8.1%	-4.3%	-1.2%	-7.6%
2006-2010	-0.7%	-1.2%	1.6%	11.0%	8.1%	3.0%	-11.5%	-9.3%	-2.2%	-0.6%	-0.5%
2011-2014	5.3%	20.6%	-3.0%	11.6%	9.6%	2.0%	-22.1%	-19.8%	-2.2%	-1.8%	-10.4%
1987-2014	2.6%	6.1%	0.2%	8.1%	5.1%	2.9%	-11.0%	-7.7%	-3.3%	-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 A3

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 A4

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%

TABLE A5

Decomposition of aggregate TFP growth of manufacturing firms in BSJBSA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Period	TFP	TE for survivors	AE for survivors	Entry effect	TE for entrants	AE for entrants	Exit effect	TE for exitors	AE for exitors	Variety effect	(Net entry effect)
1995-2000	2.9%	8.2%	-6.9%	6.0%	-3.3%	9.3%	-4.5%	2.9%	-7.3%	0.1%	1.6%
2001-2005	14.8%	26.4%	0.1%	1.1%	-1.9%	3.0%	-12.6%	-9.5%	-3.0%	-0.3%	-11.4%
2006-2010	5.0%	12.6%	2.1%	7.4%	3.8%	3.6%	-17.0%	-13.2%	-3.8%	-0.1%	-9.6%
2011-2015	2.0%	14.0%	-0.9%	4.9%	2.0%	2.9%	-15.6%	-12.6%	-3.0%	-0.3%	-10.7%
1995-2015	6.0%	14.9%	-1.7%	4.9%	0.0%	4.9%	-12.0%	-7.6%	-4.5%	-0.1%	-7.1%

TABLE A6

Decomposition of aggregate TFP growth of non-manufacturing firms in BSJBSA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Period	TFP	TE for survivors	AE for survivors	Entry effect	TE for entrants	AE for entrants	Exit effect	TE for exitors	AE for exitors	Variety effect	(Net entry effect)
1995-2000	3.2%	3.8%	-0.1%	-0.5%	-8.0%	7.5%	-1.5%	1.3%	-2.8%	1.4%	-2.0%
2001-2005	5.3%	7.1%	8.4%	5.2%	1.6%	3.6%	-15.8%	-3.6%	-12.2%	0.4%	-10.6%
2006-2010	5.3%	-0.8%	4.7%	8.8%	3.8%	5.0%	-8.4%	-3.0%	-5.4%	0.9%	0.4%
2011-2015	1.4%	3.8%	0.6%	6.9%	1.6%	5.3%	-10.2%	-4.0%	-6.2%	0.4%	-3.4%
1995-2015	3.8%	3.5%	3.2%	4.8%	-0.6%	5.5%	-8.6%	-2.2%	-6.5%	0.8%	-3.8%

