Dynamic Productivity Decomposition with Allocative Efficiency

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August 3, 2019

@SWET

Background and Aim

1. To raise aggregate productivity by improving the efficiency of resource allocation is important for both developing and advanced economies.
2. Extant approaches to decomposing aggregate productivity do not adequately measure the allocative efficiency.

⇒

1. We propose a new approach to decomposing aggregate productivity into technical efficiency, allocative efficiency, entry and exit effects, and variety effect.
2. We apply our approach to establishment- and firm-level data from Japan, and compare our results from preceding approaches and studies (Fukao and Kwon, 2006; Fukao, Kim, and Kwon, 2009; Nishimura, Nakajima, and Kiyota, 2005; Kwon, Narita, and Narita, 2015)

Composition

1. Review of preceding approaches
2. Framework of our new approach
3. Data
4. Results
5. Conclusion

Review 1: Foster, Haltiwanger, and Krizan (2001) (FHK)

- Baily, Hulten, and Campbell (1992) (BHC) , Griliches and Regev (1995), FHK, Olley and Pakes (1996) and Melitz and Polanec (2015)

(1) Aggregation

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

a_t: log of aggregate productivity, a_{it}: log of productivity of firm *i*,

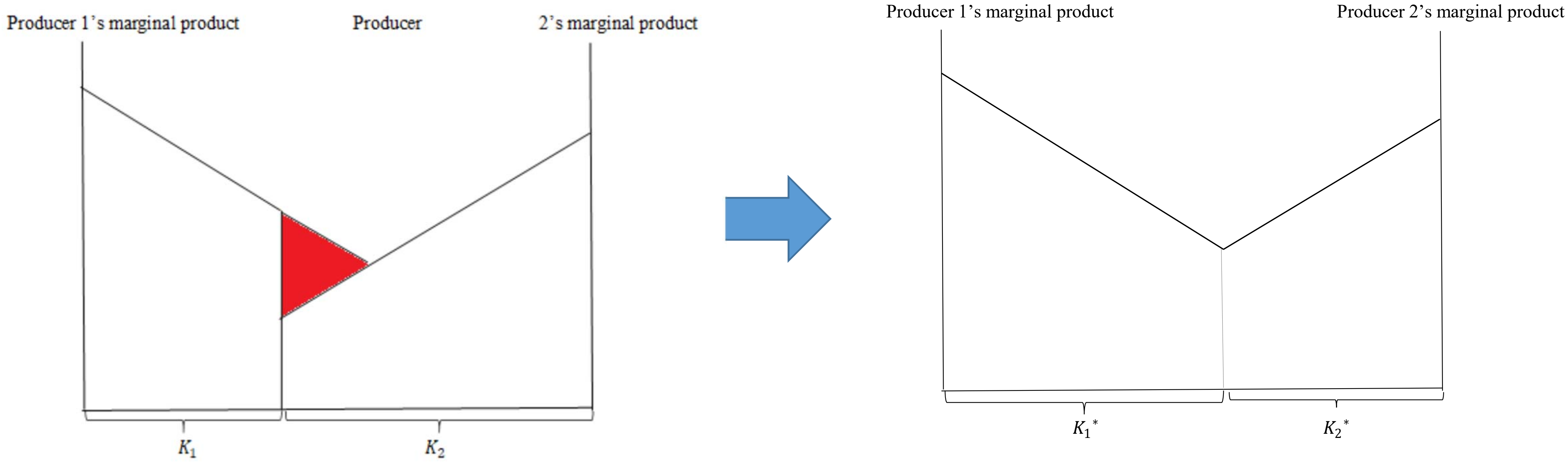
s_{it}: share of firm I (in terms of sales or employment)

(2) Decomposition (FHK)

$$\triangle a_t = \underbrace{\sum_{i \in S_t} s_{it-1} \triangle a_{it}}_{\text{Within effect;}} + \underbrace{\underbrace{\sum_{i \in S_t} \Delta s_{it}(a_{it-1} - a_{t-1})}_{\text{Between effect;}} + \underbrace{\sum_{i \in S_t} \Delta s_{it} \triangle a_{it}}_{\text{Covariance effect;}}}_{\text{Reallocation effect}} + \underbrace{\sum_{i \in E_t} s_{it}(a_{it} - a_{t-1})}_{\text{Entry effect;}} - \underbrace{\sum_{i \in X_t} s_{it-1}(a_{it-1} - a_{t-1})}_{\text{Exit effect}}$$

