PRODUCTIVITY IN INFORMATION SERVICE INDUSTRIES: A PANEL ANALYSIS OF JAPANESE FIRMS*

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We examine factors determining productivity of information-technology service activities at firm level, using most comprehensive data of information service industries in Japan. We focus on the degree of modularisation and resulting outsourcing and economies/diseconomies of scale in software development, and changes. We find that outsourcing has persistent negative effects on total factor productivity, suggesting not only productivity-enhancing modularisation is not fully utilised but also productivity-hindering remnants of traditional main-contractor-subcontractor relations still prevail in Japanese information service industries. We also find diseconomies of scale in software development, suggesting less efficient communication among development team members.

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1. Introduction

Although their importance is apparent in their large share of gross domestic product (GDP) and their lagging performance in productivity, non-manufacturing industries have not been a major target of large-scale firm-level productivity studies either of large firms or medium-to-small companies. This is a sharp contrast to the manufacturing industries where we can find many large-scale firm-level as well as plant-level studies. This scarcity of research in non-manufacturing industries is partly due to data availability.[1]

In this paper, we redress the balance between the practical importance and relative scarcity of large-scale firm-level research in non-manufacturing industries. We chose the software and other information service industries in Japan as the subjects of investigation for the following reasons.

Firstly, software and other information service industries are an integral part of the so-called “IT (information technology) Revolution”, alongside the hardware industry. Because of the prominent role of IT in recent economic development, in-depth analysis of software and other information service industries is urgently needed. We need to bear in mind that the software and other information service industries are categorised as non-manufacturing industries while the hardware industry is by definition a manufacturing industry.

Secondly, both the governments and business communities around the world consider the information service industries to be “strategic” industries. For example, in 2003 the Japanese government launched an initiative called “e-Japan Strategy II”, clearly targeting the information service industries. Some firms in the electronics industries are shifting their business emphasis from computer hardware to software and information services.[2]

Thirdly, the Japanese software and other information service industries are a unique example of the problems inherent in enhancing productivity. Although the Japanese hardware industry is one of the most productive industries in the world, there is some evidence that this is not the case in the software and other information service industries.[3] Thus, an analysis

1. Ahn (2001) and Bartelsman and Doms (2000) survey firm-level empirical analyses. Ahn touches briefly on service industries in his survey of empirical results in productivity based on firm dynamics. He points to several problems in the productivity analysis of service industries, such as appropriate measurement of outputs. Ehrlich *et al.* (1994) examine international airline companies and find an increase in TFP growth after full privatization. Gort and Sung (1999) show that increased competition due to deregulation raised TFP growth in telephone companies in the United States.

2. Most prominent is IBM. IBMís divisional revenues now reveal that revenues from software and information service divisions exceed those from hardware divisions. IBMís move prompted several Japanese firms to follow.

3. For example, no Japanese firm is in the top of the OECD (2002) revenue ranking of software licensing and service fees.

of the Japanese information service industries will shed light not only on both productivity-enhancing and productivity-hindering factors. This should be of value to the software and other information service industries in other countries as well as Japan.

To our knowledge, the few empirical studies investigating total factor productivity (TFP) growth in the software and other information service industries at firm level, study firms in the United States. Brynjolfsson and Hitt (2003) examine the contribution of computers to TFP in large US firms including several service-industry firms, and found sizeable and increasing productivity in the years after initial investment. They attribute this effect to the existence of organisational capital complementary to computers. Cusumano *et al*. (2003) investigate software-development productivity based on case studies of 104 software development projects mostly in India, Japan, the United States and the European Union. Their results indicate productivity is higher in India and Japan than in the United States and the European Union. However, they do not measure productivity by TFP; they use several project-oriented measures of performance, such as number of lines of code per programmer-month, number of defects reported per 1000 lines of code in one year after delivery to customers. To interpret their results, we need to take account of the "cultural differences," suggested by these authors. They point out that US programmers tend to emphasise shorter or more innovative programs, and spend more time optimising code, which simultaneously ultimately reduces the number of lines of code, but increases the programmer-months.

The research reported here is based on large-scale census-like survey data on all firms and establishments engaged in software and other information services, gathered in the *Survey on Selected Service Industries, Volume of Information Services*. This is the most comprehensive data on information service industries in Japan. We focus on two possible determinants of productivity: the degree of modularisation and resultant outsourcing, and economies/diseconomies of scale in software development.

A striking result of our research is that outsourcing has a persistent negative effect on TFP. Outsourcing has been considered an important source of productivity growth in information service industries for many years. However, the results from our study show this is not necessary true in all cases. We looked for factors that hinder the realisation of the productivity-enhancing effects of outsourcing. These transpired to be the traditional main-contractor-subcontractor relations that still prevail in Japanese information service industries. We also found diseconomies of scale in information service industries. This may suggest problems of communication among organisational members, especially the members of teams involved in software development.

