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Abstract

In this paper, we investigate why information and communication technology (ICT) investment in Japan has stagnated since the 1990s. Given that a notable characteristic of Japan's economy is that small as well as older firms play a much greater role than in other economies, particularly that of the United States, and that previous studies on other countries suggest that larger and younger firms are more likely to adopt new ICT technologies, our analysis mainly focused on firms' size and age.

As the first step of our investigation, using firm-level data, we examined whether larger and/or younger firms tend to have a higher ICT intensity. We found that larger firms indeed have a higher ICT intensity. In the case of firm age, there was no simple linear relationship between firm age and ICT intensity. As a next step, we estimated a Cobb-Douglas type production function and tested whether the ICT input coefficient differs across different firm-size groups and firm-age groups. We found that larger firms and younger firms tend to have a higher ICT input coefficient. The other factor that may be responsible for the differences in ICT intensity by firm size and firm age is the constraints on ICT input. To confirm this, we calculated the marginal product of ICT input by firm-size group and by firm-age group using the production function estimates. We found that smaller firms and younger firms tend to have a higher marginal product of ICT input. These findings suggest that smaller firms and younger firms face constraints that prevent them from increasing ICT input.

Next, we examined impediments to the full use of ICT by Japanese firms based on our analysis as well as preceding studies by the Japanese government and other Japanese institutions. As factors which may result in smaller firms in Japan facing a higher price for ICT inputs, we pointed out two characteristics of the Japanese economy: the underdeveloped market for business process outsourcing (BPO) and the scarcity of ICT experts. Since access to efficient vendors of ICT services is a key factor for smaller firms' procuring ICT input at a reasonable price and ICT experts in Japan tend to prefer working in large firms, these two factors make ICT input more expensive for smaller firms. On the other hand, as constraints to increasing ICT input for smaller and/or younger firms, we pointed out liquidity constraints and insufficient ICT literacy. We also pointed out a number of other special factors which help to explain why not only the ICT intensity of small firms but also that of all firms in Japan is comparatively low.

Keywords: Information and communication technology, ICT Revolution, Firm age, Firm size, ICT intensity, Business process outsourcing
JEL classification: D22, D24, L11, L86, N15

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Introduction

Using firm-level data for Japan, this paper investigates why Japan was left behind in the information and communication technology (ICT) revolution. Whereas the US economy experienced a dramatic increase in total factor productivity (TFP) growth from the mid-1990s to the early 2000s, Japan suffered a significant slowdown in TFP growth after 1991. One of the main causes of this difference is that Japan could not achieve an ICT revolution like that in the United States.[1]

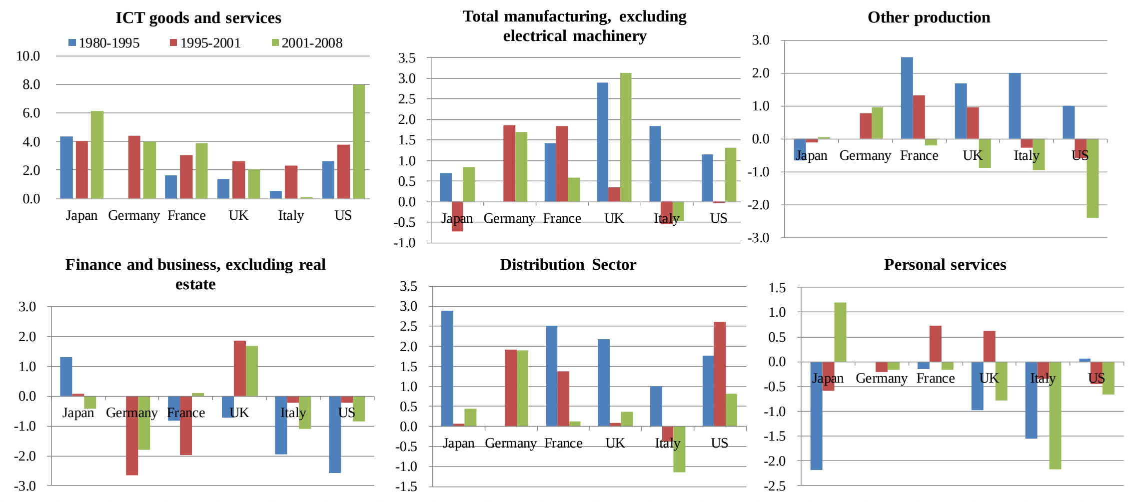
In Figure 1, the market economy is divided into six sectors and average annual TFP growth rates in each sector before and after 1995 are compared across six major developed economies. The figure shows that the United States experienced an acceleration of TFP growth not only in the ICT-producing sector (electrical machinery, post and communication), but also in ICT-using sectors, such as distribution services (retail, wholesale and transportation), and in the rest of the manufacturing sector (i.e., excluding electrical machinery).[2] Japan also experienced relatively high TFP growth in the ICT-producing sector. The problem for Japan, however, is that TFP growth in ICT-using service sectors, such as distribution services, and the rest of the manufacturing sector declined substantially after 1995. Moreover, these ICT-using sectors are much larger than the ICT-producing sector: the average labor input share (hours worked) of the ICT-producing sector in Japan's total labor input in 1995–2007 was only 4.1% (similar to the corresponding share in the United States of 3.8%). On the other hand, the labor input shares of distribution services and the rest of the manufacturing sector in 1995–2007 were 22.8% and 16.5%, respectively.[3]

[1] On the ICT revolution in the United States, see Jorgenson and Stiroh (2000) and Jorgenson (2001).

[2] The acceleration of TFP growth in the rest of the manufacturing sector in the United States occurred during the period 2001–2008.

[3] Basu et al. (2003) have shown that more than 70% of TFP growth in the United States during 1995–2003 occurred in the wholesale and retail industry. Meanwhile, for Japan, Fukao and Miyagawa (2008) have shown that about 70% of TFP growth during 2000–2005 occurred in the ICT-producing sectors.

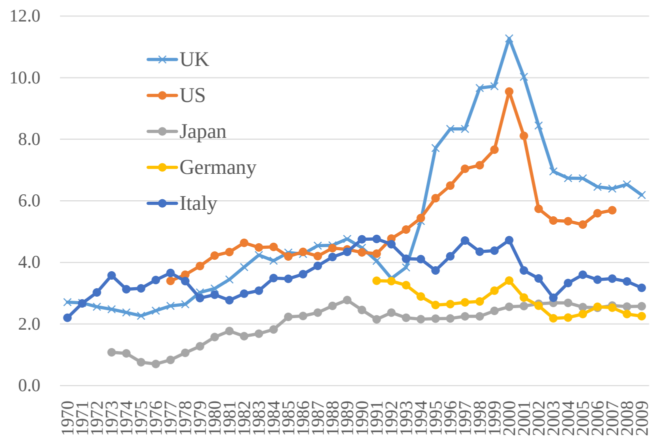
Figure 1. TFP Growth in the Market Sector, by Sector and Country: 1980–1995, 1995–2001, and 2001–2008 (Annual Rate, %)



Source: EU KLEMS Database, Rolling Updates.

Why did an ICT revolution of the magnitude observed in the United States not occur in Japan? Figure 2 provides an answer to this question.[4] In Japan, the ICT investment–GDP ratio in ICT-using service sectors such as distribution services is very low in comparison with the United States. It appears that the ICT revolution did not happen in Japan simply because Japan has not accumulated sufficient ICT capital.

Figure 2. ICT Investment–GDP Ratio in Major Developed Economies: Distribution Services



Source: EU KLEMS Database, Rolling Updates.

[4] For more details on this issue, see Fukao et al. (2012).

Motivated by these findings, this paper investigates why ICT investment in Japan has stagnated since the 1990s, especially in non-manufacturing sectors such as the distribution sector, using firm-level data. For this investigation, we mainly focus on firms' size and age.

Preceding studies suggest that the adoption of ICT technologies increases with the size of firms (Pilat 2004). For example, focusing on the US manufacturing sector, Dunne (1994) and Luque (2000) found that larger plants are more likely to employ newer technologies than smaller plants.[5] Given that the slowdown in productivity growth in Japan is mainly due to ICT-using sectors such as distribution services and other services, it is therefore patterns in the service sector that are of particular interest. Looking at the retail sector, one finds that in Japan this is indeed characterized by small shops, whereas the US retail sector is characterized large chain stores (Haskel et al. 2007). Moreover, listed firms in Japan's service sector are much smaller on a consolidated basis than their counterparts in the United States (Fukao and Miyagawa 2010). Taken together, these findings suggest that the reason for the low ICT investment in Japan's service sector is that firms in this sector tend to be comparatively small.

In order to introduce ICT, firms need to incur certain initial fixed costs, such as those associated with the revision of organizational structures and training of workers. Some of these expenditures are one shot, and it seems that once firms have adjusted their organizational structures to new ICT and have accumulated a certain mass of ICT-literate workers, they can expand their scale later without substantial additional costs. Probably because of this characteristic of ICT technology, younger and growing firms (and plants) tend to be more active in ICT investment. Dunne (1994) and Luque (2000) found that younger plants are more likely to adopt ICT than older small plants.

As a first step in our study, using Japanese firm-level data, we test whether the ICT intensity of firms tends to be lower the smaller and the older they are. We show that larger firms indeed have a higher ICT intensity than smaller firms, but there is no simple relationship between firm age and ICT intensity. We also examine in what type of ICT inputs, such as hardware, software, or ICT services (information processing service fees, operation and maintenance commission fees, etc.) the differences in ICT intensity across firms of different sizes and different ages are particularly pronounced.

