Does the Productivity J-curve Exist in Japan?
-Empirical Studies Based on the Multiple q Theory-

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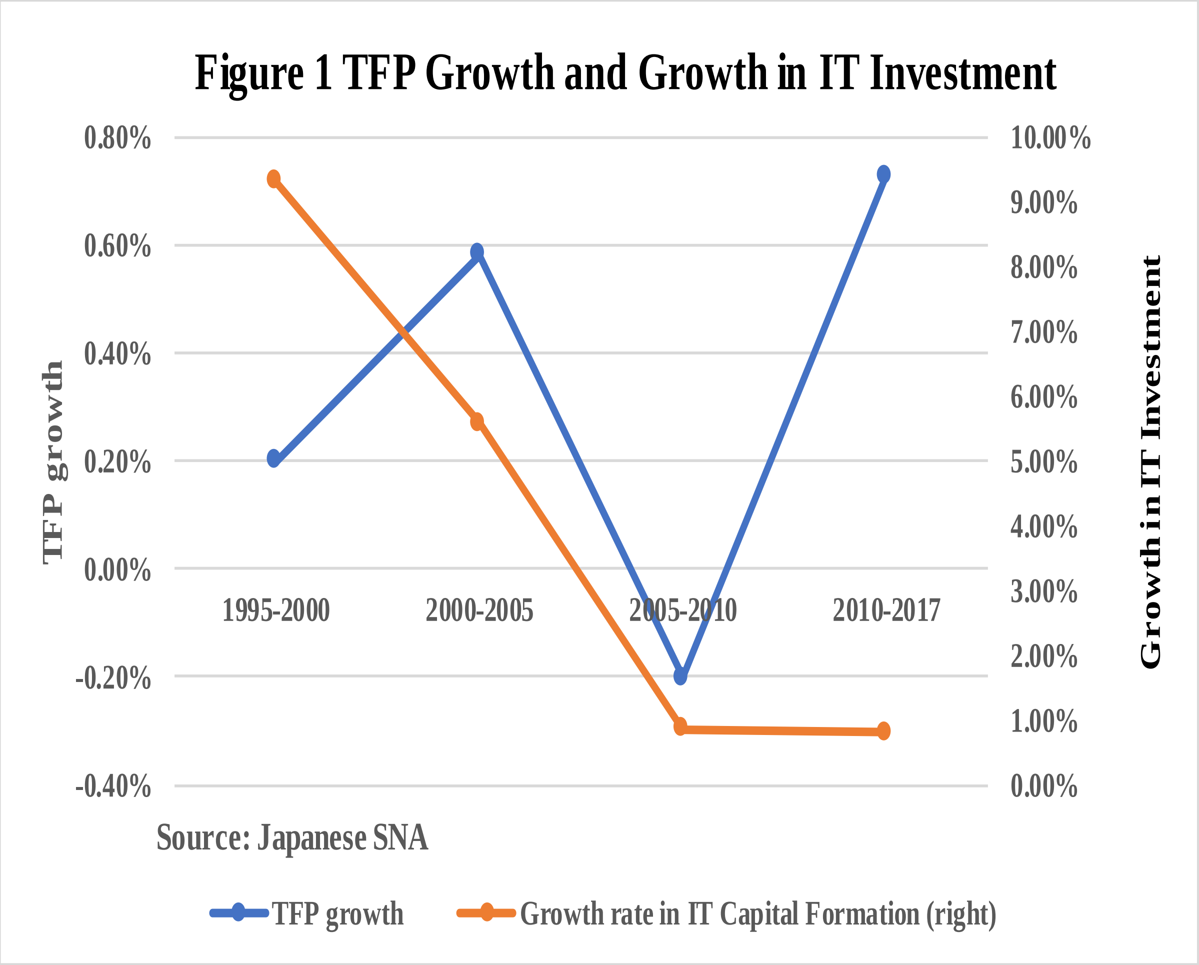
1. Motivation: Does capital formation for new technology lead to productivity improvement? (1)

- **Capital formation in IT is not directly related to productivity improvements.**