This paper is organised as follows. In Section 2, we examine factors determining productivity in the information service industries, with special emphasis on the software industry. In section 3, we describe the main characteristics of the *Survey of Selected Service Industries*, and explain the data construction in some detail. The empirical results are presented in Section 4. We discuss these results and examine the factors that lie behind them. Concluding remarks are presented in Section 5. The data are described in the Appendix.

2. Factors Determining Productivity of Information-Service Firms

In this section, we examine possible determinants of information-service firms' productivity, which will be the basis of the empirical analysis in Section 4. Since software products are the major outputs of the information service industries, we mainly look at the determinants of software development productivity.[4] We look at two determinants that are considered to be particularly influential in software development: the degree of modularisation and the scale of software development.

2.1. Modularisation

In both the popular press and academic writing, the Silicon Valley Model has attracted much attention. The argument is that in Silicon Valley in the State of California, information companies and engineers form a "community," and collaboration within the community is common, and productive. In this prevailing context of collaboration, outsourcing is a productivity-enhancing practice in software development.

However, outsourcing is not always productivity-enhancing. For example, if new products involving new designs and production methods, outsourcing may result in serious problems if the old production process had to be re-adjusted and communication among the firms is not good. In order to facilitate readjustment and improve communication to ultimately make outsourcing successful, "modularisation" of parts is vital, and modularisation is a critical aspect of the Silicon Valley Model.[5]

The concept of "modularisation" stems from the development of the IBM SYSTEM/360. Computers produced before IBM SYSTM/360

4. In 1999 the share of custom software and prepackaged software is more than 60% of the total value-added for the information service industries in Japan.

5. Here "modularization" means to design complex products and processes consisting of small-scale subsystems that are independently designed (see Baldwin and Clark 1997). The "small subsystems independently designed" are "modules". So long as the "integrability" is maintained, each subsystem can be designed independently.

had idiosyncratic specifications for specific parts, operating systems, and application software. There were few parts (either hardware and software) common to different generations of computers. Computer manufacturers developed parts and software virtually from scratch for each new generation of computers.

The concept of the IBM SYSTEM/360 was revolutionary in the sense that it was a "family" of computers. Compatibility within the family was maintained as much as possible, and was achieved through modularisation-extensively. The adoption of a modularised design and its wide-ranging application was one of the most dramatic driving forces behind the revolutionary speed of innovations in the computer industry (Baldwin and Clark 1997).

Modularisation has far-reaching consequences. Modularisation of the product architecture allows firms to modularise their production process, which leads to the modularisation of their organisation. Thus, when modularisation is "deepened", firms can outsource a part of their business. New firms are established, which in some cases are created as the result of a divestiture of outsourcing firms, and in others by spinouts, and they are awarded outsourcing contracts from the original firm. Since outsourced business is modularised or in other words standardised, these newly established firms eventually win other outsourcing contracts, and thus are able to realise economies of scale. These firms are also able to complete the learning curve quite rapidly, so that they become competitive on prices. This, in turn, enables outsourcers to "procure" parts of their business less expensively.

It should be noted that software was an integral part of computers at the time of IBM SYSTEM/360. Thus, it may not be far-fetched to assume that the same productivity-enhancing effect of modularisation applies to software development.

Successful hardware modularisation, however, may not be duplicated in the software and information service industries. Production innovation is less frequent in the software industry than the hardware industry, implying that these two industries are not really similar. Thus a simple "transplanting" of modularisation may not work well in the software industry. For example, if operating system (OS) suppliers do not open the source codes of their systems, modularisation will be far less complete than in the hardware industry.[6] Furthermore, human factors are more important in the software industry, since the tacit knowledge of engineers may not be fully "coded" or reproducible.

6. API (application programming interface) is a part of the OS that is used in application software development. Since Microsoft does not make source codes open for its WINDOWS OS, developers of WINDOWS application software cannot develop their software independently, which implies insufficient modularization. Such problems do not exist in computer hardware.

In sum, there is no theoretically clear-cut conclusion as to whether modularisation and the resulting outsourcing are productivity enhancing in the software industry, and therefore, whether modularisation and outsourcing are or are not productivity improving is in essence an empirical question.

2.2. Scale of Development Organisation

The second factor that may determine the productivity of the information service industries is the scale of the development organisation. Here we consider the development organisation in terms of basic research and development (R&D) and system-software development divisions (including system integration).