The next question we address is why the ICT intensity of small firms tends to be smaller. There are two potential answers to this question. One is that the production function differs depending on firm size. For example, if the production function on a value added basis is of a Cobb-Douglas type with constant returns to scale and the coefficient for ICT input is larger for larger than for smaller firms (which means that larger firms choose more ICT-intensive technology), then the ICT input cost over value added of large firms will be higher than that of small firms. The other potential

[5] Hollenstein (2004) and Giuntaa and Trivierib (2007) obtained similar results for Switzerland and Italy, respectively.

explanation is that because of some constraint on ICT input, such as liquidity constraints, smaller firms cannot raise their ICT input to the optimal level. We therefore estimate the production function parameters for each firm-size group and derive the marginal product of one yen of ICT input by firm size in order to examine whether there are constraints on ICT input at small firms.

Similarly, we also estimate the production function parameters for each firm-age group and derive the marginal product of ICT input. In this way, we try to answer why there is no simple relationship between firm age and ICT intensity.

Based on these empirical findings and preceding studies by the Japanese government and other institutions in Japan, we also investigate what factors inhibit the full use of ICT by Japanese firms.

The structure of the paper is as follows. In Section 2, we explain our firm-level data and test whether smaller and older firms tend to have a lower ICT intensity. In Section 3, we estimate a production function with three production factors (labor, capital, and ICT input). In the estimation, we take account of the possibility that the coefficients for the production factors may differ across firms of different size and age. Based on this estimation result, we test whether the ICT input coefficient of the production function differs by firm size and firm age.

The difference in ICT intensities across different firm-size and firm-age groups depend not only on differences in the ICT input coefficient in the production function but also on constraints on ICT input, such as liquidity constraints, which might prevent (for example) smaller firms from increasing ICT input to the optimal level. If such constraints are present, the marginal product of ICT input at smaller firms should be higher than that at bigger firms. In Section 4, to check whether this is the case, we calculate the marginal product of ICT input by firm size and by firm age using the estimated production function. In Section 5, based on our findings in Sections 3 and 4 and the results of other METI surveys, we make inferences on why the ICT intensity of small firms in Japan is so low and why younger firms, which have a higher ICT input coefficient, do not tend to have a higher ICT intensity. We also examine impediments to the full use of ICT by Japanese firms. Finally, in Section 6, we summarize our main findings and discuss their policy implications.

2. Are Smaller and Older Firms Less ICT Intensive?

In this section, using Japanese firm-level data, we examine whether smaller and older firms tend to have a lower ICT intensity than other firms. We start by explaining our dataset.

The main sources for our data are the firm-level information of the *Basic Survey of Japanese Business Structure and Actives* (*Basic Survey*) and the *Actual Conditions Survey of Information Technology* (*IT Survey*). Both surveys are conducted annually by the Ministry of Economy, Trade and Industry (METI).

The *Basic Survey* covers all firms with at least 50 employees and 30 million yen of paid-in capital in the Japanese manufacturing, mining, electricity and gas, commerce, and service industries.

The annual number of firms surveyed is more than 25,000. This is a compulsory survey and the response ratio is around 85%. The purpose of the survey is to gain a comprehensive picture of Japanese firms and to this end the survey includes basic information on each firm, such as its year of establishment, factor inputs and output, and assets and liabilities, as well as information on the composition of the firm's business activities, and on its R&D, exports, and foreign direct investment. As firms in the survey are assigned a permanent code, we can construct a firm-level longitudinal data set.

The *IT Survey* provides qualitative and quantitative data on firms' ICT activities, such as ICT expenditures broken down into detailed classifications, the type of ICT networks firms have adopted, and organizational changes firms have made for the introduction of new ICT. The survey is conducted based on random sampling and the sample size is about 9,000 firms. Since it is not a compulsory survey, the response ratio is only around 50%. The industry coverage is almost the same as that of the *Basic Survey*. Moreover, like in the *Basic Survey*, only firms with at least 50 employees and 30 million yen of paid-in capital are surveyed.

For our analysis, we merged the data of the *Basic Survey* and the *IT Survey* for the period 1995–2007 using common firm codes (which are available only in the surveys from 2000 onward) and other information. We end up with about 22,000 firm–year observations.

The *IT Survey* collects information on the following six categories of firms' expenditure on ICT inputs: (1) ICT hardware investment (purchases of computers and peripherals, telecommunication equipment, and other information devices); (2) ICT software investment (expenditure on packaged, order made, and homemade software); (3) expenditure on ICT service inputs (charges for data processing, data compilation and data input, operation and maintenance fees, payment for dispatched ICT workers, etc.); (4) other ICT expenditures (labor costs of the information system division, communication line fees, fees for usage of data centers, etc.); (5) the depreciation cost of ICT hardware; and (6) the depreciation cost of ICT software.

Ideally, we would estimate the real capital stock of ICT hardware and software using the data for (1) and (2) based on the perpetual inventory method and further estimate ICT capital service input by multiplying the ICT real capital stock thus obtained with ICT capital goods prices and capital costs (the summation of the interest rate, the capital depreciation rate, and the rate of decline of capital goods prices). However, since the *IT Survey* is a sample survey, we cannot apply the perpetual inventory method. Due to this data constraint, we use (5) the depreciation cost of ICT hardware and (6) the depreciation cost of ICT software to derive proxies of ICT hard- and software capital service input.

The depreciation cost of ICT hardware/software can be regarded as corresponding to the nominal stock value of ICT hardware/software multiplied by the depreciation rate. Therefore, the depreciation cost of ICT hardware/software is smaller than ICT capital service input, with the difference being equal to the nominal stock value of ICT hardware/software multiplied by the summation of the interest rate and the rate of decline of capital goods prices. In order to adjust for this difference, using the Japan Industrial Productivity (JIP) Database 2014[6] we calculate the ratio of the total nominal ICT hardware/software capital service input to the depreciation cost of ICT hardware/software for each industry and year and multiply (5) the depreciation cost of ICT hardware and (6) the depreciation cost of ICT software by these ratios.[7] We then use the values thus obtained as proxies of ICT hardware input and ICT software input.

We measure the ICT input of each firm by summing up four types of expenditures, namely, ICT hardware input (using data on (5) the depreciation cost of ICT hardware multiplied by the ratio of industry-level annual ICT hardware capital service input to the depreciation cost of ICT hardware), ICT software input (using data on (6) the depreciation cost of ICT software multiplied by the ratio of industry-level annual ICT hardware capital service input to the depreciation cost of ICT hardware), (3) expenditures on ICT services, and (4) other ICT expenditures. We then measure the ICT intensity of each firm in terms of the ratio of this ICT input value to gross value added.

Basic statistics on firms' ICT intensity by industry (for 27 industries) based on our pooled data for 1995–2007 are reported in Table 1.[8] Industries are ranked in descending order of their average ICT intensity. The industry average of ICT intensity is extremely high in information services (33.7%) and finance and insurance (21.6%). ICT intensity is also high in some other industries such as newspapers and printing (6.1%), wholesale (5.3%), telecommunication equipment (5.3%), telecommunication, broadcasting, and video and sound information production (4.4%), and retail (3.8%). On the other hand, ICT intensity is relatively low in industries such as agriculture, forestry, and fishery and mining (1.3%), transportation (1.9%), pulp, paper, and coated and glazed paper (2.0%), and ceramic, stone and clay products (2.1%).

In order to examine how firm size and firm age affect ICT intensity, we compare ICT intensity across groups of firms of different size (measuring firm size in terms of the number of employees)

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[6] The JIP Database 2014 is available on the following RIETI website:
http://www.rieti.go.jp/en/database/JIP2014/index.html

[7] We should also note that the economic depreciation rate may differ from the depreciation rate used by each firm for answering the survey.

[8] In Section 3 and later sections, we treat all the components of ICT input as factor of production, the cost of which makes up part of value added, and not as intermediate inputs, which must be subtracted from gross output to calculate value added. Therefore, to make Table 1 consistent with our analysis in Section 3 and later sections, we treat (3) expenditure on ICT service inputs as part of value added and not as a part of intermediate inputs. Therefore, we add this expenditure on ICT service inputs to the regular value added data derived from the *Basic Survey* when calculating the denominator of our ICT intensity values. It should also be noted that our data for (4) other ICT expenditures include certain expenditures which are not included in regular value added data, such as communication line fees and fees for the usage of data centers. However, our data for (4) also include some expenditures which are included in regular value added data, such as labor costs of the information system division. Since we do not know the composition of (4), we assume that most of (4) is already included in regular value added data and do not add this to the value added data derived from the *Basic Survey*.

and across groups of firms of different age. The results are shown in Tables 2 and 3 respectively. Average firm size and age differ considerably across industries. For example, most firms in the information services industry are very young and ICT intensive. Therefore, if we divided all firms of all industries in terms of firm age, the group of young firms would include a disproportionately large number of information services firms and the ICT intensity of this group would be correspondingly high. In order to eliminate this kind of industry effect, we divided firms into four groups with the same number of firms by firm age and by firm size within each industry and each year.[9]

Table 1. Basic Statistics for Firms' ICT Intensity by Industry: Pooled Data, 1995–2007