(1) The Solow paradox in the late 1980s

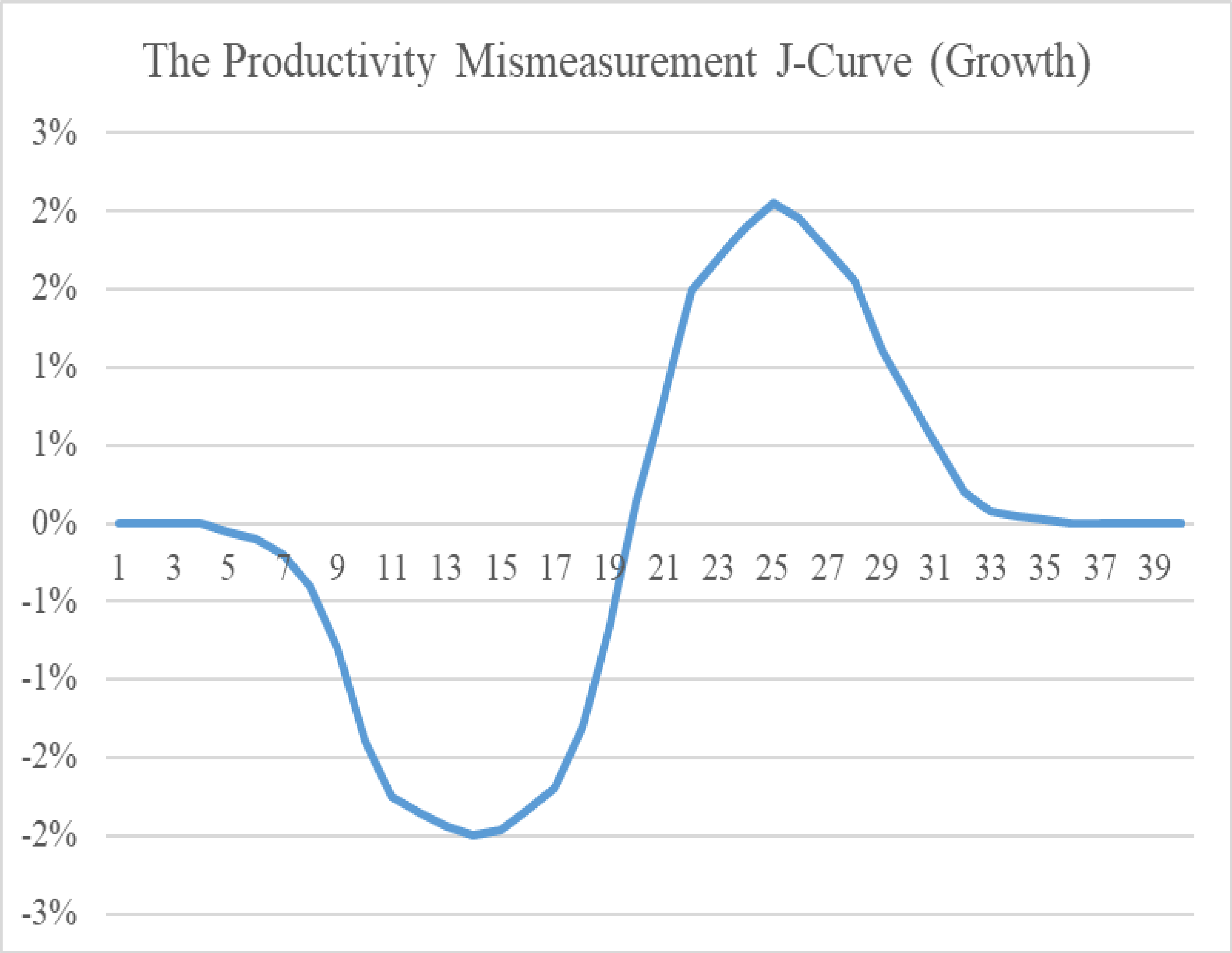
(2) The productivity gap between the U.S. and other advanced economies (EU and Japan) after the IT revolution

