The Effect of Information and Communication Technology on CEO's Span of Control: Evidence from Japanese Firms

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Abstract

This paper examines the effect of information and communication technology (ICT) on the number of employees who directly reports to the CEO (CEO's span of control). We exploit an original dataset of Japanese firms from 2008 to 2010 to ascertain the relationship between the CEO's span of control and investment in ICT. We find that the ratio of software over total assets is positively associated with the CEO's span of control. This result is consistent with the theoretical prediction by Garicano (2000). In addition, R&D intensity is negatively associated with the CEO's span of control.

JEL classification

D22; O32; L23

Keywords

Span of control; ICT; Communication cost; Learning cost; Japanese firms

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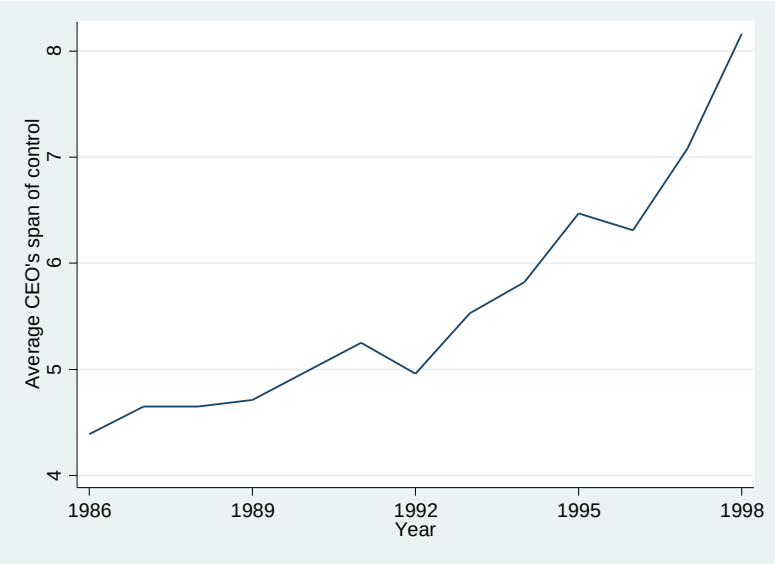
1. Introduction

As shown in Garicano (2000), the knowledge-based hierarchy model predicts that improvements in information and communication technology (ICT) increase the span of control, which is defined as the ratio of the number of managers over that of workers. Garicano (2000) argues that the costs of communication and knowledge acquisition play a key role in organizing a hierarchy. A reduction in both costs leads to an increase in a manager's span of control because it relaxes the manager's time constraint and allows the manager to answer more questions by the workers than ever. Since improvements in ICT, such as high availability of software and ICT services, reduce both costs, the involvement of ICT increases the span of control. We then explore an original dataset of internal organization in Japanese firms and examine the relationship between the CEO's span of control and ICT.

Recent years have witnessed an expansion in the CEO's span of control. For example, Rajan and Wulf (2006) find that the CEO's span of control increased steadily from 1986 to 1998, using a sample of 300 U.S. large firms. Figure 1 displays the time trend of the average CEO's span of control reported in Rajan and Wulf (2006). Though the number of positions reporting directly to the CEO was 4.4 on average in 1986, it increased to 8.2 in 1988. This trend is documented in a host of academic literature and business papers.[1]



[1] Other studies in the academic literature documenting a similar trend include Whittington et al. (1999) and Roberts (2004).

Figure 1

The Time Trend of CEO's Span of Control. *Note*: The data used in the graph is obtained from Rajan and Wulf (2006) on page 764.

