

MMRC-F-11

Total Factor Productivity in Japanese Information
Service Industries: Firm-Level Analysis

Kiyohiko G. Nishimura

Faculty of Economics, University of Tokyo and Executive
Research Fellow, Economic and Social Research Institute,
Cabinet Office, Government of Japan

Futoshi Kurokawa

Graduate School of Economics, University of Tokyo

June 2004



東京大学21世紀COE [整備済]
ものづくり経営研究センター

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Kiyohiko G. Nishimura

Faculty of Economics, University of Tokyo and Executive Research

Fellow, Economic and Social Research Institute, Cabinet

Office, Government of Japan

Futoshi Kurokawa

Graduate School of Economics, University of Tokyo

June • 2004

Abstract

We examine factors determining productivity of firms' information service activities, using most comprehensive data of information service industries in Japan. We focus on the degree of modularization and resulting outsourcing, economies/diseconomies of scale in software development, and firms' organizational changes. Outsourcing has persistent negative effects on total factor productivity, suggesting not only productivity-enhancing modularization is not fully utilized but also productivity-hindering remnants of traditional main-contractor-subcontractor

relations still prevail in information service industries. We also find diseconomies of scale in software development, suggesting less efficient communication among development team members. Finally, we find a substantial cost on firms' organizational changes on productivity.

JEL classification

L23 - Organization of Production

L25 - Firm Size and Performance

L86 - Information and Internet Services; Computer Software

O33 - Technological Change: Choices and Consequences

1. Introduction

Japan has been suffering from the most severe economic stagnation since 1990. Among possible causes of this prolonged recession, a sharp decline in productivity has attracted much attention of both economists and policy makers in the past decade.ⁱ In particular, Nishimura et al. (2002) examine and compare US experience (reported in Jorgenson et al. (2001)) and Japanese experience (reported in Nishimura and Shirai (2002)). They find a sharp contrast between productivity-improving manufacturing sectors (though there is a wide variety among them) and productivity-stagnating non-manufacturing sectors in Japan. In contrast, no comparable difference of this magnitude is found in the United States though there is a wide sectoral difference. Japanese ICT hardware-producing industries are as productive as US counterpartsⁱⁱ but Japanese ICT using industries (finance and insurance, trade, and other services) show markedly inferior performance compared with US counterparts.

In another piece of evidence, Ark et al. (2002) report that in the latter half of the 90s, IT-using industries (mostly service industries in a broad sense) show a robust 5.4% increase in the United States, while the Japanese counterparts exhibit disappointing 0.0%. Especially, a sharp contrast is notable in Wholesale and Retail Trade industries between Japan and the United States.ⁱⁱⁱ The White Paper (2001) of the Cabinet Office on the State of the Economy argues that the TFP growth in Japanese non-manufacturing declines sharply whereas the decline of TFP growth in manufacturing sectors is not so pronounced. Thus, disappointing TFP growth in non-manufacturing sectors aggravate, if not cause, Japan's economic stagnation of the 1990s.^{iv}

Although their importance is apparent in their large share of GDP and the above-mentioned disappointing performance, non-manufacturing industries have not been a major subject of large-scale firm-level empirical studies. This is a sharp contrast with manufacturing industries in which large-scale firm-level as well as plant-level studies are commonly undertaken. This scarcity of research is partly due to data availability.^v

In this paper, we fill this huge gap between practical importance and scarcity of firm-level research in non-manufacturing industries. Among a variety of non-manufacturing industries, we take up information service industries as our target industries for the following three reasons.

Firstly, information service industries include the software industry that is an integral part of

so-called “IT (information technology) Revolution” alongside with the hardware industry. Because of a prominent role of IT on recent economic development, in-depth analysis of information service industries is urgently needed. We should remind ourselves that the software industry is among non-manufacturing industries while the hardware industry is by definition among manufacturing industries.vi

Secondly, both the Government and business communities consider information service industries as “strategic” industries. The Japanese government launched an initiative called “e-Japan Strategy II” in 2003, and clearly targeted information service industries. Some firms in electronic industries are shifting their business emphasis from computer hardware to software and information services.vii

Thirdly, however, there is a seemingly high hurdle for the government and firms to achieve their goals. There are several pieces of anecdotal evidence of low potential in Japanese information service industries. For example, according to the so-called Capability Maturity Model (CMM), 23 Indian firms are in the top rank at the end of 2000, while no Japanese firm is ranked to this category.viii Similarly, no Japanese firm is in the top 5 of OECD (2002)’s revenue ranking of software licensing and service fees. Only one Japanese firm appears among the top 20. Thus, it is of utmost importance to analyze factors determining productivity in Japanese information service industries including the software industry and to discern possible impediments to improve efficiency. Although there is a sizable literature on firm-level productivity in manufacturing industries, only a few studies have been conducted on non-manufacturing industries and almost none on information service industries even in the United States, where data are relatively easily available.ix 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 raises TFP growth in telephone companies in the United States. To our knowledge, there is no empirical study investigating TFP growth of information service industries at the firm level in the United States. Even case studies that examine productivity directly are scarce.

One notable exception is Cusmano et al. (2003), who 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 that India and Japan are higher development productivity than the United States and the European Union. However, their productivity measure is not TFP but several project-oriented measures of performance such as the number of lines of code per programmer-month, and defects reported per 1000 lines of code in one year after delivery to customers. To interpret their results, we should take account of “cultural difference,” as suggested by these authors. They point out that US programmers tend to emphasize shorter or more innovative

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

programs, and spend more time in optimizing code, which ultimately reduces the number of lines of code, while simultaneously increasing programmer-months.