(3) The productivity slowdown in the U.S. after the Global Financial Crisis



1. Motivation: Does capital formation for new technology lead to productivity improvement? (2)

- **Brynjolfsson, Rock, and Syverson (2018): Capital formation for new technologies such as IT technology is associated with additional expenditures that are not included in value added. If these additional expenditures such as training and organizational change are recognized as intangible capital, then productivity measured from growth accounting will need to be revised.**
- **As the increase in capital formation for new technology is associated with large additional expenditures, the TFP growth rate measured by conventional growth accounting appears low. When the investment boom is over, the TFP growth rate recovers. →Productivity J-curve.**


The Productivity Mismeasurement J-Curve (Growth)
3%
2%
2%
1%
1%
0%
-1%
-1%
-2%
-2%
-3%
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39

2. The Aim of Our Paper and Summary of Results (1)

- Following Brynjolfsson, Rock, and Syverson (2018), we revise the TFP growth rate in Japan.
- How the measurement were revised

(1) Estimating adjustments costs (=additional expenditures of capital formation) in each asset (buildings and constructions, machineries, R&D) using listed firm-level data.

(2) Revising the TFP growth rate using estimated parameters.

2. The Aim of Our Paper and Summary of Results (2)

- **Main results**

(1) The adjustment costs of R&D are the greatest in the three types of asset.

(2) The revised TFP growth rate is slightly lower than the standard TFP growth rate for 22 years (from 1995 to 2017). The coefficient of variation in the revised TFP growth is larger than the standard.

(3) Focusing on IT intensive industries, we find the Productivity J-curve from the late 1990s to the early 2000s. As the IT revolution strated in the late 1990s, our finding is consistent with the argument of Brynjolfsson, Rock, and Syverson (2018).

3. Related literature

- **Multiple q theory: Wildasin (1984), Hayashi and Inoue (1991), Hall (2004), Cooper and Haltiwanger (2006), Suzuki and Chida (2017). Asako, Nakamura, and Tonogi (2020)**
- **Multiple q theory and IT revolution: Hall (2001), Miyagawa et al. (2016)**
- **Discussions on secular stagnation (supply side): Brynjolfsson and McAfee (2011, 2014, 2017), Aghion et al. (2019) vs Gordon (2016), Byrne, Fernald and Reinsdorf (2016), Syverson (2017)**
- **TFP measurement and intangible investment: Basu et al. (2003), Miyagawa and Kim (2008), Brynjolfsson, Rock and Syverson (2018)**

4. Theoretical Background of Empirical Study (1)

- **Standard TFP growth with** $Y = AF(\boldsymbol{K}, L)$.

$$g_A = g_Y - \sum_{j=1}^{m} \frac{F_{Kj} K_j}{Y} g_{Kj} - \left(\frac{F_L L}{Y}\right) g_L$$

- **Revised TFP growth with** Y’**=**A’F’(**K,** L, Z)

$$g_{A'} = \left(\frac{Y}{Y + \mu I_Z}\right)\left(g_Y - \sum_{j=1}^{m} \frac{F_{Kj} K_j}{Y} g_{Kj} - \frac{F'_L L}{Y} g_L - \frac{F'_Z Z}{Y} g_Z\right) + \left(\frac{\mu I_Z}{Y + \mu I_Z}\right) g_{I_Z}$$

4. Theoretical background of the empirical study (2)

- **The gap between the standard TFP growth and the revised TFP growth is expressed as follows:**

$$g_{A'} = (1 - \theta) g_A + \theta \left(g_{I_Z} - g_K \right)$$

$$\theta = \frac{\mu I_Z}{Y + \mu I_Z}$$

- **We recognize μ as a shadow price of intangible assets. This shadow price is measured from a standard investment theory with adjustment costs of investment.**