Although many empirical studies focus on firms' internal organization, those examining the effect of ICT on the CEO's span of control are scare because of the constrained data availability. For example, Bloom et al. (2014) examine the effect of ICT on the span of control of the plant manager developing about 600 American and European manufacturing firm data. They find that the introduction of ICT applications is associated with a wider span of control of the plant manager. However, they do not study the CEO's span of control since a direct measure for it is not available. Guadalupe and Wulf (2010) examine the effect of increasing competition on firms' organization, using the same data as Rajan and Wulf (2006). They find that greater competition measured by tariff reductions leads firms to increase the CEO's span of control.[2] Bresnahan et al. (2002) examine the relationship between the specific organizational practices and ICT. They use a survey of approximately 300 U.S. large firms and find evidence of complementarities between workplace organization and ICT. They show that the activities of self-managing teams and team-building and ICT capital are associated with greater increases in output.[3]

2. Data

The data for this paper is obtained from the Handbook of Organizational and Systematical Figures (Soshikizu-Keitouzu-Binran in Japanese). The survey includes detailed information of Japanese listed companies on division, business offices, plants, sections, titles, and their reporting relationships. The data is unique in that it allows us to identify the reporting relationship in hierarchies within firms. The handbook is published annually by DIAMOND, Inc.[4] We count the CEO's span of control, which is

[2] Other studies such as Caliendo et al. (2015) and Tag (2013) focus the number of layers which represent a vertical dimension of internal organization as opposed to the span of control. Caliendo et al. (2015) use a dataset of French manufacturing firms and exhibit that firms' organization is typically hierarchical and the adding a layer is positively linked with value added.

[3] Some studies develop the knowledge-based hierarchy model. Garicano and Rossi-Hansberg (2006) analyze the effect of organizational change on wage inequality, while Antras et al. (2006) analyze the effect of globalization on the organization and the structure of earnings of workers.

[4] DIAMOND, Inc. is a large publishing company specializing in businesses and economic issues. It was established in 1933 and currently has a total staff of 202 employees.

the number of employees reporting directly to the CEO, using the handbook. Figure 2 displays an example of this measure. In this example, the CEO's span of control is 5, since there are four divisions and one position directly connected to the CEO.

We select firms in the electric machinery and chemical industries in the handbook. There are two reasons for this selection. First, doing so allows us to compare the results with related studies, including Bloom et al. (2014) and Rajan and Wulf (2006). Electric machinery and chemical industries are representatives of the manufacturing in Japan. They are typically large and hire a huge number of employees. The data characteristics are close to those of the above previous studies. Second, we consider industrial differences of the effect of ICT on the span of control. Each industry inherently has

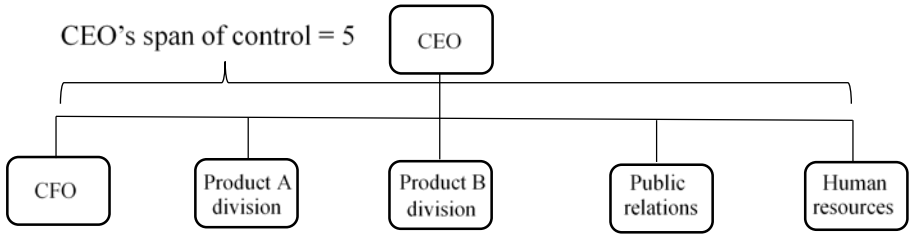


Figure 2

An illustrative example of CEO's span of control.

a different production process, and thus, this paper attempts to control the industry-specific effect.

We develop a panel structure from 2008 to 2010. Because some firms are represented as affiliated groups, 37% of the observations are excluded. The resulting sample comprises 255 firms in each year. The total sample is 765, which comes close to the size by Bloom et al. (2014) and Guadalupe and Wulf (2010). Firm-level ICT is defined as the value of software over total assets in the firms' financial reports. All listed companies are annually required to submit this publicly disclosed report to the government. The software in the report includes all kinds of ICT, covering from Enterprise Resource Planning (ERP), Computer Assisted Design (CAD) and Computer Assisted Manufacturing (CAM) to ICT applications such as document software.[5] Finally, other organizational characteristics are also

[5] Descriptive statistics of the CEO's span of control and its distributions are provided in table A1 and figure A1 in the Appendix, respectively.

obtained from the reports.[6]