The research reported here is markedly different from previous researches about information service industries in Japan and in other countries in two aspects. Firstly, this research is based on large-scale Census-like survey data on all firms and establishments engaged in information services, called the Survey on Selected Service Industries, Volume of Information Services. In contrast, existing studies in this field are at most case studies (see, for example, Sano (2001)), and in some cases they may be biased to successful firms (see, for example, Koyama and Takeda (2001)x). These studies are informative, but insufficient for the purpose of capturing the overall picture of the industry as a whole.

Secondly, we examine total factor (or multi-factor) productivity of firms. Previous studies using large-scale data are often concerned only with labor productivity (see, for example, Shintani (1998)). However, it might be misleading to base one's argument on labor productivity only, in an industry using sophisticated IT equipments like computers and servers. The necessity of TFP analysis is obvious in information service industries.

This paper is organized as follows. In Section 2, we examine factors determining productivity in information service industries, with special emphasis on the software industry. In section 3, we clarify important characteristics of the Survey of Selected Service Industries, and explain data construction in some details. Main empirical results are presented in Section 4. We then discuss these results and examine what factors are behind these results. Concluding remarks are presented in Section 5.

2. Factors Determining Productivity of Information-Service Firms

In this section, we examine possible determinants of productivity of information-service firms, which will be the basis of empirical analysis of Section 4. Since software products are major outputs in information service industries, we base our argument mostly on productivity determinants of software development. xi In particular, we consider three possible determinants: the degree of modularization, the scale of software development, and organizational structure, which have often been considered as most influential determinants of software development productivity.

2.1. Modularization

Both in popular presses and academic writings, so-called Silicon Valley Model has attracted much attention. It is often argued that in the Silicon Valley of the State of California, information companies and engineers form a “community” and collaboration within the community is common and productive.xii Based on such collaboration, outsourcing has been considered as one of the most productivity- enhancing practices.

However, simple outsourcing is not always likely to be productivity enhancing. For example, if new products come out with new production design, outsourcing may cause a serious production problem when readjustment of production process is necessary and communication between outsourcers and outsourcees are not so smooth. In order to facilitate such readjustment and communication and to make outsourcing successful, “modularization” of parts has been considered to play a vital role in the Silicon Valley.xiii

The concept of “modularization” stems from the development of IBM SYSTEM/360. Computers before IBM SYSTM/360 had their own specifications with own parts, operating system, and application software. There were few common parts (both hardware and software) between each generation of computers. Computer manufacturers developed idiosyncratic parts and software suitable for each generation of computers virtually from scratch.

The development of IBM SYSTEM/360 was revolutionary in the sense that its developers invented the concept of “family” of computers: compatibility within a family was maintained as much as possible, and in order to do so, “modularization” had been extensively utilized. The adoption of modularized design and its wide-range application were considered to be one of the most dramatic

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

driving forces behind the revolutionary speed of innovations in the computer industry (Baldwin and Clark (1997)).

Modularization has far-reaching consequences. Modularization of product architecture allows firms to modularize production process, which leads to modularization of organization. Thus when modularization is “deepened”, firms can outsource a part of their business. Outsourcees, who are sometimes spinouts of some outsourcer firms, are then able to get outsourcing contracts from various companies to realize economies of scale and to slide down the learning curve quite rapidly, so that they become competitive in prices. This in turn enables outsourcers to procure parts inexpensively. 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 the same productivity-enhancing effect of modularization applies to software development.

The successful hardware modularization, however, may not be duplicated in software and information service industries. Koyama and Takeda (2001) forcefully argue that production innovation in the software industry is less frequent than the hardware industry, implying these two industries are not so similar. Thus simple “transplanting” of modularization may not work well in the software industry. For example, if OS suppliers do not open source codes of their OS, modularization is far less complete than in the hardware industry. xiv Furthermore, human factors are relatively important in the software industry, since implicit knowledge of engineers may not be fully “coded” and reproducible.

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

2.2. Scale of Development Organization

The second possible factor determining productivity of information service industries is the scale of development organization. Here development organization includes the basic research and development division and system software development division (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 are changing quite rapidly, and suppliers have to cater for ever-changing demand of their

customers.

This observation suggests diseconomies, rather than economies, of scale in software development. In fact, Frederick P. Brooks Jr., who is often referred as the “father of IBM SYSTEM/360”, points out these possible diseconomies of scale, and argues against large-scale development. He coins the idea that inputs can be measured in man-months as a “myth” in his renowned book *Mythical Man-months* (Brooks (1995)). He argues that the time of one programmer is not substitutable by the time of another programmer, so that using one hour of 100 programmers cannot finish a project that can be finished by using 100 hours of one programmer. Consequently, programmers’ labor inputs cannot be measured by man-hours or man-months.xv

Thus, when communication is insufficient among development team members, an increase in the number of development teams may have even negative effects on the productivity of software development. This possible negative effect may be particularly keen when the development schedule is suddenly shortened and engineers are added to the development team to compensate the change.