	Industry	No. of obs.	Mean	SD	Min.	Median	Max.
20	Information services	1,468	33.72	31.00	0.00	29.49	125.95
24	Finance and insurance	247	21.60	19.28	0.00	18.23	138.64
19	Newspapers and printing	247	6.12	7.19	0.00	4.17	59.52
22	Wholesale	4681	5.30	5.98	0.00	4.01	77.59
11	Telecommunication equipment	404	5.25	5.80	0.00	3.98	50.50
18	Telecommunication, broadcasting, and video and sound information production	171	4.37	12.31	0.00	1.32	119.47
23	Retail	3419	3.84	5.06	0.00	2.85	70.69
10	Electrical machinery	1556	3.51	4.51	0.00	2.47	85.74
9	General machinery	1,409	3.44	4.99	0.00	2.46	89.98
14	Other manufacturing	866	3.42	4.54	0.00	2.19	62.60
13	Precision machinery	258	3.32	3.86	0.00	2.30	29.17
4	Chemical products	964	3.23	2.62	0.00	2.77	20.96
17	Electricity, gas and water supply	450	3.20	2.82	0.00	2.84	23.47
7	Steel	392	3.17	2.83	0.00	2.55	17.87
2	Textile products	416	3.03	3.29	0.00	2.32	23.81
1	Foods, beverages, tobacco, and prepared animal foods	1,361	2.87	3.28	0.00	2.00	34.55
27	Other non-manufacturing	1,436	2.83	6.38	0.00	1.23	93.66
8	Non-ferrous metal and metal products	956	2.73	2.98	0.00	2.02	40.34
5	Petroleum and coal products and plastics	496	2.53	2.56	0.00	1.87	28.65
12	Transportation equipment	1351	2.49	3.40	0.00	1.77	86.24
16	Construction	623	2.35	4.60	0.00	1.25	79.12
6	Ceramic, stone and clay products	372	2.10	2.12	0.00	1.53	13.97
3	Pulp, paper, and coated and glazed paper	317	1.98	2.27	0.00	1.46	22.80
21	Transportation	221	1.91	2.60	0.00	0.98	14.69
15	Agriculture, forestry, and fishery and mining	84	1.32	1.56	0.00	0.92	11.93
	Total	24,165	5.67	11.80	0.00	2.64	138.64

As Table 2 shows, there is a close relationship between firm size and ICT intensity. Large firms tend to have a higher ICT intensity. The average ICT intensity of the group of largest firms is 6.6%, which is 1.6 percentage points higher than the ICT intensity of the group of smallest firms. In the case of firm age (Table 3), no simple linear relationship can be observed. Both the oldest and the youngest firms have a higher ICT intensity than the firms in between. The average ICT intensity of the oldest firm group is 6.2% and that of the youngest firm group is 5.8%. The average ICT intensity of the oldest firm group is 0.9 percentage points higher than the average ICT intensity of the third oldest group.

When we compare median value of ICT intensity across different firm-age groups, the

[9] Because of missing values for ICT intensity, the number of firms across firm size (age) groups in Tables 2 and 3 is not exactly the same.

relationship between ICT intensity and firm age is monotonic. Younger firms are less ICT intensive. It seems that the group of youngest firms includes some exceptionally ICT intensive firms and these firms raise the average value of the ICT intensity of this firm group.

We should also note that older firms tend to be larger, so that a possible reason why older firms have a high ICT intensity is that they are larger. We will examine this issue in more detail in Section 3 by estimating production functions.

Table 2. ICT Intensity by Firm Size

Group	No. of obs.	Number of employees					ICT / VA (%)				
		Mean	SD	Min.	Median	Max.	Mean	SD	Min.	Median	Max.
Group_EMP1 (largest)	5,935	3,565	6,605	94	1,783	122,927	6.6	12.0	0.0	3.8	138.6
Group_EMP2	6,070	584	415	72	472	10,779	5.7	11.7	0.0	2.8	113.8
Group_EMP3	5,985	242	142	63	201	3,284	5.4	11.9	0.0	2.2	126.0
Group_EMP4	6,175	103	51	50	89	637	5.0	11.5	0.0	1.9	118.1
Total	24,165	1,108	3,572	50	307	122,927	5.7	11.8	0.0	2.6	138.6

Table 3. ICT Intensity by Firm Age

Group	No. of obs.	Firm age					ICT / VA (%)				
		Mean	SD	Min.	Median	Max.	Mean	SD	Min.	Median	Max.
Group_Age1 (oldest)	5,480	65	16	30	62	291	6.2	11.8	0.0	3.3	138.6
Group_Age2	6,163	49	8	21	51	81	5.4	11.2	0.0	2.7	119.5
Group_Age3	6,136	39	9	16	40	64	5.3	11.6	0.0	2.3	126.0
Group_Age4	6,346	22	10	0	22	57	5.8	12.5	0.0	2.2	124.3
Total	24,125	43	19	0	44	291	5.7	11.8	0.0	2.6	138.6

To sum up our results, smaller firms tend to have a lower ICT intensity than larger firms. In the case of firm age, there is no simple linear relationship between firm age and ICT intensity. Both young and very old firms tend to have a higher ICT intensity, while firms in between tend to have a lower ICT intensity.

As already explained, our ICT expenditure data consist of four types of ICT expenditures, that is, ICT hardware input, ICT software input, ICT services input, and other ICT expenditures. This means we can also examine whether the composition of ICT expenditures differs across different firm-size and firm-age groups.

Tables 4 shows the composition of ICT expenditures by firm-size group. The table suggests that larger firms tend to spend more on ICT software and ICT services, while smaller firms tend to spend more on other ICT expenditures. It appears that if there are obstacles hampering the use of ICT by smaller firms, these are closely related with the use of ICT software and ICT services. We will discuss this issue in Section 4.

Table 5 shows the composition of ICT expenditures by firm-age group. The figures indicate that the group of youngest firms spends more on ICT hardware and software and the group of oldest firms spends more on ICT service input and other ICT expenditures.

Table 4. Composition of ICT Expenditure by Firm Size

Group	ICT hardware/Total ICT expenditure (%)	ICT software/Total ICT expenditure (%)	ICT service input/Total ICT expenditure (%)	Other ICT expenditure/Total ICT expenditure (%)
Group_EMP1 (largest)	15.4	41.7	27.6	15.4
Group_EMP2	15.4	32.1	20.3	32.3
Group_EMP3	16.4	20.5	19.4	43.7
Group_EMP4	15.9	29.6	20.6	33.9
Total	15.8	31.1	22.0	31.2

Table 5. Composition of ICT Expenditure by Firm Age

Group	ICT hardware/Total ICT expenditure (%)	ICT software/Total ICT expenditure (%)	ICT service input/Total ICT expenditure (%)	Other ICT expenditure/Total ICT expenditure (%)
Group_Age1 (oldest)	14.5	28.2	25.0	32.2
Group_Age2	15.5	31.3	20.4	32.8
Group_Age3	16.0	23.0	20.4	40.6
Group_Age4	16.9	41.4	22.3	19.4
Total	15.8	31.1	22.0	31.2

3. Do Production Functions Differ by Firm Size and Firm Age?

In this and the next section, we examine why larger and older firms (and also firms in the youngest firm group) tend to be more ICT-intensive than other firms. As already discussed in Section 1, there are two potential explanations for this observation. One explanation is that the production function (and the production technology underlying the production function) differs by firm size and firm age. For example, if the production function on a value added basis is of a Cobb-Douglas type and the coefficient for ICT input is larger for larger firms than for smaller firms, then the optimal ICT intensity (ICT input costs over value added) of larger firms will be higher than that of smaller firms. The other possible explanation is that because of some constraint on ICT input, such as liquidity constraints, smaller firms cannot increase their ICT input to the optimal level. By estimating the production function parameters for each firm-size group and deriving the marginal product of one yen of ICT input by firm size, we examine whether such constraints on ICT input at small firms are indeed present.

As a first step, we estimate the production function. We assume a Cobb-Douglas-type value added production function. There are three production factors: labor, non-ICT capital, and ICT inputs. We assume that the coefficients for the three production factors can differ by firm-size group and firm-age group.

Specifically, we estimate the following production function:

$$\begin{aligned}\ln Y_{f,t} &= \lambda_0 + \alpha \ln(L_{f,t}) + \beta \ln(K_{f,t}) + \gamma \ln(ICT_{f,t}) \\ &+ \sum_{\theta} \alpha_\theta x_{\theta,f,t} \ln(L_{f,t}) + \sum_{\theta} \beta_\theta x_{\theta,f,t} \ln(K_{f,t}) + \sum_{\theta} \gamma_\theta x_{\theta,f,t} \ln(ICT_{f,t}) \\ &+ \sum_{\theta} \delta_\theta x_{\theta,f,t} + \varepsilon_{f,t}\end{aligned} \qquad (1)$$

where $Y_{f,t}$, $L_{f,t}$, $K_{f,t}$, and $ICT_{f,t}$ denote the gross value added, labor input, non-ICT capital stock, and ICT input of firm f in year t, respectively. θ denotes the firm-size or firm-age group and $x_{\theta,f,t}$ is a dummy variable which takes a value of one if firm f belongs to firm size/age group θ in year t. In order to take into account the possibility that the coefficient for the three factor inputs differs by firm-size group and firm-age group, we add cross-terms of $x_{\theta,f,t}$ and the log value of each factor input, $\ln(L_{f,t})$, $\ln(K_{f,t})$, and $\ln(ICT_{f,t})$. In the estimation, we also add year dummies and industry dummies. From the estimated coefficients, γ_θ, we can judge whether the coefficient for ICT input differs by firm-size group and firm-age group.

Gross value added is measured as gross output minus intermediate inputs. Intermediate input is calculated as (cost of sales + operating cost) − (wages + depreciation cost). For the commerce sector, gross output is measured by the commerce margin. As explained in greater detail in footnote 8, we treat all the components of ICT input as factors of production, the cost of which makes up part of value added, and not as intermediate inputs. Specifically, we treat (3) expenditure on ICT service inputs as part of value added and not as part of intermediate inputs.