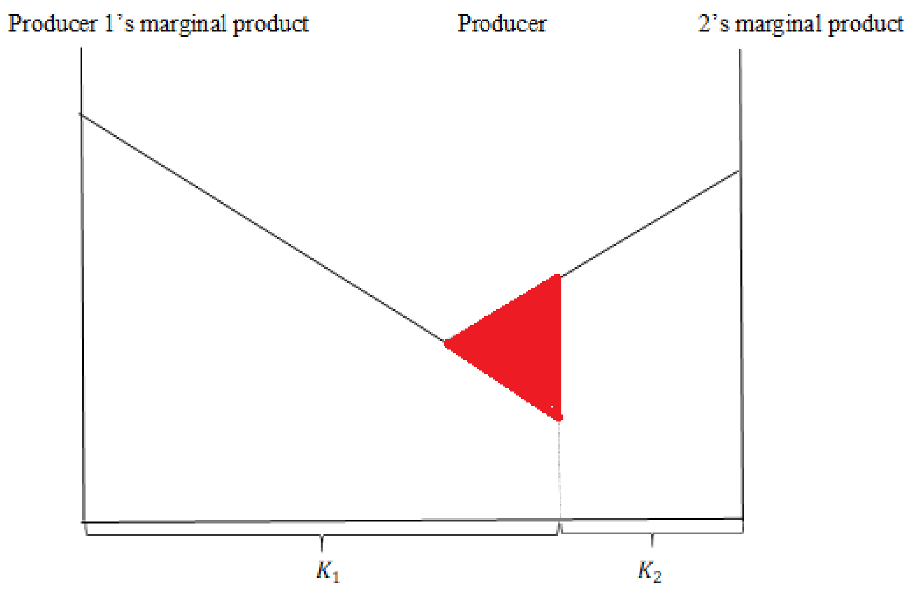
(S: survivors, E: entrants,X: exitors)

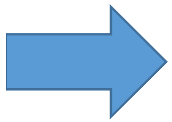
FHK: Example of a positive reallocation effect

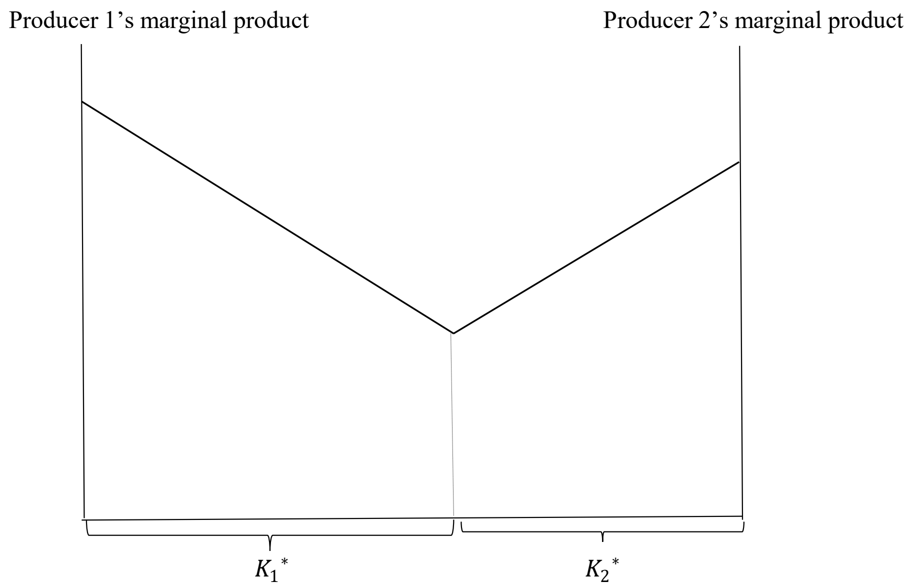


- The share of the high productivity producer increases.

FHK: Example of a negative reallocation effect







- The share of the low-productivity producer increases. According to FHK, the reallocation effect and the aggregate productivity decreases.
- In fact, resource allocation improves and aggregate productivity increases.