In contrast, there is one important example of economies of scale in software development, which is the success of the Linux system development. As is well known, the development of Linux is made possible by participation of many engineers and programmers around the world, who form an Internet virtual community. They enhance communications among them through various means of Internet technology. The most important characteristics of the development of Linux is that codes are open to their community and thus coding and debugging are efficiently undertaken in a rapid manner. The success of Linux suggests that if communication among developers is smooth, there are notable economies of scale in software development.

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 see which factor dominates in the Japanese information service industries.

2.3. Organizational Development and Productivity

We have so far examined a crucial role of communication in software development. Comparing the phenomenon described in the mythical man-month and the success of Linux, we understand importance of development-team organization that enhances or hinders effective communication.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

In fact, effectiveness of communication is also closely related to modularization. If software development is modularized in a way to enhance communication as in the Linux case, we can expect a large productivity gains. If modularization is pursued by other motivations than communication, we are likely to face inefficiency described in the mythical man-month. In a similar token, one may argue that firm organization may be as important as development team organization.

Innovations in software development are often described as leap-frogging, not gradual, in which past experiences have relatively less value than in other industries. This means that firm organization should be sufficiently flexible to accommodate such leap-frogging innovations. In fact, information service industries are known for a variety of employment contracts, ranging from standard long-term contracts for regular employees called “Shain” to short-term ones for workers choosing more flexible work styles.

One typical example is Elysium, a producer of 3D data transformation software called direct data translator.^{xvi} It was divested from Armonicos, which itself was founded by three spinouts of YAMAHA as a software firm in 1984.^{xvii} The packaged software division was divested in 1999 to become Elysium. The custom software division remains in Armonicos. Thus, even though Elysium and Armonicos are in the same 3D CAD software market, they decide to separate in order to seek efficiency and to maximize their value-making potential.

In the empirical analysis of Section 4, we examine the effect of organizational changes on productivity explicitly. In particular, we distinguish adjustment costs of firm organization from those of employment adjustment.

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

In this section, we briefly review and explain our data source, the Survey of Selected Service Industries, Volume of Information Service Industries. This survey is conducted by the Ministry of Economy, Trade and Industry (METI). However, before explaining data source, it may be worthwhile to briefly peruse Japanese information service industries.

3.1. Japanese Information Service Industries

Survey of Selected Service Industries, Volume of Information Service Industries is the most comprehensive statistics about the Japanese information service industries. Here information service industries include information processing service (including application service providers (ASP))^{xviii}, custom software, prepackaged software (business prepackaged software, software game, basic software), system management and administration, data base service (online and offline), research, and others.

In the empirical analysis we use panel data of firms between 1991 and 1998.^{xix} However, we use the most recent aggregate data (2001) here to review the current state of Japanese information service industries. The total sales of information service industries are 13.9 trillion yen, a remarkable 18.2% increase from the previous year. Note that the Japanese economy was in the deflationary stage in 2001, so that this increase in nominal terms is all the more impressive. Among all information service industries, custom software development has the largest share, which is 49.4%, and the third largest is prepackaged software development's 10.8%. Thus software development including both custom and prepackaged accounts for more than 60%. The second largest share is information processing service's 19.1%.

Prepackaged software's growth of sales is an astounding 49.1%, which is the highest among information service industries. This high rate of growth is the result of extremely high growth rates of its subcategories, that is, 162.3% growth in software games and 112.6% growth in basic software. System management and administration's growth rate is 44.8%, which is the second highest. This may be caused by a rapid growth in network systems in this field. Custom software has a decent growth rate of 8.4%, though its rate pales before the extremely high growth rate of prepackaged

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

software. Only one category exhibits negative growth, which is -10.5% of data base service. This category includes some of Internet businesses, so that this decline may reflect hard time of Internet businesses after the burst of so-called “Internet Bubble.”

Let us now turn to the demand side of information service industries. In the total contracted sales, the share of manufacturing firms is 22.6% and that of finance and insurance firms is 17.5% , and these two industries account for more than 40% . As for the growth rate, transportation and communication have the highest, which grows at the rate of 41.5% . Wholesale and retail trade industries are the second highest, and its 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, is the most comprehensive statistics about Japanese information service industries. This survey, conducted by the Ministry of Economy, Trade and Industry (METI), is a Census-like one, in which all firms and establishments engaged in information service industries are surveyed. Moreover, the coverage of the survey is far wider in its scope of information service industries than even the Establishment and Enterprise Census. The Survey collects information about establishments and firms that have some business activities in information service, while the Census gathers information about establishments and firms whose major business activities are in information service. This is particularly important since information service industries are rapidly expanding ones with many entries from and exits to other industries.

Table 1 shows the number of establishments as a whole and for each sub-categories based on firms’ organizational structure, according to aggregate figures published by the METI. In our sample period of 1991-1998, the total number of establishments ranges between the smallest number 5,812 of 1995 and the largest 8248 of 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 the firm level and we examine the effects of firm-level characteristics such as firms’ organizational structure on firms’ productivity. Thus, our basic units of investigation are firms, rather than establishments. Among all establishments listed in Table 1, we examine single establishments and headquarters in our study.