In addition, it is necessary to convert the nominal ICT input data constructed in the manner explained in Section 2 into real ICT input in order to take changes in ICT input over time into account. We do so by deflating the nominal ICT input data using the gross output deflator for the information service sector, which we obtain from the JIP Database 2011.

As labor input, we use the product of each firm's number of employees and the industry average of annual working hours, which is taken from the JIP Database 2011. Capital stock is obtained by multiplying the nominal book value of tangible fixed assets with the industry-level ratio of the real value of capital to the book value of capital, which we calculate using data from the *Financial Statements Statistics of Corporations* published by the Ministry of Finance. As ICT input, we use the sum of the four types of ICT expenditures mentioned in Section 2.[10]

The estimation results based on pooled OLS regression are reported in Table 6. In order to take account of potential endogeneity problems, we also estimated the equation employing the system generalized method of moments (GMM) approach. However, the main results remain essentially unchanged.[11] Another issue we need to take account of is that factor input coefficients may differ across industries. To take this possibility into account, we estimated equation (1) separately for (1)

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[10] We should note that our ICT input data include ICT capital service input and some labor input such as labor costs of the information system division. Since these values are not subtracted from capital and labor input, some items may be double-counted.

[11] Because of space restrictions we do not show GMM estimation results here.

manufacturing, (2) non-manufacturing excluding information services and finance and insurance, and (3) information services and finance and insurance. The results are reported in Table 7.

Table 6. Results of the Production Function Estimation: All Industries

	All industries		
	(1)	(2)	(3)
lnK	0.117 ***	0.087 ***	0.083 ***
	[11.451]	[8.820]	[7.900]
lnK・Group_Age1 (oldest)	0.036 ***		0.014
	[2.637]		[1.010]
lnK・Group_Age2	0.034 **		0.02
	[2.289]		[1.370]
lnK・Group_Age3	0.016		0.01
	[1.262]		[0.799]
lnK・Group_EMP1 (largest)		0.096 ***	0.088 ***
		[7.999]	[7.163]
lnK・Group_EMP2		0.064 ***	0.059 ***
		[4.701]	[4.344]
lnK・Group_EMP3		0.023 *	0.021 *
		[1.903]	[1.763]
lnL	0.643 ***	0.751 ***	0.725 ***
	[31.341]	[24.328]	[22.730]
lnL・Group_Age1 (oldest)	0.037		0.071 **
	[1.325]		[2.555]
lnL・Group_Age2	0.035		0.052 *
	[1.201]		[1.799]
lnL・Group_Age3	0.015		0.016
	[0.572]		[0.594]
lnL・Group_EMP1 (largest)		-0.192 ***	-0.206 ***
		[-5.634]	[-6.148]
lnL・Group_EMP2		-0.123 ***	-0.13 ***
		[-3.190]	[-3.411]
lnL・Group_EMP3		-0.038	-0.042
		[-1.058]	[-1.176]
lnICT	0.239 ***	0.197 ***	0.213 ***
	[30.059]	[23.573]	[21.938]
lnICT・Group_Age1 (oldest)	-0.039 ***		-0.049 ***
	[-3.536]		[-4.512]
lnICT・Group_Age2	-0.03 ***		-0.037 ***
	[-2.775]		[-3.407]
lnICT・Group_Age3	-0.013		-0.014
	[-1.199]		[-1.294]
lnICT・Group_EMP1 (largest)		0.042 ***	0.052 ***
		[3.887]	[4.808]
lnICT・Group_EMP2		0.034 ***	0.039 ***
		[3.164]	[3.656]
lnICT・Group_EMP3		0.002	0.004
		[0.207]	[0.419]
Group_Age1 (oldest)	-0.384 ***	-0.07 ***	-0.375 ***
	[-5.130]	[-4.342]	[-4.689]
Group_Age2	-0.407 ***	-0.082 ***	-0.37 ***
	[-5.509]	[-5.448]	[-4.868]
Group_Age3	-0.202 ***	-0.054 ***	-0.157 **
	[-2.762]	[-3.853]	[-2.187]
Group_EMP1 (largest)		0.273 **	0.384 ***
		[2.156]	[3.012]
Group_EMP2		0.115	0.17
		[0.818]	[1.217]
Group_EMP3		0.063	0.089
		[0.481]	[0.679]
Observations	22,001	22,001	22,001
Adj. R-Squared	0.917	0.919	0.919

Notes:

1. The dependent variable is the log of gross value added.

2. Figures in square brackets are t-statistics.

3. Year and industry dummies are included in all regressions, but their estimated coefficients are not reported.

4. * p<0.10, ** p<0.05, and *** p<0.01.

5. The estimation is based on pooled OLS regression.

Table 7. Results of the Production Function Estimation for Three Industry Groups

	Manufacturing	Non-manufacturing excluding information services and finance and insurance	Information services and finance and insurance
	(4)	(5)	(6)
lnK	0.13 ***	0.08 ***	0.041 *
	[7.675]	[4.586]	[1.688]
lnK･Group_Age1 (oldest)	0.042 *	-0.005	-0.013
	[1.842]	[-0.213]	[-0.532]
lnK･Group_Age2	0.049 **	0.028	-0.021
	[2.067]	[1.036]	[-0.850]
lnK･Group_Age3	0.064 ***	0.006	-0.003
	[3.015]	[0.261]	[-0.095]
lnK･Group_EMP1 (largest)	0.142 ***	0.083 ***	0.019
	[4.921]	[4.113]	[0.705]
lnK･Group_EMP2	0.085 ***	0.071 ***	-0.016
	[3.972]	[2.894]	[-0.660]
lnK･Group_EMP3	0.019	0.02	0.007
	[0.943]	[0.954]	[0.367]
lnL	0.797 ***	0.694 ***	0.584 ***
	[22.593]	[13.727]	[4.935]
lnL･Group_Age1 (oldest)	0.068 **	0.066 *	0.019
	[1.965]	[1.704]	[0.301]
lnL･Group_Age2	0.01	0.056	0.025
	[0.317]	[1.352]	[0.385]
lnL･Group_Age3	-0.014	0.018	0.044
	[-0.442]	[0.484]	[0.688]
lnL･Group_EMP1 (largest)	-0.268 ***	-0.196 ***	0.122
	[-6.005]	[-4.165]	[0.978]
lnL･Group_EMP2	-0.126 ***	-0.139 ***	0.224 *
	[-2.642]	[-2.831]	[1.876]
lnL･Group_EMP3	-0.071	-0.042	0.066
	[-1.537]	[-0.885]	[0.528]
lnICT	0.136 ***	0.255 ***	0.277 ***
	[10.641]	[14.007]	[10.705]
lnICT･Group_Age1 (oldest)	-0.064 ***	-0.037 **	-0.037
	[-3.674]	[-2.070]	[-1.530]
lnICT･Group_Age2	-0.028 *	-0.058 ***	-0.03
	[-1.649]	[-3.131]	[-1.195]
lnICT･Group_Age3	-0.034 **	-0.019	-0.04 *
	[-2.280]	[-0.989]	[-1.733]
lnICT･Group_EMP1 (largest)	0.038 **	0.041 **	-0.009
	[2.006]	[2.107]	[-0.384]
lnICT･Group_EMP2	0.038 **	0.014	0.01
	[2.332]	[0.705]	[0.415]
lnICT･Group_EMP3	0.027 *	-0.003	-0.026
	[1.853]	[-0.162]	[-1.365]
Group_Age1 (oldest)	-0.522 ***	-0.28 **	0.032
	[-4.059]	[-2.391]	[0.108]
Group_Age2	-0.388 ***	-0.412 ***	0.052
	[-3.056]	[-3.654]	[0.182]
Group_Age3	-0.332 ***	-0.163	-0.002
	[-3.039]	[-1.568]	[-0.006]
Group_EMP1 (largest)	0.329 *	0.359 **	-0.495
	[1.741]	[1.995]	[-0.875]
Group_EMP2	-0.115	0.204	-1.08 **
	[-0.545]	[0.987]	[-2.028]
Group_EMP3	0.173	0.086	-0.118
	[0.880]	[0.454]	[-0.213]
Observations	10,248	10,202	1,551
Adj. R-Squared	0.943	0.891	0.924

Note: See notes for Table 6.

Starting with the results in Table 6 and looking at the cross-terms of the firm-size dummy and ICT input, the estimated coefficients for the group of largest firms and for the next group of firms are statistically significant and positive in most specifications. On the other hand, in the case of the cross-terms of the firm-age dummy and ICT input, the estimated coefficients for the group of oldest firms and that for the next group of firms are statistically significant and negative in most specifications. The estimation results further show that older firms are more labor intensive and larger firms are more capital intensive.

When the size effect and the age effect are combined, we have a large difference in the share of ICT input costs across firm groups. For example, in the case of specification (3) in Table 6, the coefficient on the ICT input for firms which belong to both the youngest firm group and the largest firm group is 0.265 (0.213+0.052=0.265), which is 0.101 – or 62% ((0.265-0.164) /0.164=0.62) – higher than that of firms which belong to both the oldest firm group and the smallest firm group.

Table 7 shows the results on differences in the ICT input coefficient across firms of different size for the three broad industry categories. The results overall are not very different from those in Table 6. However, it should be noted that both the estimated coefficients on the cross-terms of the firm size dummies and ICT input and the estimated coefficients on the cross-terms of the firm age dummies and ICT input are not statistically significant in the case of information services and finance and insurance.