Software development is a complex process involving intensive communication among development team members. Thus, smooth communication among development team members is vital, especially under continuously changing software development environment. Development languages change quite rapidly, and suppliers have to cater for the ever-changing demand of their customers.

This observation suggests diseconomies, rather than economies, of scale in software development. In fact, Frederick P. Brooks Jr., often referred to as the "father" of IBM SYSTEM/360, points to these possible diseconomies of scale, and argues against large-scale development. In his well known book *Mythical Man-months* (Brooks 1995) he describes the idea that inputs can be measured in man months as myth. He argues that the time of one programmer is not substitutable by the time of another programmer, so that one hour from 100 programmers will not finish a project that could be completed in 100 hours of one programmer's time. Consequently, programmers' labour inputs cannot be measured in man hours or man months.

Thus, if communication among development team members is less than perfect, an increase in the numbers of development teams may even have negative effects on the productivity of software development. This possible negative effect may be heightened if the development schedule is suddenly curtailed and additional engineers are put into the development team to try to compensate for this change.

However, there is one important example of economies of scale in software development, which is the success of Linux system development. As is well known, Linux developments are made possible by the participation of many engineers and programmers around the world, who form a virtual community on the Internet. They enhance their communications using various attributes of Internet technology. The most important characteristic of Linux is that codes are open to everyone in the community and thus coding and debugging can be achieved efficiently and quickly. The success of Linux suggests that if communication among developers is smooth, significant notable economies of scale in software development are possible.

In sum, the scale of development may negatively affect productivity as in the case of the "mythical man-month", or may positively influence productivity as in the success of Linux development, depending on the smoothness of communication among development team members. In the empirical analysis, we examine which factor dominates in the Japanese information service industries.

3. Data: *Survey of Selected Service Industries: Volume of Information Service Industries*

In this section, we briefly describe our data source, the *Survey of Selected Service Industries*, *Volume of Information Service Industries*. The Ministry of Economy, Trade and Industry (METI) conducts this survey every year. In our empirical analysis, we use panel data of firms contained in this data set between 1991 and 1998. First it is worth briefly discussing the Japanese information service industries.

3.1. Japanese Information Service Industries

The *Survey of Selected Service Industries, Volume of Information Service Industries* is the most comprehensive set of statistics about the Japanese information service industries. Here information service industries include (a) information processing service (including application service providers (ASP)), (b) custom software, (c) prepackaged software (business prepackaged software, software games, basic software), (d) system management and administration, (e) data base service (online and offline), (g) research, and (h) others.

Let us use aggregate 2001 data to review the state of Japanese information service industries. The total sales of information service industries are 13.9 trillion yen, a remarkable 18.2% increase over the previous year. Note that the Japanese economy was in a deflationary stage in 2001, so that this increase in nominal terms is impressive. Among all information service industries, custom software development has the largest share, which is 49.4%, and prepackaged software development the third largest share at 10.8%. Thus software development including both custom and prepackaged accounts for more than 60%. The second largest share is information processing service at 19.1%.

The growth in sales of prepackaged software is shown to be an astounding 49.1%, which is the highest among information service industries.

This high rate of growth is the result of an extremely high growth rate of its subcategories, that is, 162.3% growth in software games and 112.6% growth in basic software. The growth rate of system management and administration is 44.8%, which is the second highest rate. This may be due to the rapid growth in network systems in this field. Custom software shows a respectable rate of growth of 8.4%, though this does not compare with the extremely high growth rate of prepackaged software. Only one category exhibits negative growth, which is data base service at –10.5%. This category includes some Internet business, so that this decline may reflect the hardships following the burst of so-called "Internet Bubble" of 2000.

Let us now turn to the demand side of information service industries. In total contracted sales, the share of manufacturing firms is 22.6%, that of finance and insurance firms is 17.5%, and these two industries account for more than 40%. As for growth rates, transportation and communication show the highest, growing at 41.5%. The wholesale and retail trade industries are the second highest, and their growth rate is 30.6%.

3.2. Characteristics of The *Survey of Selected Service Industries*

The *Survey of Selected Service Industries, Volume of Information Service Industries* covers all firms and establishments engaged in information service industries via a census of the sector and is more detailed than the *Establishment and Enterprise Census,* the other major source of data. The Survey is activity-based: it collects information about establishments and firms that have *some* business activities in information service whereas the Establishment and Enterprise Census gathers information only about establishments and firms whose *major* business activities are in information service. Since information service industries are rapidly expanding with many entries from and exits to other industries coverage of all firms with any activities is important.