3. Hypothesis and regression specification

Garicano (2000) develops the knowledge-based hierarchy model which ascertains the relationship between a firm hierarchy and the costs of knowledge acquisition and communication. He assumes that the density of problems is an exponential form with parameter λ to apply a comparative static analysis. As shown in Garicano (2000, p. 888), the span of control of each manager can be easily expressed in the following equation after optimizing the object function of the organization.

$$s = \frac{\lambda}{c} - \ln h \tag{1}$$

where c is the cost of acquiring knowledge and h represents the cost of communication. The equation implies that a decrease in the communication cost and learning costs increases the manager's span of control. On the other hand, an increase in parameter λ, which are understood as the extent of predictability of production process, decrease the span of control. As the high availability of software is thought to reduce both costs, the hypothesis of this paper is that involvement in ICT is positively associated with the CEO's span of control.

Based on the hypothesis, the firm-level reduced form regression used in this study is as follows.

$$Span_{ijt} = \beta\, ICT_{ijt} + x'_{ijt}\gamma + d_j + y_t + \alpha + u_{ijt} \tag{2}$$

where i refers to a firm, j denotes the industry, and the time period is indexed by t. α and u are the interval and the error term, respectively. The dependent variable in the equation, *Span*, is the log of the CEO's span of control. The explanatory variable, *ICT*, measures the extent of use of ICT. This variable is defined as the software over total assets in the firms' financial reports. Some organizational characteristics may lead firms to invest in ICT, which results in a reverse causality problem.[7] To

[6] Kuwahata (2014) examines the relationship between globalization of firms and internal organization, using the same data as in this study.

[7] For example, Bresnahan et al. (2002) find that workplace organization such as the introduction of self-managing teams and ICT are positively correlated.

respond to an endogeneity problem, the specifications in which all independent variables are lagged by one year and by two year are also employed. However, we primarily focus on conditional correlations between ICT and the CEO's span of control. In addition, because we exploit the panel data set, the regression including firm fixed effects is employed to control for unobserved firm-level heterogeneity.

Other controls include the log of the number of employees, R&D intensity, the holding company dummy and the subsidiary dummy. R&D intensity is defined as the R&D expenditure over the total sales. Since this paper attempts to control technological factors that affects internal organization, R&D intensity which is the typical measure of innovation is included.[8] R&D intensity is expected to be negatively related with the CEO's span of control because R&D such as the development of new products and the improvement of production process is one of the most complex production process, and thus, it is intrinsic to an unpredictable activities. For example, Garicano and Wu (2010, p 3) point out, "knowledge is demanded to perform tasks, which can vary from as simple as assembling or bookkeeping to as complex as R&D or fashion design." In addition, we include the holding company dummy, which takes the value of one if a firm is the holding company and zero otherwise. The holding company, whose aim is to own other companies' stock, may have the narrow CEO' span of control. The subsidiary dummy, which takes the value of one if a firm is the subsidiary of another company, is also included. The CEO's span of control in a subsidiary might be different because of parent-subsidiary transactions.[9] The results from these regressions are comparable with Guadalupe and Wulf (2010) and Bloom et al. (2014).

4. Results

Table 1 displays the basic results of regressions. The following findings are worth noting. First, ICT is significant and positively related with the CEO's span of control. Column 1 shows the result, which adds the log of number of employees and the electric industry dummy as control variables. The coefficient of β is positive and statistically significant. The result does not change even when adding

[8] Acemoglu et al. (2007) show that firms closer to the technological frontier are more likely to choose decentralization.
[9] A detailed description of variables and the correlation matrix are provided in table A3 and A4 in the Appendix, respectively.

other controls. Since coefficient β captures the effect of involvement in ICT on the CEO's span of control, the results imply that the use of ICT is positively associated with the span of control. This suggests that CEOs manage more subordinates owing to the reduction of communication and knowledge acquisition costs. The results are in line with Bloom et al. (2014) and consistent with the theoretical prediction by Garicano (2000).