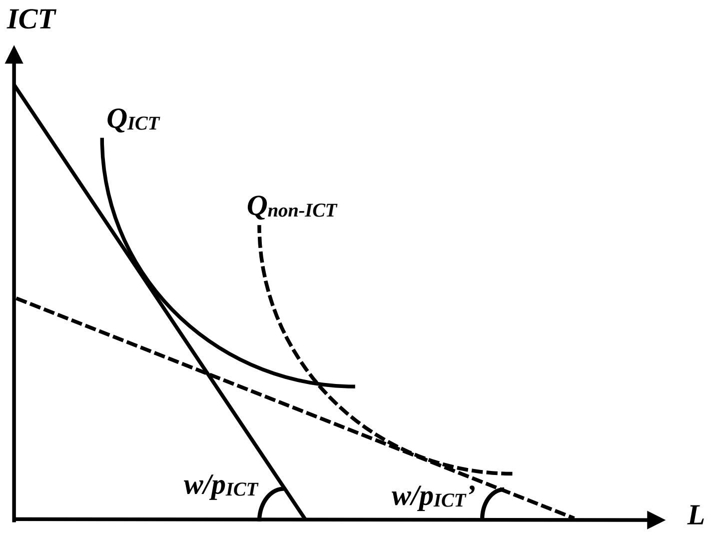
How can we explain the finding that smaller firms appear to adopt less ICT-intensive production technologies? The simplest and most plausible answer probably is that the factor prices firms face differ by firm size.[12] To see why, let us assume there are two production factors, ICT

[12] As we have already explained, our ICT input data is derived by deflating nominal ICT input values by the gross output deflator for the information service sector. Therefore, we do not take account of differences in ICT input prices faced by firms of different size or age. Does this mean that there is a risk that our estimated coefficients are biased as a result? The answer is no, at least as long we can assume that the production function is of a Cobb-Douglas type and the differences in ICT input prices across different firm groups do not change over time. This can be shown in the following way. Let p_θ denote the relative ICT input prices faced by firm group θ in comparison with the average of ICT prices faced by all firms. Assuming that p_θ does not depend on time, the production function we are estimating becomes

$$\begin{aligned}
\ln Y_{f,t} &= \lambda_0 + \alpha \ln(L_{f,t}) + \beta \ln(K_{f,t}) + \gamma \ln(p_\theta ICT_{f,t}) \\
&\quad + \sum_\theta \alpha_\theta x_{\theta,f,t} \ln(L_{f,t}) + \sum_\theta \beta_\theta x_{\theta,f,t} \ln(K_{f,t}) + \sum_\theta \gamma_\theta x_{\theta,f,t} \ln(p_\theta ICT_{f,t}) \\
&\quad + \sum_\theta \delta_\theta x_{\theta,f,t} + \varepsilon_{f,t} \\
&= \lambda_0 + \alpha \ln(L_{f,t}) + \beta \ln(K_{f,t}) + \gamma \ln(ICT_{f,t}) \\
&\quad + \sum_\theta \alpha_\theta x_{\theta,f,t} \ln(L_{f,t}) + \sum_\theta \beta_\theta x_{\theta,f,t} \ln(K_{f,t}) + \sum_\theta \gamma_\theta x_{\theta,f,t} \ln(ICT_{f,t}) \\
&\quad + \sum_\theta (\gamma + \gamma_\theta x_{\theta,f,t}) \ln(p_\theta) + \sum_\theta \delta_\theta x_{\theta,f,t} + \varepsilon_{f,t}
\end{aligned}$$

inputs and labor. Suppose that there are two technologies, an ICT-intensive technology and a non-ICT-intensive technology. Let us assume that the isoquants of the ICT-intensive technology and the non-ICT-intensive technology can be expressed by curves Q_{ICT} and $Q_{non\text{-}ICT}$ in Figure 3. In this figure, the vertical axis denotes ICT input, *ICT*, and the horizontal axis denotes labor input, *L*. Suppose that smaller firms face a higher price of ICT inputs than larger firms. In Figure 3, p_{ICT} denotes the price of ICT inputs which larger firms face and p_{ICT}' denotes the price of ICT inputs which smaller firms face. *w* denotes the wage rate. Under these circumstances, cost minimization implies that smaller firms will choose the non-ICT-intensive technology and larger firms will choose the ICT-intensive technology. In Section 5, we will discuss which factors may be responsible for raising the price of ICT inputs for smaller firms in Japan.

Figure 3. Price of ICT Inputs and the Choice of Technology



Turning to the results on the role of firm age, the following cohort effect probably helps to explain why younger firms are more ICT intensive. In their early stage, new firms choose their production technology, and once firms have adapted their organizational structure and compositional makeup of core workers to the technology they adopted, it becomes costly to change the technology they use. Since there are continuous innovations in ICT and the importance of ICT in the latest production technologies increases over time, younger firms tend to have a higher ICT intensity than older firms. In other words, older firms' production is less ICT intensive probably because they chose their technology in a non-ICT age. Another factor which may explain why older firms choose

This equation shows that ICT input price differences are controlled for by the firm group dummies $\delta_\theta x_{\theta,f,t}$.

less ICT-intensive technology is the age of their workers. As Meyer (2011) has shown, firms with a higher share of older employees tend to not to adopt new or significantly improved technologies, likely because older employees tend to be less ICT literate than younger employees. Thus, since older firms tend to have more older workers, they are slower to adopt new ICT.

4. Marginal Product of ICT by Firm Size and Firm Age

In this section, we examine whether the difference in ICT intensities across different firm-size groups and firm-age groups can be fully explained by differences in the ICT input coefficient in the production function we found above. Another factor that may be responsible for the differences in ICT intensity by firm size and firm age is constraints on ICT input, such as liquidity constraints, which might prevent, for example, smaller firms from increasing ICT input to the optimal level. If such constraints are present, the marginal product of ICT input at smaller firms should be higher than that at bigger firms.

To check whether this is the case, we calculate the marginal product of ICT input by firm-size group and by firm-age group using the estimated production function.

Partially differentiating both sides of equation (1) by ICT input yields the following equation:

$$\frac{\partial Y_{f,t}}{\partial IT_{f,t}} = \frac{\left(\gamma + \sum_{\theta} \gamma_{\theta} x_{\theta,f,t}\right)}{\left(\frac{IT_{f,t}}{Y_{f,t}}\right)} \qquad (2)$$

This equation means that the marginal product of ICT input depends on the coefficient of ICT input in the production function (the numerator of equation (2)) and the ICT intensity of the firm (the denominator of equation (2)).[13] If the ratio of the ICT intensity of the group of largest firms to that of the group of smallest firms is larger than the ratio of the coefficient of the ICT input of the largest firms to that of the smallest firms, then the marginal product of ICT input at the largest firms will be lower than that at the smallest firms. This means that either the largest firms' ICT input is greater than the optimal level or the smallest firm group's ICT input is smaller than its optimal level.

Table 8 reports the derived mean and the basic statistics of the marginal product of ICT input by firm-size group and by industry group. The calculation is based on the estimation result of specification (3) in Table 6 and the result in Table 7, where we estimated the production functions of firms in manufacturing, non-manufacturing (excluding information services and finance and insurance), and information services and finance and insurance separately. Table 8 indicates that the

[13] Since our data on ICT input are not adjusted for differences in ICT input prices faced by different firm groups, the left-hand side of the equation denotes how much value added (in 2000 prices) will increase as a result of a one yen increase in ICT input (in 2000 prices).

marginal product of the ICT input of smaller firms tends to be greater than that of larger firms. Since the derived marginal product of ICT input is quite large and it seems implausible to assume that larger firms tend to choose ICT input above the optimal level, we can probably conclude that small firms cannot raise their ICT input to the optimal level because of some constraints.

Table 9 reports the derived mean and the basic statistics of the marginal product of ICT input by firm-age group and by industry group. Like Table 8, the calculation is based on the estimation result of specification (3) in Table 6 and estimation result in Table 7. Table 9 suggests that the marginal product of the ICT input of younger firms tends to be greater than that of older firms. As in the comparison across firm-size groups, since the derived marginal product of ICT input is quite large and it seems implausible to assume that older firms tend to choose ICT input above the optimal level, we can probably conclude that younger firms cannot raise their ICT input to the optimal level because of some constraints.

To sum up our findings from Tables 8 and 9, the marginal product of ICT input at smaller and younger firms tends to be higher than at larger and older firms. It seems that smaller and younger firms cannot raise their ICT input to the optimal level because of some constraints.