Table 1 shows the total number of establishments and the number in each sub-category based on firms' organisational structure, according to aggregate figures published by METI. In the sample period 1991-1998, the total number of establishments ranges between 5,812 in 1995 and 8,248 in 1998. There are three sub-categories: single establishments (without a branch office), headquarters (with branch offices), and branch offices. The category of single establishments has the largest share of 50% on the average.

The purpose of our study is to investigate productivity at firm level. Thus, our basic units of investigation are firms, rather than establishments. Among the establishments listed in Table 1, we examine single-establishment firms (single establishments) and multiple-establishment firms (headquarters) in our study.

The *Survey of Selected Service Industries* is particularly suited to firm-level analysis of information service industries in several respects. Firstly, the

1. The Numbers of Establishments in Information Service Industries
(*Survey of Selected Service Industries*)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Single	3563	3205	3041	2902	2822	3289	3186	4361	4217
Headquarters	1702	1883	1708	1538	1496	1379	1338	1687	1612
Branch Offices	1831	1889	1683	1542	1494	1629	1568	2200	2128
Total	7096	6977	6432	5982	5812	6297	6092	8248	7957

Survey minutely distinguishes revenues, costs, labour inputs and capital stocks for information service activities from those for other activities. This is important since some firms in our sample are only partly engaged in information service activities. In our empirical analysis, we use revenues, costs, labour inputs, and capital stocks for information service activities only, to obtain value-added and other data necessary for TFP calculation. That is, our value-added, labour input and capital stock data are solely related to information service activities, and are not "contaminated" by other activities.

One characteristic of the capital investment data in this data set is many zeros and blanks in the category of "acquisition of structure and buildings" and "acquisition of machines and equipment" on the one hand, and relatively large payments for computer-time lease and other rental payments that are presumably building rents. This implies that a traditional perpetual inventory method may not be appropriate, especially in the case of capital service inputs of computers, where capitalization is more appropriate. Thus, in the following analysis, we use the perpetual inventory method whenever possible, but when it is not appropriate, we resort to other procedures to obtain capital service inputs.

3.3. "Firms with Well-Established Information Service Activities"

We follow a standard neoclassical growth accounting framework to calculate TFP based on a value-added production function with capital and labour.[7] The procedure and data sources are explained in the Appendix.

Because of very high turnovers it is not possible to compute TFP growth for all firms. Therefore, we restrict our attention to *firms whose information service activities are well established*. We established two criteria, and we consider only firms satisfying all these criteria in the empirical analysis.

7. It might be desirable to distinguish IT capital stocks from other capital stocks as Nishimura and Shirai (2003) do in their industry-level TFP analysis. Unfortunately, the data do not include such detail.

In the first step, if firms whose information service activities yield negative value-added and/or hire no workers in a particular year, these firms are excluded from the sample for that particular year. If these firms show positive value-added after that year, they are included in the sample thereafter. The occurrence of negative value-added is fairly rare, affecting less than 1% of our total firm-years. In the second step, firms that did not have five consecutive years of information service-related equipment investment were also excluded from our sample.[8] This yielded 1,106 firms with well-established information service activities. Our sample period is 1991-1998, and our sample is an unbalanced panel.

To identify the characteristics of our samples: "firms with well-established information service activities", we compared the whole samples and our truncated samples (see Tables 2 and 3).

Table 2 reports summary statistics for the whole sample after excluding firms with negative information-service value-added and/or no information-service worker; while Table 3 presents statistics for our samples. The major variables are the ratio of information-service outsourcing to information-service sales, the number of SE (system engineers), and the ratio of information-service profits to information service operating expenses, which we consider later as determinants of TFP growth.

Comparing Tables 2 and 3, we find that the picture is fairly similar for the total sample (excluding abnormal firms) and our "firms with established information services", except in relation to number of system engineers. For example, for ratio of outsourcing to information service sales, the total sample average is 0.140, while it is 0.148 in firms with established information activities. However, the number of system engineers is substantially higher in firms with established information service activities, so that our target is slanted towards larger firms. When interpreting the results, these characteristics should be kept in mind.

4. Models, Estimation Results and Discussion

4.1. Choice of Variables

4.1.1. Modularization and Outsourcing

In Section 2, we examined the possible effects of modularization on information service productivity. We showed that modularization enables firms to outsource parts of their products in an efficient way. Thus, the

8. This is necessary since we use the five-year average investment growth rate to estimate benchmark-year capital stocks.

2. Total Samples Excluding Negative Value-Added and Zero Workers: 1991-1998
Summary Statistics of Major Variables: Following variables are those of information service activities of firms.