Second, R&D intensity is negatively associated with the CEO's span of control. This result is obtained in all specifications in table 1. Our data indicate that the more a firm engages in R&D, the narrower the CEO's span of control. One possible reason for this is that decisions to conduct R&D activities require more complex production processes. The decrease in the predictability of production process increases the need to rely on higher-level decision makers as shown in Garicano (2000).

Third, the industry-specific factors affect the CEO's span of control. The coefficient of the electric industry dummy is negative and statistically significant. This result implies that the CEO's span of control in the electric machinery industry are smaller than those in the chemical industry. This result might reflect the difference in production process between industries. In addition, the industry-level effect of ICT on the span of control is heterogeneous. Since the interaction terms between software and the electrical industry dummy in columns 4 is negative and statistically significant, the effect of ICT on the CEO's span of control in the electrical industry is smaller than that in the chemical industry, on average. The chemical industry is capital intensive; thus, there exists a strong link between ICT and the span of control.

Finally, the number of employees has a positive sign and is statistically significant in columns 1 to 4. This implies that the larger a firm, the wider the span of control, confirming the existing evidence in the literature, such as Bloom et al. (2014) and Guadalupe and Wulf (2010).

Table 1 Basic estimation results

	Dependent variable: ln CEO's span of control			
	[1]	[2]	[3]	[4]
Software/Total assets	0.186	0.194	0.195	1.011
	[2.45]**	[2.48]**	[2.47]**	[6.31]***
R&D/Total sales		-0.020	-0.020	-0.024
		[-9.34]***	[-9.23]***	[-10.52]***
ln the number of employees	0.278	0.277	0.278	0.278
	[22.72]***	[22.69]***	[22.57]***	[22.58]***
Electric dummy	-0.082	-0.084	-0.086	-0.080
	[-2.24]**	[-2.28]**	[-2.30]**	[-2.11]**
holding dummy			0.062	0.063
			[1.01]	[1.02]
Subsidiary dummy			-0.022	-0.021
			[-0.41]	[-0.41]
Software/Total assets * Electric dummy				-0.888
				[-5.27]***
Constant	0.705	0.710	0.708	0.700
	[9.04]***	[9.08]***	[8.91]***	[8.81]***
Adjusted R-squared	0.367	0.3671	0.3659	0.3667
N	765	765	765	765

Note: The asterisks ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively. *T* statistics (in parentheses) are computed from Heteroskedasticity-robust standard errors.

Table 2 Estimation results (lagged by year and fixed effects)

	Dependent variable: ln CEO's span of control			
	One year lagged	Two years lagged	Fixed effects	Fixed effects
	[1]	[2]	[3]	[4]
Software/Total assets	0.909	0.878	0.193	0.198
	[7.12]***	[10.77]***	[9.73]***	[11.43]***
R&D/Total sales	-0.024	-0.704		-0.001
	[-9.43]***	[-0.91]		[-2.46]**
ln the number of employees	0.286	0.306	0.110	0.092
	[18.73]***	[13.21]***	[0.81]	[0.68]
Electric dummy	-0.072	-0.071		
	[-1.53]	[-0.99]		
Subsidiary dummy	0.043	0.038		-0.061
	[0.70]	[0.55]		[-1.88]*
holding dummy	0.001	0.266		-0.047
	[0.01]	[1.71]*		[-0.79]
Software/Total assets * Electric dummy	-1.013	-0.9324		
	[-7.13]***	[-9.41]***		
Constant	0.647	0.539	1.705	1.831
	[6.50]***	[3.54]***	[2.00]**	[2.06]**
Adjusted R-squared	0.373	0.397	0.012	0.019
N	510	255	765	765

Note: The asterisks ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively. *T* statistics (in parentheses) are computed from Heteroskedasticity-robust standard errors.

Table 2 displays the results by the lagged model and the fixed effects model. The dependent variables in column 1 are lagged by one year, while those in column 2 is lagged by two years. Column 3 and 4 display the results of the fixed effect model. The following findings are worth noting.