Review 2 ：Petrin and Levinsohn (2012) (PL)

- FHK does not consider the marginal product value.
- PL captures the reallocation effect by the difference in the marginal product value and the factor price.

(1)Aggregation : Change in value added-change in inputs with weights of factor prices)

$$APG = \sum_i dVA_i - \sum_i \sum_k W_{ik} dX_{ik}$$

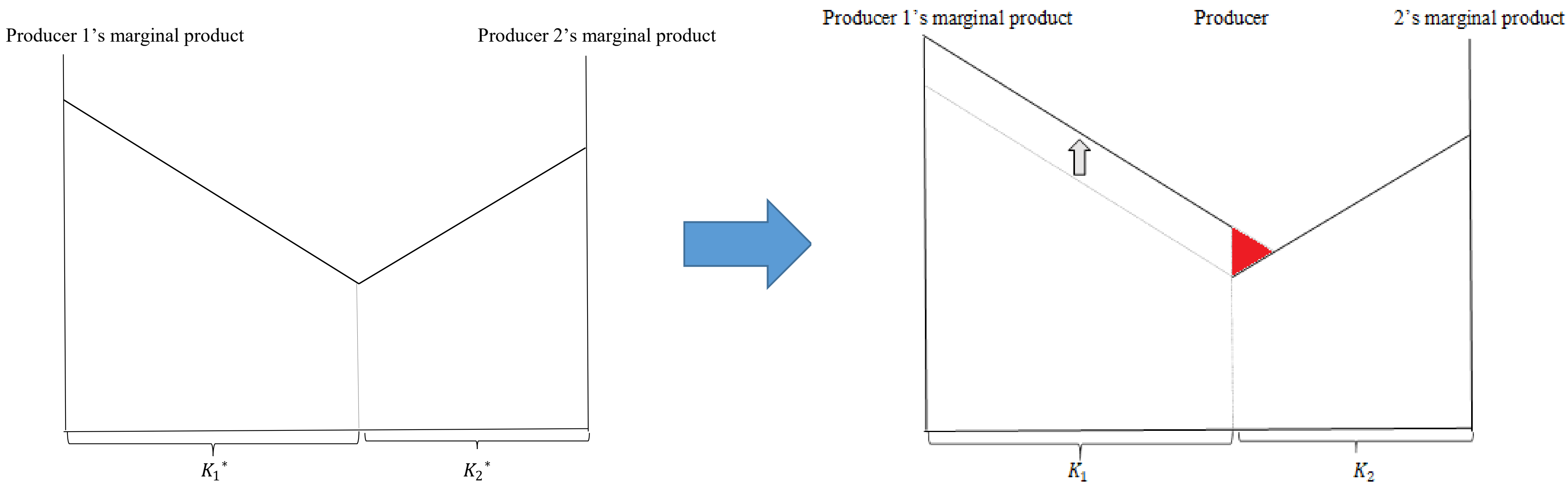
(2)Decomposition：

$$APG_{Gt} = \underbrace{\sum_i \bar{D}_{it} \Delta a_{it}}_{\substack{\text{TE} \\ \text{(technical efficiency)}}} + \underbrace{\sum_i \bar{D}_{it} \sum_k (\varepsilon_{ik} - \bar{s}_{ikt})\, \Delta lnX_{ikt} + \sum_i \bar{D}_{it} \sum_k (\varepsilon_{ij} - \bar{s}_{ijt}) \Delta lnM_{ijt}}_{\substack{\text{RE} \\ \text{(reallocation efficiency)}}} - \underbrace{\sum_i \bar{D}_{it} \Delta lnF_{it}}_{\substack{\text{FC} \\ \text{(fixed cost)}}}$$

$\bar{D}_{it}$: Sales/Total value added(Domar weight) 、ε_{ik}: production elasticity of input k,

$\bar{s}_{ikt}$: share of input k in sales $\qquad \varepsilon_{ik} - \bar{s}_{ikt} \Leftrightarrow P_i \frac{\partial Q_i}{\partial X_{ik}} - W_{ik}$

PL: Example of zero RE



- Input allocation does not change, so that RE of PL is zero.
- In fact, optimal allocation changes, and allocative efficiency worsens.