The Survey of Selected Service Industries is particularly suited for firm-level analysis of information

service industries in several respects. Firstly, the Survey meticulously distinguishes revenues, costs, labor inputs and capital stocks in firms' information service activities from their other activities. This is important since some firms in our samples engage only partially in information service activities. In our empirical analysis, we use these revenues, costs, labor inputs, and capital stocks solely in their information service activities to construct value-added and other data necessary for TFP calculation. That is, our value-added, labor input and capital stock data are solely of firms' information service activities, and thus they are not "contaminated" by other activities.xx

A notable characteristic of capital investment data in this data set is many zeros and blanks found in the category of "acquisition of structure and buildings" and "acquisition of machines and equipments", on the one hand, and relatively large payments of computer-time lease and other rental payments that are supposedly building rents. This implies that in some cases 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 as much as possible, but when it is not appropriate, we resort to other procedures to get capital service inputs.

Finally, there is no intangible asset data in the Survey. In particular, there is no data of software assets that firms have. It is inconceivable that firms engaging information service activities have no software assets. Consequently, we should take this fact in mind and take measures to correct possible biases stemming from the lack of software asset information.

3.3. 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.

3.3.1. Output: Real Value-Added_{xxi}

Value added of each firm is calculated by the following formula, which follows the definition of the value-added in the Survey itself.

Real value-added (index) =

$(\text{Sales} - \text{Operating Expenses} + \text{Total Compensation} + \text{Rents}) / \text{Price Index}$

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

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

by the Bank of Japan.

We exclude firms having negative value-added in a particular year from our samples of that year. However, the number of these firms is very small, accounting only 0.88% of total firm-years, so that this does not cause any significant bias.

3.3.2. Inputs

As for factor inputs, we have labor hours^{xxii}, equipment stock services, and building and structure capital services. (As usual, we assume services are proportional to the amount of stocks throughout this paper.)

We use perpetual inventory methods as much as possible to construct capital stocks data. For depreciation rates we rely mostly on Fraumeni (1997)'s rates. For deflators, we construct deflator data based on data supplied by P. Shreyer of OECD, which are harmonized price indexes of capital stocks. We construct our depreciation rates and deflators using weights suitable for Japanese information industries^{xxiii}.

A distinctive characteristic of information service industries is an importance of computer (and computer time) lease. Fortunately, the Survey has data about computer and computer-time lease. We capitalize these lease costs to get a computer stock data. (This conversion is necessary for consistency since we use stock data as inputs assuming service flows are proportional to stock values.)

One note should be due for buildings and structure. We encounter many zeros in building and structure investment. This means many small information service firms do not own buildings and structure but simply rent them. Since we have information about building rents, we utilize this information to estimate building and structure capital stocks.^{xxiv}

3.3.3. 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,xxv 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,xxvi and q_{it} is the price of i th capital stocks.

3.3.4. 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) labor 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.

3.4. “Firms with Well-Established Information Service Activities”

It is not possible to compute TFP growth of all firms because very high turnovers. For this reason, we restrict our attention on firms whose information service activities are well established. We set the following two criteria, and firms satisfying all these criteria are put in the following empirical analysis.

In the first step, if firms whose information service activities yield negative value-added and/ or hire no worker in a particular year, we exclude these firms from our sample of the particular year. If these firms show positive value-added after that year, they are included in our sample thereafter. As reported earlier, actual occurrence of negative value-added is rather rare, accounting less than 1% of our total firm-years.

In the second step, if firms do not have five consecutive years of information service-related equipment investment, we excluded from our sample. This is necessary since we use the five-year average investment growth rate to estimate benchmark-year capital stocks.xxvii By doing this, we restrict our attention virtually on firms with well-established information service activities.

Through this procedure, we get 1,106 firms with well-established information service activities.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Our sample period is 1991-1998, and our sample is an unbalanced panel.

To discern the characteristics of our samples, “firms with well-established information service activities”, we compare the whole samples and our truncated samples in the following tables.

Table 2-1 reports the summary statistics of the whole samples after excluding firms with negative information-service value-added and/or no information-service worker, while Table 2-2 shows that of our samples. Here major variables are the ratio of information-service outsourcing to information-service sales, the number of SE (system engineers)^{xxviii}, the ratio of SE to the total information-service work force, and the ratio of information-service profits to information service operating expenses, which we consider later as determinants of TFP growth.

Comparing Table 2-1 and 2-2, we find that quite a similar picture between the total samples (excluding abnormal ones) and our “firms with established information services”, except for the number of SE’s and the number of information service workers. For example, the ratio of outsourcing to information service sales, the total samples’ average is 0.1378, while 0.1482 in firms with established information activities. Similarly, the ratio of SE’s is 0.2839 in the total sample, while 0.3789 in our target of investigation. However, the number of information service workers and SE’s is substantially higher in firms with established information service activities, so that our target is slanted to larger firms. In order to interpret our results, these characteristics of our target of investigation should be kept in mind. ^{xxix}

Let us now turn to the issue of firms’ organizational dynamics and its effects on TFP growth in our samples. In order to discern the effects of firm dynamics, we disaggregate our samples further into four segments.^{xxx} These four segments are:

- Group 1 (Single-Establishment Firms): firms that remain single establishments throughout the sample period.
- Group 2 (Multiple-Establishment Firms): firms with the headquarters and branch offices throughout the sample period.
- Group 3 (Expanded-to-Multi Firms): firms that start as single establishments and become multi-establishment firms by the end of the sample period.
- Group 4 (Shrunk-to-Single Firms): firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Table 3 reports the average of major variables for each segment. As for the estimated TFP growth, Group 2 (Multi-Establishment Firms) has the highest TFP growth rate (2.61%), while Group 4 (Shrunk to-Single Firms) exhibits the lowest (0.51%). We will consider determinants of the TFP behind these figures. Group 2 (Multi-Establishment Firms) has the highest outsourcing to sales ratio (17.69%), while Group 1 (Single-Establishment Firms) shows the lowest (13.09%).