First, the coefficients of ICT remain negative and statistically significant. These results are consistent with the conclusion that the use of ICT has a substantial positive impact on the CEO's span of control.

Second, the coefficients of the other control variables are almost identical to those in Table 1 but they have slight differences. The coefficients of R&D intensity lagged by two years is negative but is not significant. The results might imply that the CEO's span of control depends on the R&D activities that are conducted up to one year ago, whereas the effect of investment in ICT on the organization continues for several years. Also, the coefficients of the number of employees in column 3 and 4 lose the explanatory power. This might be caused by the high correlation between the firm-level dummies and the number of employees.

5. Conclusion

This paper exploited the organizational data of approximately 700 firms and examined the relationship between the CEO's span of control and the involvement in ICT. We found that the ratio of software over total assets is positively associated with the CEO's span of control, consistent with the theoretical prediction. Also, we find that R&D intensity is negatively associated with the CEO's span of control. The generality of this finding should be strengthened in future research. Moreover, it would be interesting to analyze the causal effects of ICT on internal organization and wage inequality in a firm.

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Appendix. Data Description

Table A1 Basic statistics of the log of CEO's span of control by year

Year	Mean	Std.Dev	Min	Max	Observation
2008	2.3903	0.5992	1.000	4.205	255
2008	2.4019	0.6149	1.000	4.234	255
2008	2.4045	0.6262	1.000	4.263	255

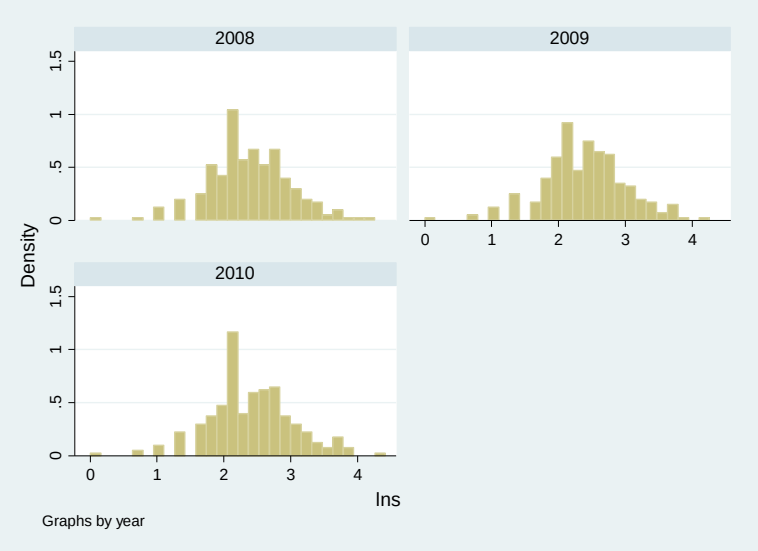

Figure A1 Distribution of the log of the CEO's span of control.

Table A2 Basic statistics of all variables

Variable	Mean	Std.Dev	Max	Min	Observation
ln (CEO's span of control)	2.3989	0.6128	4.263	0.000	765
Software/total assets	0.0133	0.1016	2.581	0.000	765
ln (the number of employees)	6.2699	1.3421	10.526	1.946	765
R&D/total sales	0.1004	0.9319	18.339	0.000	765
Subsidiary dummy	0.1281	0.3344	1	0.000	765
Electric dummy	0.600	0.4902	1	0.000	765

Table A3 Correlation matrix

		[1]	[2]	[3]	[4]	[5]	[6]
ln (CEO's span of control)	[1]	1.0000					
Software/total assets	[2]	0.0286	1.0000				
ln (the number of employees)	[3]	0.6036	0.0017	1.0000			
R&D/total sales	[4]	-0.037	0.0384	-0.0176	1.0000		
Subsidiary dummy	[5]	-0.0426	0.0048	-0.0427	-0.0158	1.0000	
Electric dummy	[6]	-0.0241	0.0502	0.0661	-0.0473	0.1453	1.0000