4. Theoretical background of empirical study (3)

・**We solve the following optimal problem of each asset to maximize discounted value of a firm.**

$$Max\ V(0)$$

$$= \int_0^{\infty} \Bigg[p_Y(t)A(t)F\big(\boldsymbol{K}(t), L(t)\big) - w(t)L(t)$$

$$- \sum_{i}^{m} \Big\{ p_{Ij}(t)I_k\ (t) + p_{Ij}(t)\phi_j(I_j(t), K_j(t))\}]\beta(t)dt$$

$$\frac{\mathrm{d}\ K_j(t)}{dt} = I_j(t) - \delta_j K_j(t)$$

$$\phi_j = \frac{\gamma_j}{2}(\frac{I_j}{K_j})\quad {}^2K_j$$

4. Theoretical background of empirical study (4)

- **Using optimal conditions in the previous maximizing problem, we obtain** $\frac{\mu}{p_I} = \frac{\lambda}{p_I} - 1 = q - 1$.
- **From an optimal condition where the marginal benefit of investment is equal to marginal adjustment costs of investment,**

$$\sum_{j=1}^{m} \phi_{Ij}\, \omega_j = \frac{V}{pK} - 1$$

- **From** $\boldsymbol{\phi_{Ij} = \gamma_j \frac{I_j}{K_j}}$**, and** $\boldsymbol{\frac{V}{pK} = q}$, **the above equation is rewritten as**

$$q - 1 = \sum_{j=1}^{m} \gamma_j \frac{I_j}{K_j} \omega_j$$

5. Data for the Estimation

- **To revise TFP growth, we need the parameter of the adjustment cost of an asset (γ_j) which is estimated from the equation in the previous slide.**
- **We estimate this equation using listed firm-level data. We obtain all data except R&D data from the DBJ Financial Statements Database.**
- **We obtain R&D data before 1999 from the database published by Toyokeizaishinposha. After 2000, we obtain R&D data from the DBJ database. After 2014, however, we are not able to obtain R&D data due to the change in the Japanese accounting system, so our data covers 1990 to 2013.**

6. Summary of Estimation Results (1)

- **Estimation Results Using All Samples**

(1) In estimation results using all samples, all coefficients in OLS estimations and GMM estimations are positive and significant.

(2) Adjustment costs of R&D are the greatest in the three types of assets.

(3) The estimated coefficients are converted to those by Brynjolfsson, Rock , and Syverson (2018).

(4) For example, the coefficient of R&D stock (14.61) is equal to 3.31 in the case of the estimation of Brynjolfsson, Rock, and Syverson (2018). As their estimated value is 2.73, the marginal benefit of R&D in Japan is larger than that in the US.

Estimation results (all samples)

	OLS			GMM	
VARIABLES	(1)	(2)	VARIABLES	(3)	(4)
(I/K)1 (buildings and constructions)	5.564***	4.753***	(I/K)1 (buildings and constructions)	7.134***	6.020***
	(0.349)	(0.335)		(0.933)	(0.826)
(I/K)2 (machineries)	6.277***	4.250***	(I/K)2 (machineries)	8.461***	5.009***
	(0.415)	(0.402)		(1.012)	(0.942)
(I/K)3 (R&D)	14.61***	11.73***	(I/K)3 (R&D)	19.08***	15.04***
	(0.647)	(0.624)		(2.319)	(2.112)
R1 (interest_debt_ratio)		0.231***	R1 (interest_debt_ratio)		0.302***
		(0.0233)			(0.0759)
R2 (cashflow_ratio)		11.10***	R2 (cashflow_ratio)		12.83***
		(0.385)			(1.210)
Constant	-1.200***	-1.625***	Constant	-1.704***	-2.066***
	(0.0493)	(0.0506)		(0.165)	(0.162)
Observations	9,411	9,411	Observations	9,411	9,411
R-squared	0.122	0.202	Number of firms	475	475
Number of firms	475	475	Hansen J stat.	395.4	439.8
Within R-squared	0.122	0.202	Degrees of Freedom	252	340
Between R-squared	0.0367	0.190	p-value	1.96e-08	0.000207
Overall R-squared	0.0736	0.178	Arellano-Bond test for AR(1)	-6.910	-7.946
sigma_u	1.160	1.044	p-value	0	0
sigma_e	1.509	1.439	Arellano-Bond test for AR(2)	-1.605	-0.902
			p-value	0.109	0.367

6. Summary of Estimation Results (2)

・Estimation Results by Sector

(1) We focus on the IT-intensive industries and non-IT-intensive industries.