	Average	Min.	Max.	# of Firms	# of Firm-Year's
Labor Productivity Growth	0.031 (0.493)	–8.099	8.486	7610	32060
Outsourcing-to-Sales Ratio	0.140 (0.159)	0.000	1.000	11076	44535
Number of SE's	32.091 (142.379)	0.000	9425.222	11076	44535
Profit-to-Operating-Cost Ratio	0.281 (1.748)	–0.961	161.000	11074	44504

Note: Standard deviations in parenthesis.

3. Firms with Well-Established Information Service Activities: 1991-1998
Summary Statistics of Major Variables: Following variables are those of information service activities of firms.

	Average	Min.	Max.	# of Firms	# of Firm-Year's
Labor Productivity Growth	0.042 (0.352)	–4.193	4.248	1106	6117
Outsourcing-to-Sales Ratio	0.148 (0.144)	0.000	0.890	1106	6117
Number of SE's	79.353 (231.828)	0.047	4519.204	1106	6117
Profit-to-Operating-Cost Ratio	0.233 (1.317)	–0.653	89.595	1106	6117

Note: Standard deviations in parenthesis.

degree of outsourcing may be a measure of the degree of modularization, although the degree of modularization itself is not observable. Consequently, in our empirical analysis, we use the degree of outsourcing, which is the ratio of outsourcing to total sales in information service activities, as a variable for modularization and resulting outsourcing.

There are three kinds of modularization:[9] (a) modularization of product architecture (modularization in development process), (b) modularization of production process, and (c) modularization of supplier relations.

9. See Fujimoto (2002).

Outsourcing is a result of (c), which is based on (b) and (a). However, outsourcing may not be motivated solely by modularization, and other factors may prompt firms to outsource their business activities. We will explicitly consider the latter possibility in our later interpretation of the empirical results obtained in this paper.

4.1.2. Scale of Development Organization and the Number of System Engineers

The second determinant we examined in Section 2 is the scale of software development. Ideally, if a measure of the average quality-adjusted scale of software development in a firm is available, this is the variable that should be used for the empirical analysis. However, since the average scale of software development is not directly observable, we need a proxy for this variable.

Software development is skilled-labour intensive, and thus the scale of development is likely to be highly correlated with the size of the skilled workforce. In the context of information service industries, and especially the software industry, the skilled workforce includes system engineers, programmers, and research scientists, about which we have data from the *Survey of Selected Service Industries, Volume of Information Service Industries*. System engineers play a pivotal role in software development, especially in custom software one, which dominates Japanese software development.

Tailoring software to the demands of customers is of utmost importance. System engineers in the worker classification of the Survey are those responsible for receiving customers' needs and interpreting them into schemes that are programmable. They are responsible for deciding on the most suitable development languages and organizing the programmers to get the best out of them. Based on the importance of system engineers to Japanese software development, we use their number as a proxy for the scale of software development.[10]

4.1.3. "Profit-driven R&D Investment" Hypothesis and the Profit-to-Cost Ratio

Finally, it has often been argued that the higher a firm's profits, the higher the level of R&D activities (and thus TFP), especially when a firm is liquidity constrained. This "profit-driven R&D investment" may be relevant in the information service industries in Japan since relatively small firms in our samples may have been liquidity-constrained in the period 1991-1998. To control for this possibility, we consider the ratio of gross profits to operating costs of information service activities as one determinant of TFP.

10. We tried number of programmers and number of research scientists in our preliminary analysis, but they had no significant effects on TFP. Thus, we exclude them in the present analysis.

4.2. Models and Estimation

Taking account of the arguments above, we formalize the level of TFP in information service industries as follows:

$$\ln \mathrm{TFP}_{i,t} = \alpha_0 + \alpha_{1i}t + \sum_{j=1}^{J} \beta_j x_{ij,t} + \sum_{k=t+1}^{T} \gamma_k d_{k,t} + \varepsilon_{i,t} \tag{1}$$

Here i denotes the i-th firm and t denotes the year. Equation (1) implies that theTFP of the i-th firm's information service activities in year t, $TFP_{i,t}$, is determined by a constant α_0, a stochastic trend factor $\alpha_{1i}t$ (explained later), microeconomic variables $x_{ij,t}$ discussed in the previous sections, time dummy $d_{k,t}$ representing macroeconomic conditions (which is 1 if $t = k$ and 0 if otherwise), and disturbances $\varepsilon_{i,t}$. In this formulation, the stochastic trend factor varies across firms, representing firm heterogeneity.

As explained in the previous section, we consider the following microeconomic determinants $x_{ij,t}$.[11]

1) OUT: the ratio of outsourcing expenditure to total sales in information service activities, which is used as an index of modularization.

2) lnSE_number: the logarithm of the number of system engineers, which is used as an index of the scale of development.