4. Models, Estimation Results and Discussion

4.1. Choice of Variables

4.1.1. Modularization and Outsourcing

In Section 2, we have examined possible effects of modularization on information service productivity. There we have pointed out that modularization enables firms to outsource parts of their products in an efficient way. If this is the case, the degree of outsourcing may measure 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 representing modularization and resulting outsourcing.

According to Fujimoto (2002), there are three kinds of modularization: (a) modularization of product architecture (modularization in development process), (b) modularization of production process, and (c) modularization of supplier relations. Outsourcing is a result of (3), which is based on (b) and (a). However, outsourcing may not solely be motivated 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 empirical results obtained in this paper.

4.1.2. Scale of Development Organization and the Number of SE's

The second determinant we have 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 we should use in our 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-labor intensive, and thus the scale of development is likely to be highly correlated with the size of skilled work force. In the context of information service industries and especially the software industry, skilled work force include SE's (system engineers), programmers, and research scientists, about which we have data in the Survey of Selected Service Industries, Volume of Information Service Industries. Among them, SE's have a pivotal role in software development, especially in custom software one, which dominates Japanese software development.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

In custom software development, to tailor software to the demand of customers is of utmost importance. SE's in the worker classification of the Survey are those who responsible to listen customers' needs and to interpret them into schemes which are programmable. They are also responsible to select most suitable development languages and to organize programmers to get the best out of them. Taking account of SE's importance in Japanese software development, we use their number as a proxy of the scale of software development.xxxi

4.1.3. Other Possible Determinants

(1) Unobservable Software Capital Stocks and the SE ratio.

As explained before, there is no information about non-tangible software capital stocks in the Survey. However, it is inconceivable that there is no software capital stock in information service firms. To ignore this unobservable capital stock may lead to overestimation of TFP. Thus, we need to control these unobservable software capital stocks using a proxy variable.

Presumably the more a firm is technology-oriented, the more its unobserved software capital stocks are. In this sense, the ratio of the number SE's in the total number of information service workers, representing the firm's technological orientation, is likely to be a good measure of unobserved software capital stocks.

(2) "Profit-driven R&D Investment" Hypothesis and the Profit-to-Sales Ratio.

It has often been argued that the higher a firm's profits are, the higher the level of research and development activities is, leading to a higher TFP. This "profit-driven R&D investment" may be relevant in information service industries in Japan since relatively small firms in our samples may be liquidity-constrained in our sample period of 1991-1998. To control this possibility, we consider the ratio of gross profits of information service activities to their operation costs as one determinant of TFP.

(3) Employment Adjustment Costs

In Section 2, we have pointed out a possibility that changes in firm organization affect TFP such as transformation from a single-establishment firm to a multi-establishment-firm. In our empirical analysis, we consider the effects of firms' organizational dynamics on TFP by disaggregating our samples in four groups explained in Section 2.

Beside these "adjustment costs" of organizational changes, there are other important adjustment costs in Japan, which are employment adjustment costs. Although information service industries are relatively new industries and that we find rather flexible labor contracts in these industries compared

with other industries, there remains a sizable cost of employment adjustment in information service industries like other Japanese industries. Such adjustment costs may lower overall productivity of a firm, leading to a lower TFP.

To take account of these employment adjustment costs, we consider the squared rate of change in the number of information service workers in the following empirical analysis.

4.2. Models and Estimation

Taking account of arguments in previous sections, we formalize that the level of TFP in information service industries is determined in the following way:

$$(1) \quad \ln TFP_{i,t} = \alpha_0 + \alpha_{1i}t + \sum_{j=1}^J \beta_j x_{ij,t} + \sum_{k=t+1}^T \gamma_k d_{k,t} + \varepsilon_{i,t} \quad i = 1, \dots, I, \quad t = 1, \dots, T$$

Here i denotes the i -th firm and t denotes the year. Equation (1) implies that the total factor productivity of the i -th firm's information service activities in year t , TFP_{it} , is determined by a

constant α_0 , a time trend $\alpha_{1i}t$, microeconomic variables $x_{ij,t}$ discussed in the previous sections, time dummy $d_{k,t}$ representing macroeconomic conditions, which is 1 if $t=k$ otherwise 0, and disturbances $\varepsilon_{i,t}$. In this formulation, the time trend is constant but it varies across firms representing firm heterogeneity.

As for microeconomic determinants $x_{ij,t}$, we consider the followings.xxxii

- 1) OUT: the outsourcing-to-sales ratio in information service activities, which is used as an index of modularization.
- 2) SE: the number of SE's, which is used as an index of the scale of development organization.
- 3) SE-RATIO: the ratio of the number of SE's to the total information service workers, which is used to take account for unobservable software capital stocks.
- 4) PROFIT: the ratio of gross profits to operating expenses in information service activities.

In some cases, we consider the effects of employment adjustment costs on TFP. There we will add

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

the following variable.

5) ADJUST: the squared rate of employment change.