(2) In the case of IT-intensive industries, all coefficients show the expected signs and are significant.

(3) As IT-intensive industries consist of high technology industries such as electric parts, electric machinery industries, and information and communication service industries, the associated costs of R&D stock are lower than those of all industries.

(4) In contrast to IT-intensive industries, the adjustment costs of R&D stock are higher than those in the non-IT-intensive industries.

Estimation results (IT-intensive industries)

	OLS			GMM	
VARIABLES	(1)	(2)	VARIABLES	(3)	(4)
(I/K)1 (buildings and constructions)	5.725***	4.240***	(I/K)1 (buildings and constructions)	7.684***	5.038***
	(0.490)	(0.464)		(1.168)	(1.023)
(I/K)2 (machineries)	6.344***	3.746***	(I/K)2 (machineries)	7.892***	3.360***
	(0.581)	(0.557)		(1.097)	(0.963)
(I/K)3 (R&D)	12.19***	9.083***	(I/K)3 (R&D)	15.54***	9.916***
	(0.761)	(0.723)		(2.135)	(1.864)
R1 (interest_debt_ratio)		0.745***	R1 (interest_debt_ratio)		1.201***
		(0.0554)			(0.217)
R2 (cashflow_ratio)		11.53***	R2 (cashflow_ratio)		13.11***
		(0.468)			(1.385)
Constant	-1.089***	-1.756***	Constant	-1.463***	-2.193***
	(0.0686)	(0.0733)		(0.183)	(0.206)
Observations	5,360	5,360	Observations	5,360	5,360
R-squared	0.113	0.222	Number of firms	269	269
Number of firms	269	269	Hansen J stat.	263.5	265.6
Within R-squared	0.113	0.222	Degrees of Freedom	252	340
Between R-squared	0.0318	0.255	p-value	0.296	0.999
Overall R-squared	0.0689	0.229	Arellano-Bond test for AR(1)	-6.026	-6.664
sigma_u	1.214	1.045	p-value	1.68e-09	0
sigma_e	1.506	1.411	Arellano-Bond test for AR(2)	-0.980	-0.336
			p-value	0.327	0.737

Estimation results (non-IT-intensive industries)

	OLS			GMM	
VARIABLES	(1)	(2)	VARIABLES	(3)	(4)
(I/K)1 (buildings and constructions)	5.362***	4.778***	(I/K)1 (buildings and constructions)	6.960***	5.741***
	(0.496)	(0.479)		(1.100)	(1.047)
(I/K)2 (machineries)	6.274***	4.887***	(I/K)2 (machineries)	8.367***	5.874***
	(0.589)	(0.572)		(1.411)	(1.381)
(I/K)3 (R&D)	20.80***	18.68***	(I/K)3 (R&D)	22.63***	16.76***
	(1.220)	(1.188)		(3.537)	(2.855)
R1 (interest_debt_ratio)		0.107***	R1 (interest_debt_ratio)		0.255***
		(0.0259)			(0.0632)
R2 (cashflow_ratio)		11.59***	R2 (cashflow_ratio)		14.08***
		(0.665)			(1.812)
Constant	-1.394***	-1.847***	Constant	-1.622***	-2.092***
	(0.0701)	(0.0736)		(0.208)	(0.197)
Observations	4,051	4,051	Observations	4,051	4,051
R-squared	0.141	0.206	Number of firms	206	206
Number of firms	206	206	Hansen J stat.	203	203.7
Within R-squared	0.141	0.206	Degrees of Freedom	252	340
Between R-squared	0.0305	0.115	p-value	0.990	1
Overall R-squared	0.0798	0.147	Arellano-Bond test for AR(1)	-3.719	-4.179
sigma_u	1.087	1.026	p-value	0.000200	2.92e-05
sigma_e	1.505	1.448	Arellano-Bond test for AR(2)	-1.182	-1.204
			p-value	0.237	0.229