Contribution of our new approach

1. PL takes input share as given. We take producer-level distortions as given, and measure the allocative efficiency by the difference in marginal product value and factor price.

2.　We distinguish quantity-based productivity（TFPQ）from revenue-based productivity.

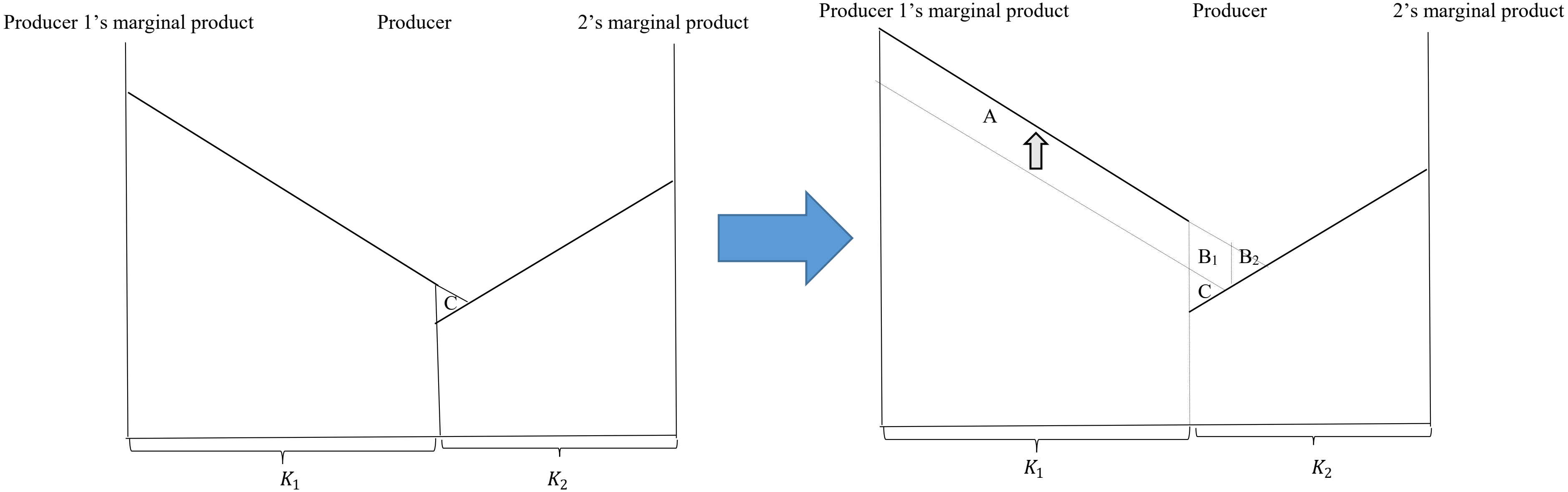
3.　We capture the variety effect（Fattal Jaeff, 2018; Yang, 2016）.

⇒Osotimehin (2019)

Osotimehin (2019)

- Osotimehin measures ΔTE as the impact of changes in firm－level productivity holding fixed the distortion, and hence her TE is affected by distortions. Our TE captures only TFPQ and is not affected by distortions.
- $$\Delta \ln TFP^{C} \approx \underbrace{\sum_{i \in C_t} \frac{Y_i}{Y^C} \frac{\Delta A_i}{A_i} + \beta \sum_{i \in C_t} \frac{\tau_i - \bar{\tau}^L}{1+\tau_i} \frac{Y_i}{Y^C} \frac{\Delta A_i}{A_i}}_{\Delta\,\mathrm{TE}} - \frac{\beta}{1-\beta} \underbrace{\sum_{i \in C_t} \frac{\tau_i - \bar{\tau}^L}{1+\tau_i} \frac{Y_i}{Y^C} \frac{\Delta \tau_i}{1+\tau_i}}_{\Delta\,\mathrm{AE}}$$
- Osotimehin does not capture the variety effect, while we do.
- Osotimehin captures the allocative efficiency (AE) across industries while we focus on the AE within industries.