We use a standard growth accounting procedure to get firms' TFP growth, so that we base our analysis in the following "growth" or first-difference formulation (2).xxxiii.

$$(2) \quad \Delta \ln TFP_{i,t} = \alpha_{1,j} + \sum_{j=1}^J \beta_j \Delta x_{ij,t} + \sum_{k=t+1}^T \gamma_k \Delta d_{k,t} + e_{i,t},$$

where $\Delta Y_t = Y_{t+1} - Y_t$ and xxxiv

$$e_{i,t} = \varepsilon_{i,t+1} - \varepsilon_{i,t}$$

In addition, we assume that the time trend, $\alpha_{1,i}$, is the sum of a constant and an unobservable individual specific effect:

$$\alpha_{1,i} = \alpha_1 + u_i,$$

where α_1 denotes the constant and u_i denotes the unobservable individual specific effect. Then the equation (2) can be written as ordinary one-way error component regression model with time dummy (3). xxxv

$$(3) \quad \Delta \ln TFP_{i,t} = \alpha_1 + \sum_{j=1}^J \beta_j \Delta x_{ij,t} + \sum_{k=t+1}^T \gamma_k \Delta d_{k,t} + u_i + e_{i,t},$$

It is well known that to apply standard procedures such as OLS causes problems if variables are non-stationary.xxxvi However, to apply tests of stationarity, we should take into account our samples' characteristics of large cross-sectional but small time dimensions (at most nine years) and a unbalanced panel. To check stationarity of variables in our panel, we carry unit root testsxxxvii developed by Breitung and Meyer (1994) [BM] and Bond et al. (2002) [OLS1, OLS2 (t-test based on OLS estimation)] for panels with large cross-sectional dimensions but small time dimensions such as ours. xxxviii The results of these tests are reported in Table 4. The unit root hypothesis is soundly rejected in all unit root tests for the first differenced variables.

It is uncertain that whether $e_{i,t} = \varepsilon_{i,t+1} - \varepsilon_{i,t}$ satisfies standard liner regression model assumptions about disturbances.xxxix Consequently, we estimate (3) for cases of (a) error terms without

autocorrelation, and (b) error terms with autocorrelation. For simplicity, we consider AR (1) in the case of autocorrelation.

Furthermore, there is a good possibility that error terms of each individual firm may have heteroscedastic structure. To take a proper account of this possibility, we also estimate (3) by FGLS (Feasible General Least Squares) for the case that error terms in regressions are autocorrelated and heteroscedasticity is present across firms and years, where autocorrelation coefficients are not identical across panels.

So, we consider three estimation procedures to take account of them and to check robustness.

Panel OLS: (random-effects model/fixed-effects model).

Panel AR1 (random-effects model/fixed-effects model): assuming error terms are first-order autoregressive.

FGLS (Feasible General Least Squares): assuming error terms are AR (1), where first-order autocorrelation coefficients are heterogeneous and heteroscedasticity is present across firms and years.

4.3. Results and Discussion

4.3.1. A Brief Summary

The results of estimation is reported Table 5 through Table 10. Table 5 is the results of Panel OLSx1, Table 6 is those of Panel AR(1), and Table 7 is those of FGLS. Cases with employment adjustment costs are shown in Table 8 (Panel OLS), Table 9 (Panel AR(1)), and Table 10 (FLGS). In addition, each table shows the difference among firms with different organizational dynamics over time. We show the results of all firms in our samples (“firms with well-established information service activities”) in the column of “All”. The results of Group 1 (single-establishment firms), Group 2 (multiple-establishment firms), Group 3 (expanded from single to multiple), and Group 4 (shrunk from multi to single) are shown respectively in these tables. xli

The Sample period is 1991-1998 for Table 5 through Table 7, and 1991-1997 for Table 8 through Table 10.xlii Although the number of firms varies among tables, roughly 1,100 firms are in our samples.

As shown in Tables 5 and 7, the null hypothesis of no autocorrelation in error terms is rejected in all cases (see All, Groups 1, 2, 3 and 4) at the 1% significance level, we hereafter concentrate our discussion mostly on Tables 6 and 9 (Panel AR(1)) and Tables 7 and 10 (FGLS), with some reference

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

to Tables 5 and 7 to check robustness.

Let us consider estimation results of all firms, which are reported in the column “All” of Tables 5 through 10. In all these tables, we have fairly consistent and significant results: the coefficient of the d-OUT, d-SE, d-SE-RATIO and d-PROFIT is 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-SE-RATIO and d-PROFIT is positive. Period dummies are all significant at the 1% level when employment adjustment costs are not incorporated in Tables 5 through 7. However, their effects are substantially reduced when employment adjustment costs are explicitly considered in Tables 8 through 10.

4.3.2. Outsourcing and Remnants of Traditional Relationship

A remarkable result in these tables is that the outsourcing-to-sales ratio (OUT) has a significant negative effect on TFP. This result is quite robust in all specifications. This robust negative effect of outsourcing is striking. As in the Section 2, modularization behind outsourcing should improve productivity, 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 industrial structure of the Japanese software industry suggests that the negative effect of outsourcing stems from a remnant of traditional subcontracting practices found in this industry. In the traditional relationship, there are main contractors on the one side that get contracts from customers being often large corporations and/or central as well as local governments. On the other side of the relationship, there are sub-contractors that depend mostly on main contractors to allocate business to them.