7. Revised TFP Growth Rate (1)

- **We are able to measure the shadow price of intangibles using an estimated parameter.**

$$\frac{\mu_j}{p_{Ij}} = \gamma_j \frac{I_j}{K_j}$$

- **The standard and revised TFP growth rates are measured from SNA data and estimated parameters.**
- **We do not use insignificant coefficients (when partial q is equal to 1) for the revision of the TFP growth.**

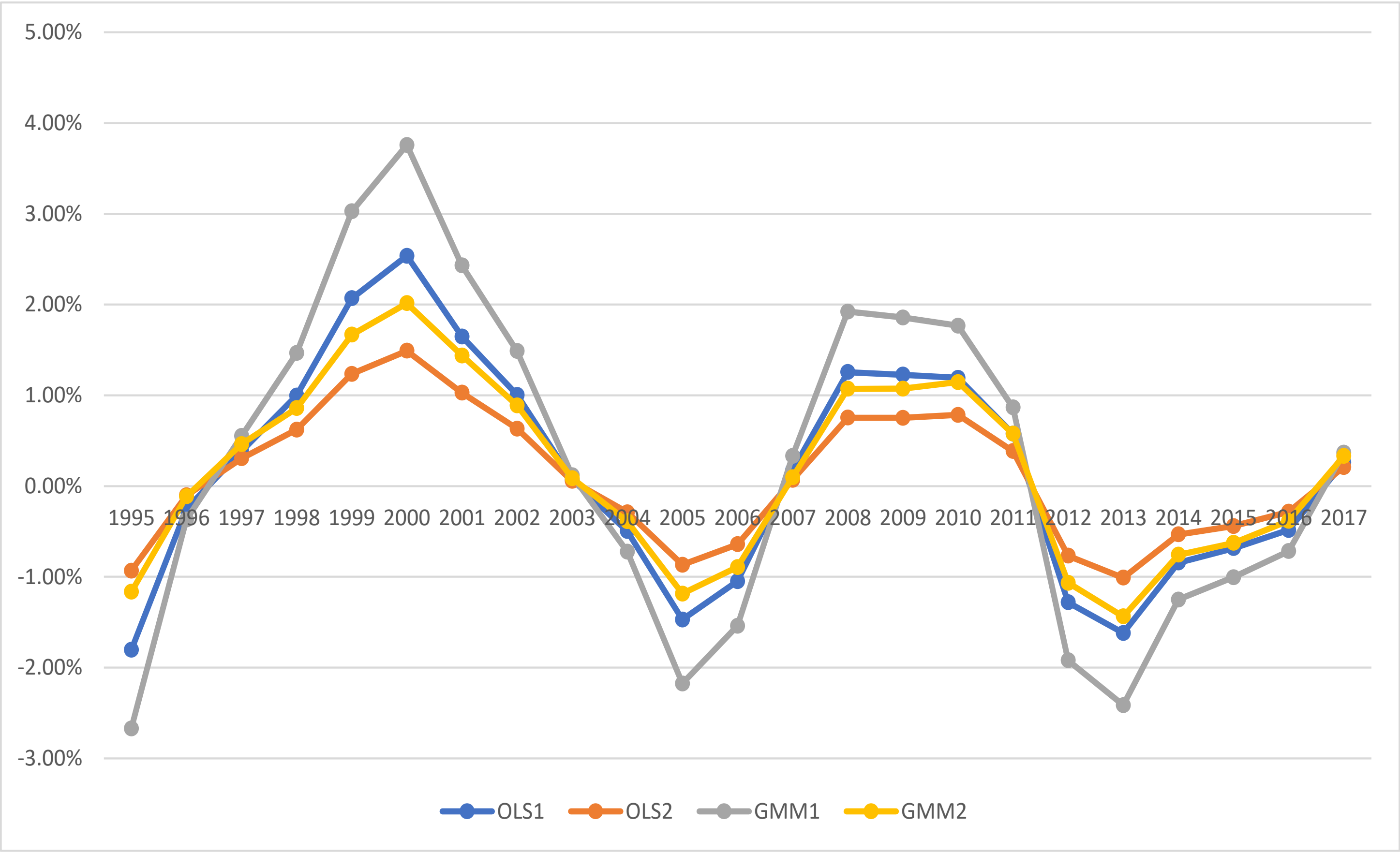
7. Revised TFP Growth Rate (2)