Osotimehin: Example of her ΔTE that depends on previous AE



- Osotimehin:
  ΔTE: A+B_1 , ΔAE: -B_1 (B_1=B- B_2 , B_2=C,)
- Our approach
  ΔTE: A+B_1+ B_2, ΔAE: -(B_1+ B_2)

Framework of decomposition
1. Setup

- We need a model to measure the value of marginal product. We use Hsieh and Klenow (2009).
- Sector-level aggregation: CES

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

⇒Demand for intermediate good producer i (price elasticity: η)

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

- Production function for producer i : CRS Cobb-Dogulas

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

- Profit of producer i :

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

τ_{Yit}: distortion on output, τ_{Kit} : distortion on capital

- AE does not change even if we consider distortions on labor.

Framework of decomposition
2. Distortions, TFPQ, and TFPR

- FOCs

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

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

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

where $m_s = \frac{\eta_s}{\eta_s - 1}$, and $\kappa_{st} = ({P_{st}}^{\eta_s} Y_{st})^{\frac{-1}{\eta_s - 1}}$

- Distortions on input are the difference between output elasticity and factor share.
- Revenue-base productivity: $TFPR_{it} = p_{it} A_{it}$

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

Dispersion in TFPR reflects the difference in distortions among producers.

Framework of decomposition
3. Sectoral aggregation

- Sectoral aggregation

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

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

Sectoral TFP A_{st} is lower as $TFPR_{it}$ is more dispersed among producers.

Framework of decomposition
4. Sectoral decomposition

- Average productivity: $\bar{A}_t = \left(\frac{1}{N_t}\right)^{\frac{1}{\eta-1}} A_t$; N_t: total number of producers in sector s
- Average productivity of survivors: $\bar{A}_{st} = \left(\frac{1}{N_{st}}\right)^{\frac{1}{\eta_s-1}} A_{st}$ (16)
- ; $N_t^{C_t}$ is the number of producers that survive from t to $t+1$.
- Hypothetical average productivity of producers without distortions

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

- Allocative efficiency：Ratio of actual to hypothetical average productivity: $\overline{D_t^{C_{st}}} = \frac{\overline{A_t^{C_{st}}}}{\overline{H_t^{C_{st}}}}$
- $$ln\left(\frac{A_{s,t+1}}{A_{st}}\right) = \underbrace{ln\left(\frac{\overline{H_{s,t+1}^{C_{st}}}}{\overline{H_{st}^{C_{st}}}}\right)}_{\text{TE}} + \underbrace{\ln\left(\frac{\overline{D_{t+1}^{C_{st}}}}{\overline{D_t^{C_{st}}}}\right)}_{\text{AE}} + \underbrace{ln\left(\frac{\overline{A_{s,t+1}}}{\overline{A_{s,t+1}^{C_{st}}}}\right)}_{\text{Entry effect}} \underbrace{- ln\left(\frac{\overline{A_{st}}}{\overline{A_{st}^{C_{st}}}}\right)}_{\text{Exit effect}} + \underbrace{\frac{1}{\eta_s-1}\ln\left(\frac{N_{s,t+1}}{N_{st}}\right)}_{\text{Variety effect}} \qquad (20)$$

Framework of decomposition
5. Aggregation

- Final goods producer: CRS Cobb-Dogulas aggregation of sectoral goods:

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

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

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

Framework of decomposition
6. Notes on AE

- Distortions are caused by many factors:
  - Taxes and regulations
  - Adjustment costs
  - Financial constraints
  - Markup
- We focus on static allocative efficiency, although inefficient static allocation may be dynamically efficient due to adjustment costs.

Data

1. Establishment-level data

   Source: Census of Manufactures and Economic Census for 2014: *CM*

   Merit：covers a long period: 1986-2014.

   Cost: covers only manufacturing establishments

   We restrict our sample to the establishments with 30 employees and more that report tangible fixed assets

2. Firm-level data

   Source: Basic Survey of Japanese Business Structure and Activities: *BSJBSA*

   Covers firms with 50 or more employees and with paid-up capital of over 30 million yen both in manufacturing and nonmanufacturing industries.