FIGURE A1

Year-on-year changes in aggregate TFP and its components: Baseline results

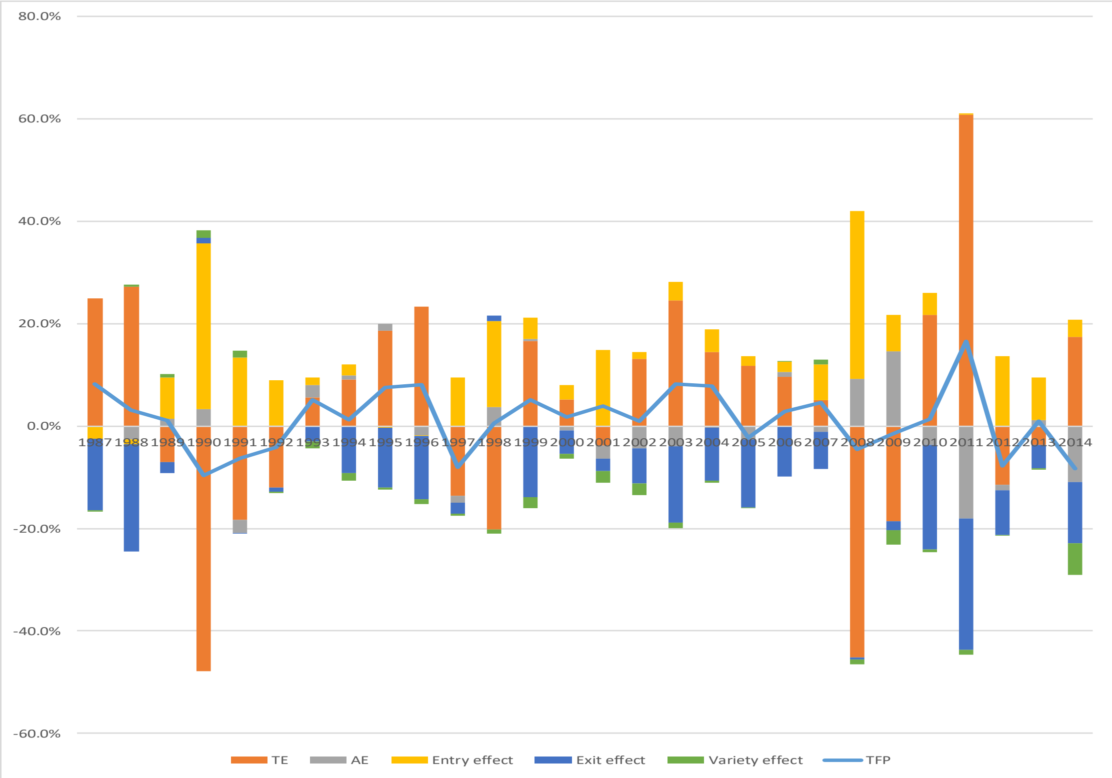
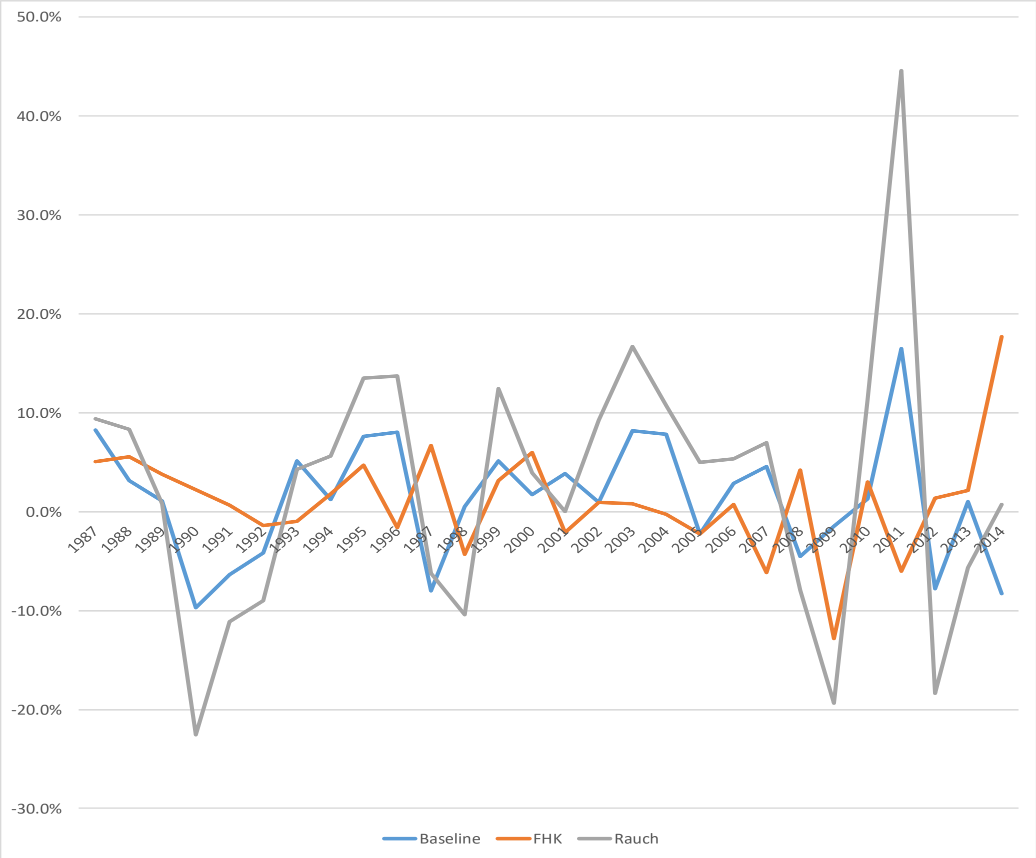


FIGURE A2

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.