- **The average rate of the revised TFP growth is slightly lower than that of the standard measure of TFP growth in all industries, because growth in intangible investment associated with machinery and buildings and construction investment declined much greatly in the periods of the Japanese financial crisis and the Global Financial Crisis.**
- **The fluctuations of the revised TFP growth rate are more volatile than those of the standard one.**
- **In all industries, the productivity J-curve appears to exist in the 2010s.**

Comparison between standard and revised TFP measures (all industries)

all industries	Standard TFP growth	Revised TFP growth (OLS1)	Revised TFP growth (OLS2)	Revised TFP growth (GMM1)	Revised TFP growth (GMM2)
Average growth rate (1995-2017)	0.648%	0.542%	0.560%	0.487%	0.508%
Standard deviation	0.013	0.035	0.025	0.048	0.030
Coefficient of variation	2.022	6.495	4.482	9.792	5.992

Productivity J-curves in all industries



7. Revised TFP Growth Rate (3)

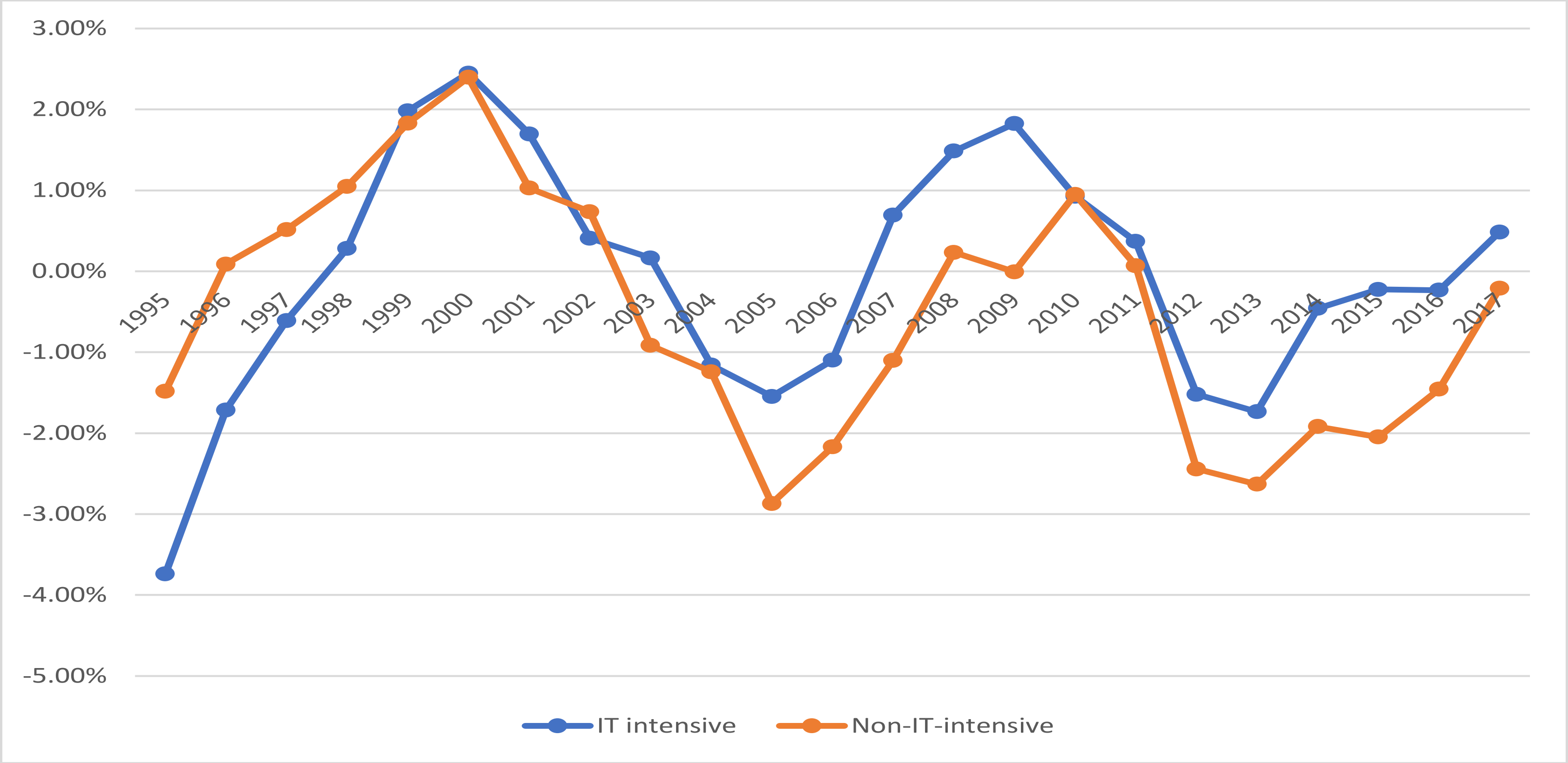
- **In the IT-intensive sector, the average rate of the revised TFP growth is slightly higher than that of standard TFP growth.**
- **In this sector, the movements of the gap between the standard and the revised TFP growth in the late 1990s resembles the letter J.**
- **As the IT revolution started in the late 1990s, these movements in this period are consistent with the argument of Brynjolfsson, Rock, and Syverson (2018).**
- **Although we observe J-curves in the middle of the 2000s and the 2010s, these J-curves were not results of the investment boom.**