Table 8. Marginal Product of ICT Input by Firm-Size Group
Based on the Estimation Result of Specification (3) in Table 6 and the Result in Table 7

Group by no. of employees		No. of obs.	Mean	SD	Min.	Median	Max.
All industries	Group_EMP1 (largest)	5,389	15.07	131.55	0.08	4.81	6,146
	Group_EMP2	5,541	18.09	159.15	0.08	6.05	10,422
	Group_EMP3	5,439	19.71	114.21	0.03	6.18	5,785
	Group_EMP4	5,508	22.33	150.92	0.06	6.74	8,959
	Total	21,877	18.81	140.21	0.03	5.79	10,422
Manufacturing	Group_EMP1 (largest)	2,506	6.24	27.37	0.14	3.19	1,085
	Group_EMP2	2,599	10.70	47.37	0.25	4.78	1,461
	Group_EMP3	2,543	17.02	88.01	0.19	6.38	4,031
	Group_EMP4	2,565	15.28	60.72	0.16	5.62	2,209
	Total	10,213	12.33	60.21	0.14	4.78	4,031
Non-manufacturing	Group_EMP1 (largest)	2,511	26.53	237.01	0.31	5.62	8,252
	Group_EMP2	2,559	26.22	256.76	0.22	6.56	11,937
	Group_EMP3	2,523	26.11	147.31	0.04	6.95	3,723
	Group_EMP4	2,549	31.43	271.23	0.21	7.58	12,406
	Total	10,142	27.58	233.28	0.04	6.60	12,406
IT services, finance & insurance	Group_EMP1 (largest)	372	2.87	10.86	0.05	0.45	183
	Group_EMP2	383	3.11	11.61	0.06	0.43	135
	Group_EMP3	373	3.14	13.15	0.04	0.23	152
	Group_EMP4	394	4.31	11.11	0.05	0.51	76
	Total	1,522	3.37	11.71	0.04	0.41	183

Table 9. Marginal Product of ICT Input by Firm-Age Group
Based on the Estimation Result of Specification (3) in Table 6 and the Result in Table 7

Group by firm age		No. of obs.	Mean	SD	Min.	Median	Max.
All industries	Group_AGE1 (oldest)	5,057	14.69	136.25	0.05	4.39	6,146
	Group_AGE2	5,619	13.54	57.01	0.03	5.34	1,807
	Group_AGE3	5,524	22.86	165.29	0.06	6.96	8,959
	Group_AGE4	5,677	23.77	171.32	0.07	7.27	10,422
	Total	21,877	18.81	140.21	0.03	5.79	10,422
Manufacturing	Group_AGE1 (oldest)	2,327	8.04	87.93	0.16	2.90	4,031
	Group_AGE2	2,607	9.95	25.13	0.31	4.85	447
	Group_AGE3	2,635	13.22	58.02	0.14	5.33	2,209
	Group_AGE4	2,644	17.56	56.36	0.22	7.14	1,461
	Total	10,213	12.33	60.21	0.14	4.78	4,031
Non-manufacturing	Group_AGE1 (oldest)	2,371	24.40	207.63	0.21	5.72	8,252
	Group_AGE2	2,648	18.08	90.67	0.04	5.69	2,241
	Group_AGE3	2,525	34.71	296.76	0.23	7.58	12,406
	Group_AGE4	2,598	33.23	281.07	0.22	7.82	11,937
	Total	10,142	27.58	233.28	0.04	6.60	12,406
IT services, finance & insurance	Group_AGE1 (oldest)	359	2.96	11.09	0.04	0.39	135
	Group_AGE2	364	3.11	12.44	0.05	0.46	183
	Group_AGE3	364	2.71	6.82	0.04	0.23	63
	Group_AGE4	435	4.48	14.45	0.06	0.61	152
	Total	1,522	3.37	11.71	0.04	0.41	183

5. What Impedes the Full Use of ICT by Japanese Firms?

In this section, we examine impediments to the full use of ICT by Japanese firms based on our analysis in Sections 3 and 4 as well as preceding studies by the Japanese government and other institutions in Japan.

As seen in Section 3, ICT intensity is especially low at smaller firms. Moreover, as seen in Sections 4 and 5, it appears that both smaller firms' choice of non-ICT-intensive technology and obstacles to ICT use by small firms are responsible for the low use of ICT at small firms. We also argued that a likely explanation for smaller firms' choice of non-ICT-intensive technology is a higher price for ICT inputs for smaller firms. Turning to firm age, we found that younger firms choose more ICT-intensive technology. We also found that younger firms appear to be facing constraints with regard to ICT input and that their ICT input is below the optimal level.

Let us first consider what factors might make smaller firms in Japan face a higher price for ICT inputs. One possible element is that since it is too costly for small firms to have their own ICT service division providing a full range of ICT services, having access to efficient vendors of ICT services is a key factor for procuring ICT inputs at a reasonable price; however, in Japan, the market for business process outsourcing (BPO), which includes outsourcing of ICT processes, is not well developed. According to METI (2014b), the size of the BPO market in Japan was 663 billion yen in 2012, whereas in the United States it was 12 trillion yen in the same year (the original source is HfS Research, *State of the Outsourcing Industry 2013*).

The underdevelopment of the BPO market in Japan is closely related with the rigidity of the labor market. Since it is difficult for Japanese firms to lay off workers, Japanese firms hesitate to restructure costly internal business processing divisions. Moreover, even when they restructure such divisions, they often relocate workers in such divisions to affiliates or firms in the same business group and procure business process services from the firms to which they transferred former employees. Because of these constraints, Japanese firms cannot procure business services from the most productive vendors, reducing the benefit of BPO and keeping the BPO market underdeveloped. According to METI (2008), 43.1% of Japanese firms which rely on BPO outsourced services either to their affiliates or to firms in the same business group. Moreover, the underdevelopment of the BPO market makes it difficult for firms, especially those that do not belong to a firm group, to find reliable vendors. According to METI (2014a), 37.1% of Japanese firms indicated that they wanted objective indicators and a certification system regarding the ability of BPO vendors. In the United States, only 19.0% of firms indicated that such indicators or certification system were necessary. As a result of these problems, BPO is mainly conducted by large firms. According to METI (2014a), in the case of firms with more than 5,000 employees, 55.1% of surveyed firms relied on BPO. In contrast, in the case of firms with fewer than 300 workers, only 22.8% of firms relied on BPO. These data are consistent with our finding in Table 4 that smaller firms tend to spend more on ICT hardware than other firms but less on ICT software and ICT services.

Another factor which makes ITC inputs expensive for small firms is the difficulties they face in recruiting ICT experts. According to a survey by NISTEP (1993) on graduates of the undergraduate department of technology of the Tokyo Institute of Technology (Tokyo Tech), the University of Tokyo, and the Massachusetts Institute of Technology (MIT) who graduated in 1960, 1970, 1980 or 1985, 40.1% of graduates from the two Japanese universities cited success in the firm where they were currently working as their career ambition, while only 10.4% replied that their ambition was to found a new firm. In contrast, only 22.0% of graduates from MIT cited success in their current firm as their career ambition and 25.7% hoped to establish their own firm. Moreover, while only 16.2% of graduates from the two Japanese universities had changed jobs in the past, more than 70.2% of MIT graduates had done so. Probably reflecting these differences in desired career paths and in labor markets, a much larger percentage of graduates from the two Japanese universities are working at large firms than MIT graduates. Specifically, in 1991, 54.0% of graduates of the two Japanese universities worked at firms with more than 10,000 employees, 20.8% worked at firms with 3,000–9,999 employees, and 10.7% worked at firms with fewer than 300 employees. In the case of MIT graduates, 35.3% worked at firms with more than 10,000 employees, 11.2% worked at firms with 3,000–9,999 employees, and 32.3% worked at firms with fewer than 300 employees.

In addition to these differences among graduates, the supply of ICT software experts in Japan is much smaller than that in the United States (Arora et al. 2011).[14] These factors are likely to make ICT input prices in Japan more expensive for smaller than for larger firms.

Next, let us consider what factors prevent smaller firms and younger firms from raising their ICT input to the optimal level and keep their marginal product of ICT input at a high level. One plausible factor is liquidity constraints. Not only purchases of ICT hard- and software, but also many other types of ICT expenditure, such as expenditure for data processing and data input, the labor costs of information system divisions, etc., have some characteristics of investment, that is, they are expenditures for future output and profits. In the two lost decades, large firms accumulated large amounts of liquid assets, since they made substantial profits but investment opportunities were scarce. In contrast, most smaller and/or growing young firms need to finance their investment externally. Yet, because most Japanese banks still require tangible assets as collateral for lending and venture capital markets are not well developed in Japan, it is difficult for such small/young firms to finance intangible ICT investment such as purchases of ICT software or a reorganization of their information system. As a result, many small/young firms in Japan may be liquidity-constrained when investing in ICT intangibles. In the case of firm size, this explanation is consistent with our finding in Tables 4 and 5 that smaller firms spend considerably less on ICT software and ICT service inputs than larger firms.

Another likely explanation is that many small firms in Japan do not have sufficient knowledge with regard to new ICT and do not realize the potential merits of ICT inputs. According to a survey by the Japan Electronics and Information Technology Industries Association (JEITA) of executives and managers of non-IT business units of Japanese and US firms with more than 300 employees, the share of respondents at Japanese firms that answered that they had never heard of or did not know much about private clouds, public clouds, the business use of mobile technology, big data, and social networks were 45.8%, 45.8%, 21.8%, 42.6%, and 25.9% respectively. In the case of US firms, the corresponding shares were 9.3%, 1.0%, 3.6%, 2.1%, and 3.6% (JEITA 2013). While this survey does not cover small firms, judging from the difficulties small Japanese firms face in attracting ICT experts, it can be conjectured that, if anything, the situation is probably even worse and that most small Japanese firms have a serious ICT literacy problem.[15]

Another issue related to the ICT literacy problems is that most small firms do not conduct

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[14] According to the 2008 *IT Survey*, 39% of responding firms indicated that a scarcity of ICT workers impeded their exploitation of ICT.

[15] According to the 2013 *IT Survey*, in the case of firms with 200 or fewer employees, only 16% of responding firms purchased cloud computing services, while in the case of firms with more than 5,000 employees, 64% of responding firms purchased such services.

ex-ante or ex-post evaluations of ICT investment effect. According to the 2013 *IT Survey*, in the case of firms with 200 or fewer employees, only 21% of responding firms conducted such evaluations, while in the case of firms with more than 5,000 employees, 82% of responding firms conducted such evaluations. Probably because small firms do not conduct evaluations of ICT investment effects, they do not realize that they are missing the opportunity to benefit from the high marginal product ICT input offers.