3) PROFIT: the ratio of gross profits to operating expenses in information service activities.

We use a standard growth accounting procedure to find firms' TFP growth, and we base our analysis on the following "growth" or first-difference formulation (2).

$$\Delta \mathrm{in} TFP_{i,t} = \alpha_{1,i} + \sum_{j=1}^{J} \beta_j \Delta x_{ij,t} + \sum_{k=t+1}^{T} \gamma_k \Delta d_{k,t} + e_{i,t}, \tag{2}$$

where $\Delta Y_t = Y_{t+1} - Y_t$ and $e_{i,t} = \varepsilon_{i,t+1} - \varepsilon_{i,t}$. Equation (2) depicts how firm i's TFP *growth* is determined.

We considered two additional factors. As explained before, information services are categorized in several subgroups such as custom software and data base services[12]. It is quite likely that TFP growth is similar within subgroups, but different between them. In addition, TFP growth might be dependent on firm-specific idiosyncratic factors that are not observable. Taking these two factors into account, we assume that

11. See Appendix for the way these variables are constructed.

12. We classify firms into product subgroups in such a way that no less than 50% of their total sales involve products from this subgroup. Product subgroups we consider are (a) Information Processing Service (including ASP), (b) Custom Software, (c) Pre-packaged Software, (d) System Management and Administration, (e) Data Base Service, (f) Research and (g) Other.

the (stochastic) term $\alpha_{1,i}$ in TFP growth regression (2) is the sum of a constant α_1, product-subgroup dummies $\Sigma\gamma_{ih}y_{ih}$ where $y_{ih} = 1$ if firm i belongs to subgroup h and $= 0$ otherwise, and an unobservable idiosyncratic random variable u_i

$$\alpha_{1,i} = \alpha_1 + \sum_{h=1}^{H} \gamma_{ih} y_{ih} + u_i .$$

Then equation (2) can be written as an ordinary one-way error component regression model (3) with differences in explanatory variables $\Delta x_{ij,t}$ (d-OUT, d-SE, d-PROFIT, where d- denotes difference) as well as product subgroup dummies y_{ih} and differences in time dummies $\Delta d_{k,t}$.

(3)
$$\Delta \ln TFP_{i,t} = \left(\alpha_1 + \sum_{h=1}^{H} \gamma_{ih} y_{ih}\right) + \sum_{j=1}^{J} \beta_j \Delta x_{ij,t} + \sum_{k=t+1}^{T} \gamma_k \Delta d_{k,t} + (u_i + e_{i,t})$$

To estimate (3), we take account of possible simultaneity explicitly between TFP growth and explanatory variables. It is likely that explanatory variables, in particular the outsourcing-to-sales ratio and the profit-to-cost ratio, are endogenous and thus they may be correlated with errors in equation (3). To deal with this issue, we employ an instrumental variables method for panel data. We use GLS estimators of the random effects model (Baltagi and Chang, 2000). As instruments, we use the first lags of all explanatory variables and current government investment and expenditure.[13] The results are reported in the first and the second columns of Table 4. The first column shows the result of the regression analysis ignoring product subgroup heterogeneity, and the second incorporates the heterogeneity. To save space, we omit the results of time dummies, which are statistically significant and quite similar for all regression equations.

To check for robustness, we also report the results of Panel OLS. Since random effect models are accepted by Hausman's specification tests, we only report the results of random effect models.[14] In Table 4, all coefficients (except for constant terms in IV) are statistically significant at the 1% level.

13. We tried other sets of instruments, but found that the results were qualitatively and quantitatively similar.

14. Furthermore, we examined the panel AR(1) method assuming disturbances are auto-correlated at first-order, and we obtained almost the same results (not reported here).

4.3. Results and Discussion

Let us consider the estimation results in Table 4. We have fairly consistent and significant results: the coefficients of the d-OUT, d-SE, and d-PROFIT are significant at the 1% level, where "d-" means the first difference. The sign of d-OUT and d-SE is negative, while that of d-PROFIT is positive. Time dummies (not reported here) are all significant at the 1% level.

4.3.1. Outsourcing and Remnants of Traditional Relationship

A remarkable result found in Table 4 is that the outsourcing-to-sales ratio (OUT) has a significant *negative* effect on TFP. This result is quite robust in all specifications. Moreover, close examination of data shows that it is not a simplistic case that less productive firms are outsourcing their business to more productive firms. Outsourcing firms are often major ICT vendors, which supposedly have high productivity.