   Period:1995-2015

Variables

- Classify establishments/firms into industries according to JIP database (52 manufacturing industries for CM and BSJBSA, and 26 nonmanufacturing industries for BSJBSA
- Assume a single-good producer.
- R=0.1 (r=0.04, δ =0.06)
- η

(1) Baseline: η =3 for all industries (Hsieh and Klenow, 2009; Osotimehin, 2019)

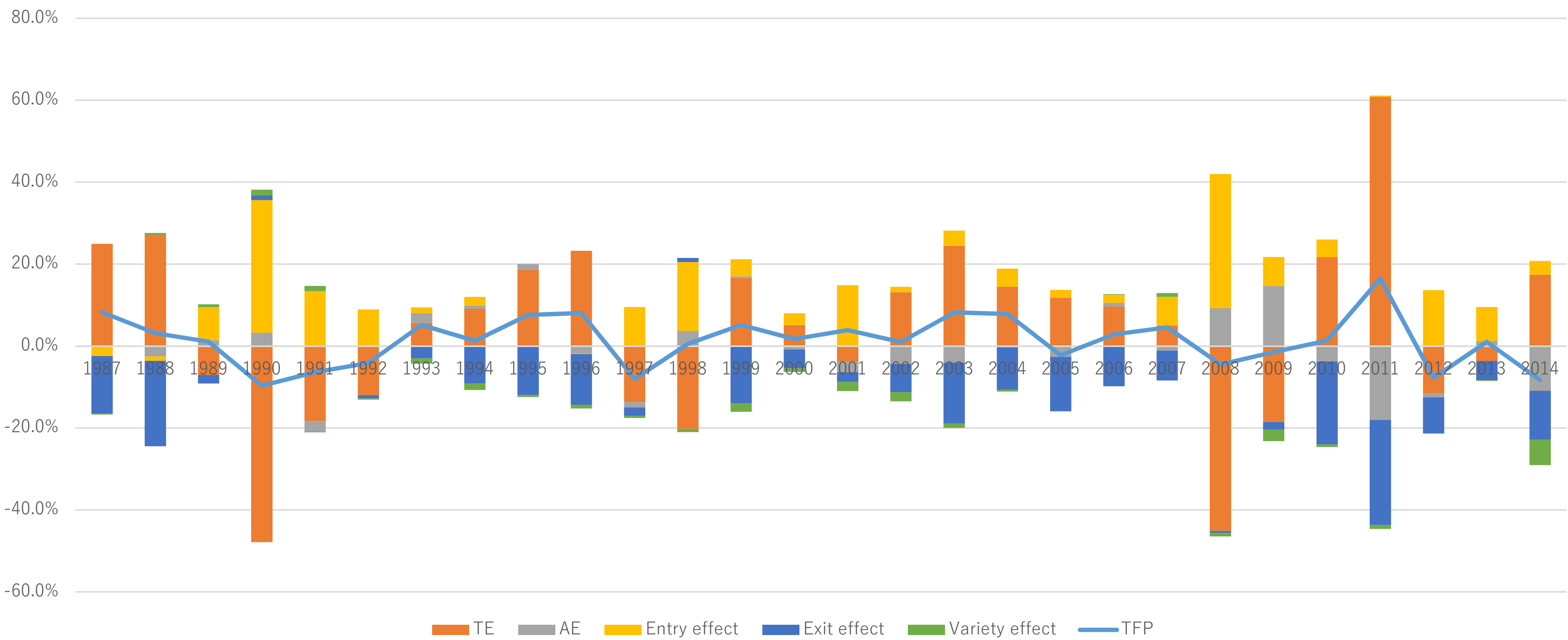
(2) Apply estimates of Broda and Weinstein (2006) to the three categories of goods: 3.5, 2.9, and 2.1.

- α: industry-level labor share.
- $\kappa_{st} = ({P_{st}}^{\eta_s} Y_{st})^{\frac{-1}{\eta_s - 1}}$: P_{st} is sectoral deflator from JIP. Y_{st} is the simple sum of nominal value added divided by the sectoral deflator.
- Outliers: trim top and bottom 1% of TFPQ and TFPR from pooled data.
- No of obs.

CM: 34,608 to 57,626 establishments per year. In total, 1,386,336 establishment-year obs.

BSJBSA: 21,512 to 28,662 firms per year. In total, 585,208 firm-year obs.