Main contractors outsource their business not to promote the efficiency in software development but to make sub-contractors as “buffers” of economic fluctuations to reduce costs of adjustment 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 in these main contractors. If so, they violate the dictum of “do not outsource the core of your competence.”

For sub-contractors, their poor financial positions make them unable to take advantage of such outsourcing. Outsourced sub-contractors have little human-capital investment as well as little physical-capital investment.

This inefficient subcontracting system, however, cannot survive if new efficient firms enter the

market. Unfortunately, strong preferences of buyers (consisting of local and central governments and large corporations) to “established vendors” make entry of new, especially small, firms very hard and thus this industrial structure is sustained for a long time.

4.3.3. Mythical Man-Month and Communication Problems

In Section 2, we have argued that the 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 mythical man-month dominates Japanese information service industries. Effective communication to reduce costs between SE’s and their customers and among SE’s themselves is lacking, and this is likely to be one of major obstacles of Japanese firms to improve their efficiency in information service provision.

In this respect, central and local governments should play an important role to reverse this tendency. Central and local governments are major customers of information service firms. However, these governments are often pointed out to be rather incompetent to articulate their real needs when they place orders to information service firms. Because of this lack of articulation, communications between these governments as customers and SE’s in supplier firms are not smooth and in some cases this leads to last-minute specification changes that are very costly in software development.

To test the magnitude of this “incompetent government” effect, we put a dummy variable representing a particular firm’s dependency on government contracts as one explanatory variable in the FGLS estimation of Table 7. Table 12 shows the results for the case in which the government dummy is 1 when the ratio of government contracts to the total information service contracts exceeds 30%, 40% and 50%, respectively. In all cases, the dummy of firms’ dependency on government contracts is statistically significant and has a negative sign. Clearly, governments themselves should act to rectify this problem.

4.3.4. Other Determinants

As for other determinants, we have statistically significant positive effects of the SE-RATIO as expected, which is the proxy of unobservable software capital stocks in firms. We also get statistically significant positive effects of the PROFIT. This suggests many of information service firms may be liquidity constrained. However, there may be other possible explanations of these

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

positive effects of profits on productivity, and thus the results should be considered at most as suggestive.

4.3.5. Strong Effects of Employment Adjustment

Let us now turn to the issue of employment adjustment costs. Tables 8, 9 and 10 report the results. For all firms (see “All” category), we see a substantial downward effect of employment adjustment on productivity. This result is pretty robust across estimation methods we take, and consistent with the commonly held view of high employment adjustment costs in Japan.

However, more in-depth analysis of data shows variation across firms’ organizational changes. In particular, while we have a strong negative effect of employment adjustment for firms of multiple-establishment firms (Group 2) and expanded firms from single to multiple (Group 3), we obtain no significant effect for single establishment firms (Group 1) and a significantly positive and large effect for firms shrunk from multiple to a single establishment (Group 4).

This last finding may be particularly interesting. This shows that when a firm takes a drastic measure to restructure itself to trim out all subsidiaries to become a single establishment, the more thoroughly its accompanying employment adjustment (that is, employment reduction) is, the higher its productivity is.

4.3.6. Effects of Firms’ Organizational Changes (Group1--4)

We now examine the effects of firms’ organizational changes on firms’ productivity. The basic econometric picture of all subcategories (Groups 1 through 4) is qualitatively the same as “All”: In the OLS Panel, the Hausman test leads to random-effect models, and there is serial correlation in error terms so that we use AR(1) and FGLS results mostly in our discussionxlili.

Group-wise estimation results are similar among these Groups. OUT, SE, SE-RATIO and PROFIT have mostly statistically significant coefficients at either 1% or 5% level and the same sign as in the case of “All”. However, the magnitude of their effects varies among these Groups, suggesting a strong effect of firms’ organizational changes on productivity.

As for the negative effect of outsourcing, Table 6 (Panel AR(1)) shows the following order of magnitude:

Group 1 (single) < Group 4 (shrunk) < Group 2 (multi) < Group 3 (expanded)

Similarly, Table 7 (FGLS) has comparatively smaller effects and shows the following order of magnitude

Group 1 (single) < Group 2 (Multi) < Group 4 (shrunk) < Group 3 (expanded).

Thus in both tables, the negative effect of outsourcing is the smallest in single establishments and the largest in firms expanded from a single establishment to multiple establishments.

A particularly interesting result is that the negative effect of outsourcing is far less pronounced in single establishments (Group 1) than multiple establishment (Group 2). This result is a piece of supporting evidence for the hypothesis we developed in Section 4.3.2. There we have argued that traditional relationship between large main contractors and small subcontractors leads to inefficiency in outsourcing. This argument is more relevant to large firms in Group 2, than small firms in Group 1, so that this observed sharp difference strengthens our argument. However, negative effects remain in Group 1 though their magnitude is far smaller than in Group 2. This may reflect small-scale traditional subcontracting systems even in Group 1.

Negative effects of outsourcing are the largest in expanded firms (Group 3). When organization is expanding, there exists larger demand for outsourcing not from efficiency consideration but from keeping up increasing demand. Since outsourcing here is not from modularization, resulting effects of outsourcing are rather negative. This shows the existence of organizational adjustment costs distinct from employment adjustment costs.