So far we have discussed factors which hamper the adoption of ICT-intensive technology and increases in ICT input at small firms in Japan. Another reason why Japan seems to have fallen behind the United States in the use of ICT likely is that such small firms are much more prevalent in Japan than in the United States. Let us confirm this here. Tables 10(a) to (d) show the number of employees by firm-size group in Japan and the United States in all industries, in retail, in transport and communication, and in manufacturing. All the tables show that a larger percentage of employees work at smaller firms in Japan than in the United States.

Specifically, in the case of all industries, 42.5% of employees in Japan work at firms with fewer than 100 employees, while 27.8% work at firms with 1,000 or more employees. In the United States, the corresponding shares are 36.5% and 43.8% respectively. In the case of retail, 48.1% of employees in Japan work at firms with fewer than 100 employees and 31.9% work at firm with 1,000 or more employees. In the United States, the corresponding shares are 37.5% and 49.2% respectively.[16] Next, in transportation and communication, 32.4% of employees in Japan work at firms with fewer than 100 employees and 33.4% work at firms with 1,000 or more employees. The corresponding shares in the United States are 23.8% and 61.6%. Finally, in manufacturing, 38.1% of employees in Japan work at firms with fewer than 100 employees and 29.8% at firms with 1,000 or more employees, while the corresponding shares for the United States are 23.9% and 52.5% respectively.

Table 10. Number of Employees by Firm-Size Group: Japan-US Comparison

(a) All industries

	Japan				United States			
Firm size (No. of employees)	2001		2006		2001		2006	
(a) 1 to 4	1,486,150	4%	1,574,110	5%	5,866,666	5%	6,262,490	5%
(b) 5 to 9	2,176,265	7%	1,993,335	6%	6,844,090	6%	7,274,534	6%
(c) 10 to 19	2,954,728	9%	2,736,690	9%	8,369,988	7%	8,794,210	7%
(d) 20 to 49	4,442,234	13%	4,188,269	13%	11,767,978	10%	12,260,057	10%
(e) 50 to 99	3,300,383	10%	3,166,835	10%	8,442,216	7%	8,868,873	7%
(f) 100 to 249	4,177,981	13%	4,144,598	13%	9,813,665	9%	10,497,066	9%
(g) 250 to 499	2,832,588	9%	2,794,966	9%	6,258,633	5%	6,762,233	6%
(h) 500 to 999	2,528,727	8%	2,573,958	8%	5,866,407	5%	6,063,319	5%
(i) 1000+	9,274,478	28%	8,935,484	28%	51,128,895	45%	52,125,133	44%
Total	33,173,534		32,108,245		114,358,538		118,907,915	

[16] As mentioned in Section 1, another difference that should be pointed out is that the US retail sector is characterized by large chain stores (Haskel et al. 2007).

(b) Retail

	Japan				United States			
Firm size (No. of employees)	2001		2006		2001		2006	
(a) 1 to 4	789,819	13%	625,195	11%	1,062,053	5%	1,101,567	4%
(b) 5 to 9	507,874	9%	415,987	7%	1,470,780	6%	1,569,985	6%
(c) 10 to 19	705,610	12%	628,979	11%	1,904,010	8%	2,064,520	8%
(d) 20 to 49	767,783	13%	669,467	12%	2,675,629	12%	2,942,955	12%
(e) 50 to 99	419,252	7%	341,953	6%	1,668,362	7%	1,870,352	7%
(f) 100 to 249	508,036	9%	422,022	8%	1,481,273	6%	1,638,001	6%
(g) 250 to 499	373,506	6%	339,030	6%	843,713	4%	929,095	4%
(h) 500 to 999	341,549	6%	353,124	6%	714,735	3%	794,140	3%
(i) 1000+	1,477,098	25%	1,780,906	32%	11,269,323	49%	12,524,996	49%
Total	5,890,527		5,576,663		23,089,878		25,435,611	

(c) Transportation and communication

	Japan				United States			
Firm size (No. of employees)	2001		2006		2001		2006	
(a) 1 to 4	51,258	2%	37,893	1%	224,922	3%	229,301	3%
(b) 5 to 9	79,662	3%	67,218	2%	234,217	3%	227,971	3%
(c) 10 to 19	171,129	6%	149,115	5%	306,482	4%	298,995	5%
(d) 20 to 49	375,886	13%	343,637	12%	455,880	7%	459,931	7%
(e) 50 to 99	335,773	11%	310,490	11%	341,053	5%	353,750	5%
(f) 100 to 249	462,619	16%	454,895	16%	386,327	6%	419,916	6%
(g) 250 to 499	278,216	9%	280,279	10%	245,053	4%	291,340	4%
(h) 500 to 999	215,859	7%	224,798	8%	261,947	4%	255,113	4%
(i) 1000+	1,005,802	34%	937,570	33%	4,369,224	64%	4,070,378	62%
Total	2,976,204		2,805,895		6,825,105		6,606,695	

(d) Manufacturing

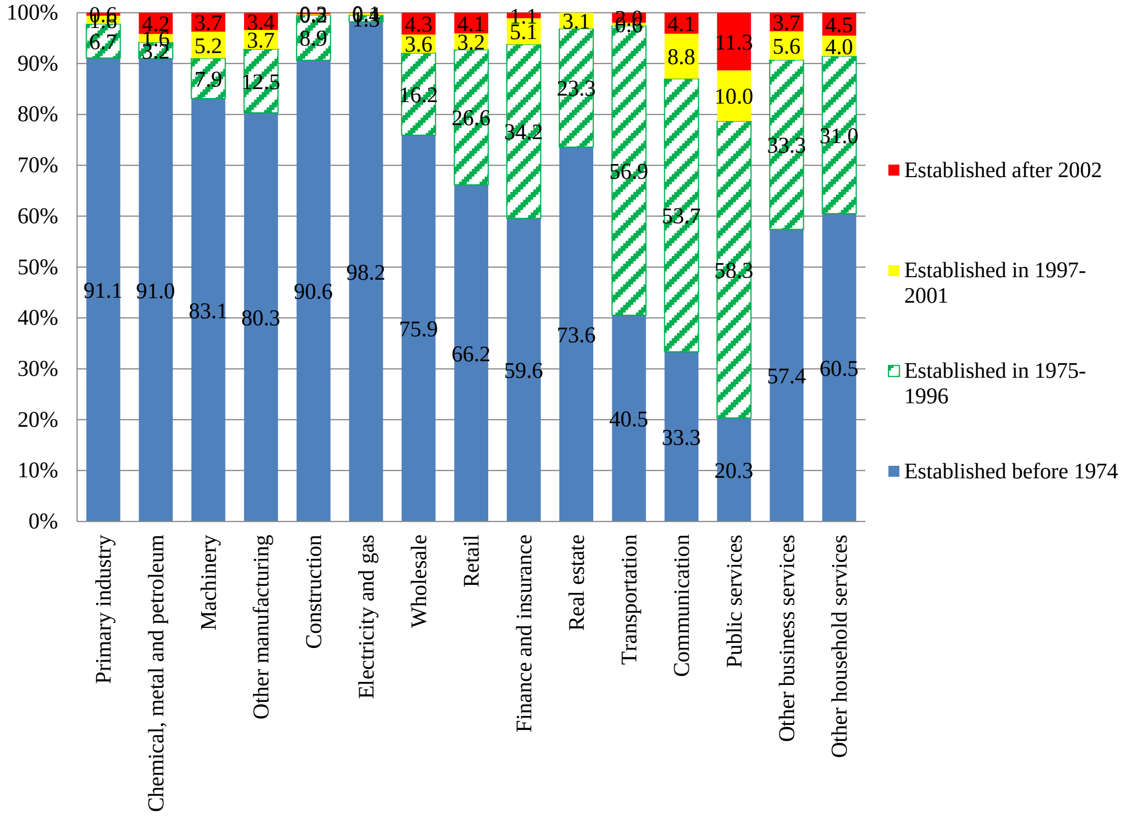
	Japan				United States			
Firm size (No. of employees)	2001		2006		2001		2006	
(a) 1 to 4	458,154	5%	363,892	4%	229,037	1%	223,716	1%
(b) 5 to 9	531,096	5%	432,717	5%	392,072	2%	371,885	2%
(c) 10 to 19	703,125	7%	601,620	7%	674,415	4%	628,010	4%
(d) 20 to 49	1,181,754	12%	1,046,411	12%	1,366,785	8%	1,233,262	8%
(e) 50 to 99	970,714	10%	898,544	10%	1,243,375	7%	1,135,717	8%
(f) 100 to 249	1,272,742	13%	1,243,568	14%	1,663,833	9%	1,526,959	10%
(g) 250 to 499	851,956	9%	851,150	10%	1,157,707	7%	1,049,426	7%
(h) 500 to 999	782,480	8%	726,704	8%	1,157,581	7%	987,476	7%
(i) 1000+	3,059,670	31%	2,614,799	30%	9,881,928	56%	7,902,920	52%
Total	9,811,691		8,779,405		17,766,733		15,059,371	

Sources: For Japan, *Establishment and Enterprise Census* for 2001 and 2006; for the United States, *Business Dynamics Statistics*.

These figures mean that in addition to the impediments to raising ICT input faced by smaller firms in Japan, such firms also play a much larger role in the Japanese economy, and it is the combination of these factors that explains why the average ICT intensity is lower in Japan than that in the United States.