4. Estimation Results: 1991-1998.

dependent variable: TFP growth

	IV	IV	Panel OLS	Panel OLS
d-OUT	– 1,1175 ***	– 1,1245 ***	– 0,8343 ***	– 0,8387 ***
	(0,2239)	(0,2233)	(0,0672)	(0,0672)
d-lnSE_number	– 0,2724 ***	– 0,2706 ***	– 0,0591 ***	– 0,0593 ***
	(0,0435)	(0,0434)	(0,0101)	(0,0102)
d-PROFIT	0,0562 ***	0,0561 ***	0,0761 ***	0,0760 ***
	(0,0064)	(0,0065)	(0,0030)	(0,0030)
Constant	– 0,0413	– 0,0263	– 0,1574 ***	0,1481 ***
	(0,0302)	(0,0183)	(0,0362)	(0,0367)
Time Dummy	Yes	Yes	Yes	Yes
Product-Subgroup Dummy	No	Yes	No	Yes
Adj. R-squared	0,1706	0,1823	0,0907	0,1051
# of Firms	1086	1086	1106	1106
# of Firm-Year's	5346	5346	6117	6117

Notes: Standard deviations are in parenthesis. "***", "**", and "*" denote significance at 1%, 5%, and 10%, respectively.
IV denotes the instrumental-variable method for panel data and instruments are the first lags of explanatory variables and government investment and expenditure.
Panel OLS reports the results of the random-effect model (see the text).
The number of firms each year varies because of the unbalanced nature of our panel.

The robust negative effect of outsourcing is striking. As in the Section 2, modularization behind outsourcing should improve rather than reduce productivity. Thus, a robust negative result of outsourcing on TFP suggests that outsourcing in Japanese information service industries has a different origin from modularization, which hinders productivity.

In fact, in-depth analysis of the industrial structure of the Japanese software industry suggests that the negative effect of outsourcing stems from the remnants of traditional subcontracting practices found in this industry. In the traditional relationship, there are *main contractors* (often major ICT vendors) on the one side, who get contracts from customers which are often large corporations and central and local governments. On the other side of the relationship, there are *sub-contractors* (medium-to-small firms) that depend mostly on the main contractors to allocate business to them.

Main contractors outsource their business not to promote efficiency in software development, but to make sub-contractors act as "buffers" against economic fluctuations to reduce the costs of adjustments necessitated by such fluctuations. It is sometimes argued that this cost consideration of main contractors leads to "over-outsourcing" to sub-contractors in the sense that programming expertise is not properly retained within these main contractors. If this is the case, they are violating the dictum of "do not outsource the core of your competence."

For sub-contractors, their poor financial position makes them unable to take advantage of outsourcing. These sub-contractors have little human-capital or physical-capital investment.

This inefficient subcontracting system cannot survive, however, if new efficient firms enter the market. Unfortunately, buyers' (consisting of local and central governments and large corporations) preferences to use "*established* vendors" makes the entry of new, especially small, firms difficult and thus this industrial structure can exist for a long time.

4.3.2. *Mythical Man-Month* and Communication Problems

In Section 2, we argued that scale of development may affect productivity positively in some cases, and negatively in others, depending on the smoothness of communication between customers and development team members and among development team members themselves. The results of our study strongly suggest diseconomies of scale in software development: the scale of development organization affects firms' productivity negatively.

Thus, the phenomenon of the *mythical man-month* dominates Japanese information service industries. Effective communication to reduce costs between system engineers and their customers, and among system engineers themselves, is lacking, and this is likely to be one of major obstacles to Japanese firms improving the efficiency of their information service provision.

In this respect, central and local governments should play a major role in reversing this tendency. Central and local governments are the major customers of information service firms. However, governments are often shown to be incompetent in articulating their needs when they place orders with information service firms. As a result of their lack of eloquence, communications between governments as customers and system engineers in supplier firms are not smooth, and in some cases, this leads to last-minute specification changes that in software development are very costly.

5. Concluding Remarks

In this paper, we examined factors determining the productivity of information service firms' activities, using very comprehensive data on the information service industries in Japan. Among the possible determinants, we focused on (1) the degree of modularization and resulting outsourcing, (2) economies/diseconomies of scale in software development.

Our results might be rather worrying for Japanese government officials promoting "e-Japan Strategy II" initiatives to revitalize the Japanese economy. Firstly, we showed that outsourcing has persistent negative effects on TFP, suggesting that not only is productivity-enhancing modularization not fully utilized but also that productivity-hindering remnants of traditional main-contractor-subcontractor relations still persist in information service industries. This shows that increasing productivity cannot be achieved simply by introducing productivity-enhancing modularization into information service industries. A fundamental restructuring of business practices is necessary to transform traditional main-contractor-subcontractor relations into modularized, horizontal as well as vertical, mutually supportive community-like relations. To achieve this goal, governments as buyers should play a central role.