Comparison between standard and revised TFP measures (IT-intensive and non-IT-intensive)

	Standard TFP growth	Revised TFP growth (OLS 1)	Revised TFP growth (OLS 2)	Revised TFP growth (GMM 1)	Revised TFP growth (GMM2)
Average growth rate (1995-2017)	**0.795%**	**0.933%**	**0.808%**	**0.935%**	**0.761%**
Standard deviation	**0.014**	**0.044**	**0.025**	**0.055**	**0.023**
Coefficient of variation	**1.727**	**4.666**	**3.084**	**5.907**	**3.059**

	Standard TFP growth	Revised TFP growth (OLS 1)	Revised TFP growth (OLS 2)	Revised TFP growth (GMM 1)	Revised TFP growth (GMM2)
Average growth rate (1995-2017)	**0.112%**	**0.646%**	**0.576%**	**0.657%**	**0.455%**
Standard deviation	**0.017**	**0.042**	**0.036**	**0.051**	**0.036**
Coefficient of variation	**15.421**	**6.543**	**6.233**	**7.809**	**7.950**

Productivity J-curves in IT-intensive and non-IT-intensive industries



8. Concluding Remarks and Future Research Agenda (1)

- **Brynjolfsson, Rock and Syverson (2018) showed that the TFP growth rate measured by standard growth accounting is biased, because it does not consider unmeasured intangibles.**
- **As capital formation for new technology is associated with large associated costs, the gap between the standard and revised TFP growth rates is likely to be large after the creation of the General Purpose Technology such as the IT revolution.**
- **When we estimate adjustment costs of three types of assets using listed firm-level data, the adjustment costs of R&D asset are the greatest.**

8. Concluding remarks and future research agenda (2)

- **Using the estimated parameters, we measure a revised TFP growth rate.**
- **In all industries, the average rate of the revised TFP growth rates are less than that of the standard TFP growth rate.**
- **In the IT- intensive sector, the standard TFP growth is underestimated in the late 1990s. As it is overestimated in the early 2000s, the movements in the gap between the standard TFP growth and the revised TFP growth resemble the letter J.**
- **These movements in the IT-intensive sector are consistent with the productivity J-curve discussed by Brynjolfsson, Rock, and Syverson (2018).**

Thank you for your attention!

I wish that all of you stay safe!

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