Next, let us focus on firms' age. As we have already seen, younger firms tend to choose a production technology with a higher ICT input coefficient. However, there appear to be impediments that prevent younger firms from raising their ICT input to the optimal level and keep their marginal product of ICT input at a high level. As pointed out, one factor probably is liquidity constraints. Another factor that can be pointed out is that most young firms are small. They therefore face the impediments to ICT input of small firms already mentioned. Put differently, the estimated higher marginal product of ICT input for the younger firm groups reported in Table 9 shows the combined effect of firm age and firm size, since the younger firm groups contain many small firms. Does this mean that if Japan could remove the impediments to ICT input for smaller and younger firms and reduce the price of ICT inputs for smaller firms, there would be a large increase in ICT input and an ICT revolution driven by younger firms? The answer is probably no. Because of the low entry and exit rates in Japan, the market share of younger firms in most industries is very low. As Figure 4 shows, firms that have been around for 35 years or more have a majority of the market share in all industries except transportation, communication, and public services. While unfortunately we do not have comparable data for the United States, it is likely that because of Japan's low metabolism the market share of older firms is higher than that in the United States. It thus appears that Japan's low metabolism is another obstacle to an ICT revolution.

Figure 4. Sales Share by Firm-Age Group in 2009



Source: Fukao et al. (2012).

Note: The original data are from the *Establishment and Enterprise Census*.

To conclude this section, let us point out a number of other special factors which help to explain why not only the ICT intensity of small firms but also of all firms in Japan is comparatively low. The first is that most ICT contributes to the reduction of unskilled labor, but the high cost of laying off workers in Japan reduces the cost-saving benefits to firms of introducing ICT. Second, ICT services and software tend to be much more expensive in Japan than the corresponding services in the United States. Table 11 shows the price of ICT services and software in Japan relative to the corresponding services and software in the United States for FY 2012. US prices in US dollars are converted to yen using the average exchange rate for FY 2012, which was 78.6 yen per dollar. Since 2012, the yen has depreciated by about 30%. But even when we use an exchange rate of 120 yen per dollar, prices in Japan are still higher than those in the United States in most ICT services and software listed in Table 11. For example, the cost of outsourcing payroll accounting in Japan is 2.56×78.6/120=1.68 times that in the United States when we compare price levels in the two countries using an exchange rate of 120 yen per dollar. Japanese firms on average face higher prices for ICT service and software than US firms, and this probably leads them to choose production technologies with a smaller ICT input coefficient than US firms. As pointed out by Allen (2009), it was probably the extremely cheap energy available in Britain at the time that made Britain the birthplace of the (first) industrial revolution. Japan needs to lower price of ICT inputs to achieve an ICT revolution.

Table 11: Japan-US ICT Service Price Comparison for 2012

	Relative price: Japan/US
Telephone call (within city)	1.62
Telephone call (400 km)	3.56
Minimum charge for telephone line (business use)	0.99
Telephone call (international)	9.54
High-speed digital leased line	4.05
International leased line	7.94
Minimum charge for ADSL internet connection	1.09
Cellular phone call charge (one minute)	3.56
Cellular phone monthly fee (packaged plan)	2.92
Packaged software (average cost to purchase 100 sets of Windows Vista, Word 2007, and Excel 2007)	2.27
Outsourcing of payroll accounting	2.56

Source: METI, *The Survey on Foreign and Domestic Price Differentials for Industrial Intermediate Input 2012*.

Third, most Japanese firms regard ICT as a cost-cutting measure; in contrast, US firms tend to regard ICT as a way to develop new products and services or innovative business models. US firms are more likely to regard ICT as a core part of their corporate strategy and probably for this reason invest more in ICT inputs. According to JEITA (2013), the first and second most common objectives of ICT expenditure by Japanese firms that increased their ICT budget were cost cutting (48.2%) and the development of new products or services (22.4%); in contrast, for US firms, the first and second most common objectives of ICT expenditure by firms that increased their ICT budget were the development of new products or services (41.0%) and innovation in business models (28.8%).[17]

A fourth factor is that in order to avoid changes in corporate structure, employment adjustment, and training of workers, Japanese firms tend to choose custom software rather than packaged software, making ICT investment more expensive and network externality effects smaller, since each firm uses different custom software. Fifth and finally, during the two lost decades, Japanese firms reduced intangible investment (Fukao et al. 2009), probably for cost cutting purposes. ICT input and intangible assets may be close complements, as studies such as those by Bresnahan et al. (2002), Basu et al. (2003), and Crespi et al. (2007) have shown.[18] The reduction of intangible investment by Japanese firms may have contributed to the low productivity of ICT inputs and may have hampered investment in ICT inputs.

It seems that Japan's low ICT intensity is not only a problem of small-sized firms but also of firms of other sizes.

6. Conclusion

In this paper, we investigated why ICT investment in Japan has stagnated since the 1990s. Given that a notable characteristic of Japan's economy is that small as well as older firms play a much greater role than in other economies, particularly the United States, and that previous studies on other countries suggest that larger and younger firms are more likely to adopt new ICT technologies, our analysis mainly focused on firms' size and age. To conclude this paper, we summarize our main findings and consider their policy implications.

As a first step of our investigation, using firm-level data, we examined whether larger and/or younger firms tend to have a higher ICT intensity. We found that larger firms indeed have a higher ICT intensity. We also found that input of ICT software and ICT services was relatively low at smaller firms. Our empirical analysis further revealed that in the case of firm age, there was no simple linear relationship between firm age and ICT intensity. Both young and very old firms tend to have a higher ICT intensity, while firms in between tend to have a lower ICT intensity. As a next step, we estimated a Cobb-Douglas type production function and tested whether the ICT input coefficient differs across different firm-size groups and firm-age groups. We found that larger firms and younger firms tend to have a higher ICT input coefficient and that most of the differences in the ICT input

[17] On this issue, also see Motohashi (2010).
[18] On this issue, also see Acharya and Basu (2010) and Corrado et al. (2014).

coefficient across firm size/age groups are statistically significant. The other factor that may be responsible for the differences in ICT intensity by firm size and firm age is constraints on ICT input. To check whether this is the case, we calculated the marginal product of ICT input by firm-size group and by firm-age group using the production function estimates. We found that smaller firms and younger firms tend to have a higher marginal product of ICT input. These findings suggest that smaller firms and younger firms face constraints that prevent them from increasing ICT input. In sum, smaller firms are less ICT intensive because of two factors: they use production technology with a lower ICT coefficient and they are constrained in increasing ICT input. One plausible explanation why smaller firms choose production technologies with a lower ICT coefficient is that they face higher ICT input prices. In the case of firm age, our results suggest that younger firms use production technologies with a higher ICT coefficient, but they are more constrained in increasing ICT input than older firms. Probably because of these two opposite forces, we do not observe a simple relationship between firm age and ICT intensity.

Next, we examined impediments to the full use of ICT by Japanese firms based on our analysis as well as preceding studies by the Japanese government and other institutions in Japan. As factors which may result in smaller firms in Japan facing a higher price for ICT inputs, we pointed out two characteristics of the Japanese economy: the underdeveloped market for business process outsourcing (BPO) and the scarcity of ICT experts. Since access to efficient vendors of ICT services is a key factor for smaller firms' procuring ICT input at a reasonable price and ICT experts in Japan tend to prefer working in large firms, these two factors make ICT input more expensive for smaller firms. On the other hand, as constraints to increasing ICT input for smaller and/or younger firms, we pointed out liquidity constraints and insufficient ICT literacy. Because most Japanese banks still require tangible assets as collateral for lending and venture capital markets are not well developed in Japan, it is difficult for such small/young firms to finance intangible ICT investment such as purchases of ICT software or a reorganization of their information system.

We also pointed out a number of other special factors which help to explain why not only the ICT intensity of small firms but also of all firms in Japan is comparatively low. These include (1) the high cost of laying off workers that are no longer needed as a result of the introduction of ICT, (2) the high cost of ICT inputs in comparison with the United States, (3) the tendency of Japanese firms to regard ICT just as a cost cutting means and not as a path to innovation in business models, (4) the tendency of Japanese firms to choose custom software rather than packaged software in order to avoid changes in corporate structure and employment adjustment, and (5) the reduction of investment in intangibles more generally by Japanese firms.

What policy implications can we derive from these findings? Possible policies to enhance ICT input in Japan include the following.

First, it is important to develop the market for BPO, which includes outsourcing of ICT processes. To promote productive ICT vendors and the outsourcing of ICT service by smaller/younger firms, the government could introduce a certification system and objective indicators regarding the abilities of BPO vendors. Second, to resolve the scarcity of ICT experts, the government could support the training of ICT experts at universities and relax regulations on immigration of foreign ICT experts. To increase the supply of ICT experts to smaller firms, it is also important to support ICT experts who change their job by, for example, improving Japan's Job Card System to verify the skills ICT experts have accumulated. Third, to reduce ICT input prices, the government could enhance competition in the market for ICT services and ICT hard- and software and promote international trade in ICT services. Fourth, to resolve the problem of ICT illiteracy, the government could conduct publicity campaigns introducing new ICTs and best practice in ICT use, especially at small and medium-sized firms. Fifth, to relax liquidity constraints on smaller/younger firms, the government could provide support – either directly or through the establishment of appropriate mechanisms – the financing of ICT investment. Sixth and finally, to enhance ICT use, we need to change not only the market for and use of ICT inputs but also Japan's broader economic system, such as its inflexible labor market and sluggish market selection mechanism with low entry and exit rates.

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