Baseline results from the CM



Baseline results from the CM: 5-year average

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%

- AE fell to zero in the banking crisis period(1996-2000) and turned to negative in the following 5-year (2001-2005).
- TE fell to negative in the GFC period (2006-2010)
- Entry effects are consistently positive and exit effects are consistently negative.
- Variety effect is negative except for the bubble period (1987-1990).

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

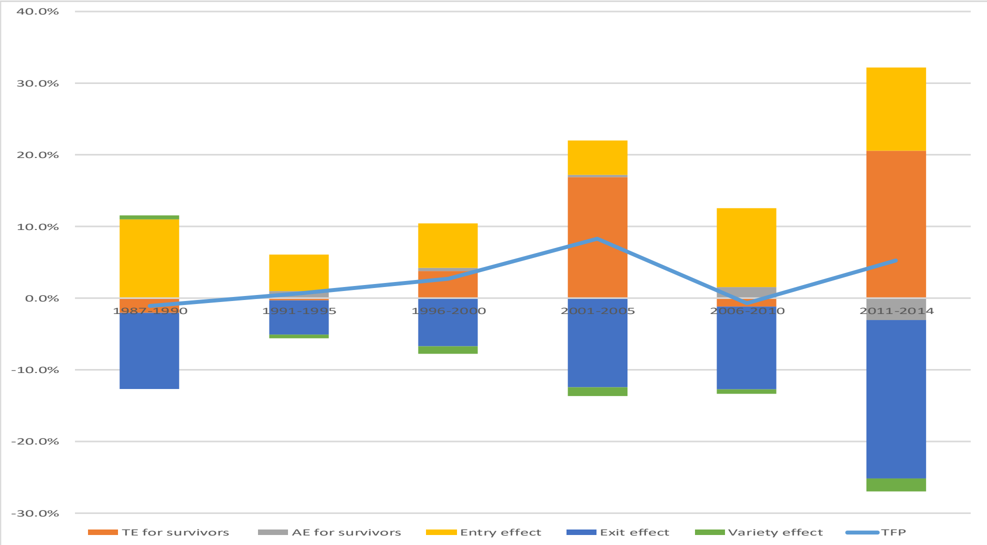
Adjustment costs of inputs might hinder smooth movement of inputs across establishments when only a part of establishments are hit by positive productivity shocks.

Dynamic correlation of the growth rate of aggregate output with the aggregate TFP growth and its components.

	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	*

- TE is positively correlated only with one-year lead of output
- AE is negatively correlated with aggregate output.
- Adjustment costs?

Different demand elasticities (η): 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%

- Aggregate TFP is more volatile than the baseline, but the movements of each components are similar to the baseline result.

Comparison between common demand elasticity (baseline) and different demand elasticity (based on Rauch classification)

FHK decomposition (using the same data)

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%

- Reallocation effect is consistently positive and relatively large, reflecting large covariance effects.

Comparison with preceding evidences from CM

1. Fukao, Kim, and Kwon (2009)

- Apply FHK decomposition to CM (1981-2003).

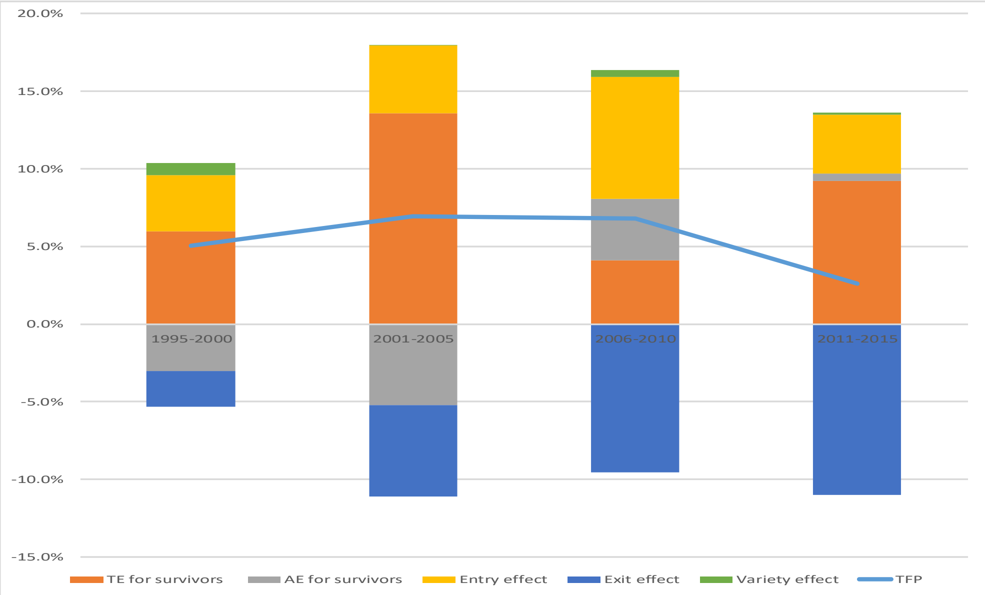
	TFP growth	Within	Reallocation	Entry effect	Exit effect
1981–1990	1.81	1.18	0.13	0.73	−0.24
1990–2000	1.27	0.72	0.29	0.54	−0.29