Secondly, we found diseconomies of scale in software development, suggesting less efficient communication among members in large development teams. Communication gaps were identified between information service providers (particularly the system engineers who are in charge of coordinating development) and their customers. Among these customers, central and local governments are the most important, and our preliminary empirical study shows that these governments hinder information service firms' productivity, rather than enhance it, which contrasts with the assumptions in the "e-Japan Strategy II". Lack of information service expertise on the side of central and local governments seems to be one cause of these problems, and governments should try to rectify this in order to promote productivity-enhancing practices in these industries.

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APPENDIX

Framework of TFP Growth Measurement

We follow standard neoclassical growth accounting framework. In particular, we assume constant returns to scale and flexible factors of production.

1. Output: Real Value-Added

Value added for each firm is calculated using the formula below, which follows the definition of value-added in the *Survey* itself.

Real value-added (index) =
(Sales – Operating Expenses + Total Compensation + Rents) / Price Index

Here, as a deflator, we use the Corporate Service Price Index (CSPI) of the Information Service Industry, compiled by the Bank of Japan.

One could argue, as Baily (1986) and Bartelsman and Gray (1996) do, that firms' outputs should be gross outputs rather than value-added. However, gross outputs seem less appropriate in information service industries, including the software industry, because outsourcing is prevalent in these industries. Outsourcing is not a usual input in the production process, and whether or not to outsource some business is a strategic decision rather than a technological constraint. In this case, the framework of gross production treating outsourcing as a usual input may lead to misrepresentation of the production function. See Hulten (2001) on this issue.

2. Inputs

For factor inputs, we have labour hours, and capital service from equipment stocks, and from buildings and structure. (As usual, throughout this paper we assume service is proportional to the amount of stocks.) Labour hours are estimated by multiplying the number of workers by the average work hours in information service industries, using the *Monthly Labor Survey*.

We use perpetual inventory methods (PIM) as much as possible to construct capital stocks data. For depreciation rates we rely mostly on Fraumeni's (1997) rates. For deflators, we construct deflator data based on data supplied by P. Schreyer should this be Schreyer of the OECD, which are harmonized price indexes of capital stocks. We construct our depreciation rates and deflators using weights suitable for Japanese information industries. For weights, we use those in the 1995 Input-Output Tables' fixed-investment matrix data.

A distinctive characteristic of information service industries is the importance of computer (and computer time) lease. Fortunately, the

Survey gathers data about computer and computer-time lease. We capitalize these lease costs to get computer stock data. (This conversion is necessary for consistency since we use stock data as inputs assuming service flows are proportional to stock values.)

We encounter many zeros in building and structure investment. This means many small information service firms do not own buildings or structures, but simply rent them. Since we have information about building rents, we utilize this information to estimate building and structure capital stocks. Unfortunately, however, we do not have direct data on an individual firm's building and structure rents; we only have information about the percentage of building and structure rents in the total cost on the average. We construct imputed building rents relying on this average figure assuming individual building rents do not differ from the average.

3. User Cost

To estimate user costs, we use the following standard formula:

$$UCC_{it} = \frac{1 - u_t z_{it}}{1 - u_t}(\rho_t + \delta_i)q_{it}$$

Here UCC_{it} is the t-th period user cost of the i-th capital stocks, ρ_t is the t-th period dividend yields of the First Division of the Tokyo Stock Exchanges (here we follow Hall (1990)), δ_i is the depreciation rate of the i-th stocks, u_t is the effective marginal corporate tax rate of the t-th period, and z_{it} is the capital consumption allowance of the i-th capital stocks, and q_{it} is the price of the ith capital stocks. The effective tax rates and the discounted value of future depreciation are calculated using information contained in the *Annual Report of Incorporated Enterprise Statistics*, the *Annual Report on Finance of Local Governments*, and the *Survey on Incorporated Enterprises*. We follow here the procedure in Homma *et al.* (1984).

4. TFP Growth

Using data described so far, we calculate TFP growth in the following formula.

$$TFPGrowth = \{\ln V_{t+1} - \ln V_t\} - \frac{1}{2}\sum_{i=1}^{5}(s_{i,t+1} + s_{i,t}) \cdot \{\ln F_{i,t+1} - \ln F_{i,t}\},$$

where V is real value-added, F_i is the i-th inputs and s_i is their cost share. In particular, we consider as inputs (a) labour hours, (b) equipment capital stocks, (c) imputed computer capital stocks by capitalizing lease payments, (d) building and structure stocks estimated by the perpetual inventory method, and (e) imputed building and structure stocks by capitalizing building rents.