2. Kwon, Narita, and Narita (2015)

- Apply PL to CM (1981-2000)

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%

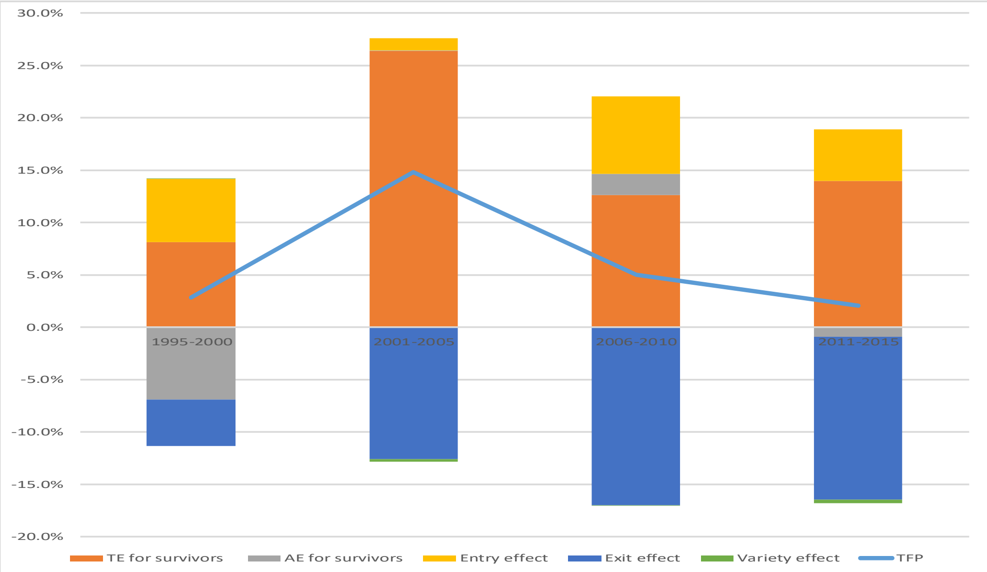
Decomposition results from manufacturing and nonmanufacturing firms in BSJBSA



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%

- Negative AEs for 1995-2000 and 2001-2005.
- Positive, but small TE for 2006-2010.
- Positive variety effect.

Decomposition results from 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%

- Negative AE for 1995-2000 (misallocation is severer among large firms?)
- Large negative exit effects.

Comparison with preceding evidences from BSJBSA

1. Nishimura, Nakajima, and Kiyota (2005)

- Apply the Griliches-Regev approach to BSJBSA for 1994-1998.
- Entry and exit effects (VA-weighted average) are both negative.

2. Fukao and Kwon (2006)

- Apply FHK to BSJBSA for 1994-2001.
- Within=1.2%, reallocation=0.3%, net entry=0.6%.

Summary

- AE fell during the banking crisis period (1996-2000), while TE fell during the GFC period (2006-2010).
- Suggests that AE matters for aggregate TFP in the medium to long run.

Future work

1. Refine the decomposition method and estimation

✓ industry-level estimation of parameters (esp., markup).
✓ Multiproduct establishments/producers.
✓ Misallocation across industries.
✓ Incorporate fixed costs/adjustment costs.

2. Explore the driving forces of each component.

✓ Financial shocks, export shocks, natural disasters, etc.
✓ Exploit the variation across industries and regions.