Let us now turn to the issue of diseconomies of scale in software development. Table 6 shows the following ranking in the order of magnitude:

Group 3 (Expanded) < Group 1 (Single) < Group 2 (Multi) < Group 4 (Shrunk),

while Table 7 reveals

Group 3 (Expanded) < Group 1 (Single) < Group 2 (Multi) < Group 4 (Shrunk).

Thus, a consistent picture emerges.

A remarkable result is that negative effects diseconomies of scale in development organization are far less pronounced in single establishments (Group 1). (Group 3, which are expanded from single establishments, are likely to have much in common with single establishments with respect to software development organization.) Since single establishments have the simplest organization structure that facilitate relatively smooth and efficient communication both inside and outside, this result suggests our communication argument about the cause of diseconomies of scale is in a right track. Moreover, we find that negative effects of outsourcing are the largest in expanding organization (Group 3), where smooth communication is rather difficult. In sum, our results strongly suggest smooth communication is very important to achieve higher productivity.

5. Concluding Remarks

In this paper, we have examined factors determining productivity of information service activities of firms, using most comprehensive data of information service industries in Japan. Among possible determinants, we have focused on (1) the degree of modularization and resulting outsourcing, (2) economies/diseconomies of scale in software development, and (3) firms' organizational changes.

We have found somewhat disturbing results for Japanese government officials promoting "e-Japan Strategy II" initiatives to revitalize the Japanese economy. Firstly, we have shown that outsourcing has persistent negative effects on total factor productivity, suggesting not only productivity-enhancing modularization is not fully utilized but also productivity-hindering remnants of traditional main-contractor-subcontractor relations still prevail in information service industries. This shows that to increase in productivity is not a simple task to be achieved 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 crucial role.

Secondly, we have found diseconomies of scale in software development, suggesting less efficient communication among development team members. Communication gaps are also pointed out between information service providers (particularly system engineers who are in charge of coordinating development) and their customers. Among these customers, central and local governments are most important, and our preliminary empirical study shows that these governments hinder information service firms' productivity, rather than enhance it, contrary to the presumption of "e-Japan Strategy II" proponents. Lack of information service expertise on the side of central and local governments is the cause of these problems, and these governments should rectify their own problems when they promote productivity-enhancing practices in the industries at the same time.

Although these tasks seem formidable, these governments have no other choice than transforming themselves into informationally and technologically advanced customers of information service firms, to promote true modularization and efficient communication between customers and information service providers.

References

- Ahn, S., "Firm Dynamics and Productivity Growth: A Review of Micro Evidence for the OECD Countries," OECD, OECD Economics Department Working Paper no. 297 (2001).
- Aoki, M and H. Ando (written and Eds.), *Modularization* (Tokyo: TOYO KEIZAI Inc., 2000). (in Japanese).
- Aoki, M. and M. Okuno, *Comparative Institutional Analysis of Economic Systems* (Tokyo: University of Tokyo Press, 1996). (in Japanese).
- Baily, M. N. "Productivity Growth and Materials Use in U.S. Manufacturing," *Quarterly Journal of Economics* 101 (1986), 185-95.
- Baldwin, C. Y. and Kim B. Clark, "Managing in an Age of Modularity," *Harvard Business Review* Sep./Oct. (1997), 99-120.
- Baltagi, B. H., *Econometric Analysis of Panel Data* (New York: John Wiley & Sons, 1995).
- Baltagi, B. H. and P. X. Wu, "Unequally spaced Panel Data Regressions with AR(1) Disturbances," *Econometric Theory* 15 (1999), 814-823.
- Bartelsman, E. J. and M. Doms, "Understanding Productivity: Lessons from Longitudinal Micro-data," *Journal of Economic Literature* 38:3 (2000), 569-594.
- Bartelsman, E. J. and W. Gray, "The NBER Manufacturing Productivity Database," NBER, NBER Technical Working Paper No. 205 (1996).
- Basu, S., J. G. Fernald, N. Oulton and S. Srinivasan, "The Case of the Missing Productivity Growth: Or, Does information technology explain why productivity accelerated in the United States but not the United Kingdom?," Federal Reserve Bank of Chicago, FRBC Working Paper No. 03-08 (2003).
- Bond, S., C. Nauges and F. Windmeijer, "Unit Roots and Identification in Autoregressive Panel Data Models: A Comparison of Alternative Tests," No C5-4 in 10th International Conference on Panel Data, Berlin, July 5-6, 2002 from International Conferences on Panel Data (2002).
- Bosworth, B. P. and J. E. Triplett, "Services Productivity in the United States: Griliches's Services Volume Revisited," prepared paper for NBER CRIW Conference in Memory of Zvi Griliches (2003).
- Breitung, J. and W. Meyer, "Testing for Unit Roots in Panel Data: Are Wages on Different Bargaining Levels Cointegrated?," *Applied Economics* 26 (1994), 353-361.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

- Brooks, Frederick P., Jr., *The Mythical Man-Month: Essays on Software Engineering Anniversary edition* (New York: Addison-Wesley Publishing Company, 1995).
- Cabinet Office, *Annual Report on Economy and Finance* (Tokyo: Government Printing Office, 2001). (in Japanese).
- Colecchia, A. and P. Schreyer, "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries," OECD, OECD STI Working Papers 2001/7 (2001).
- Conference for Improving Software Development and Procurement Processes, "Toward Establishing Evaluation Indexes of Software Development and Procurement Processes in Japan (Tentative Version)," (2001). (in Japanese)
- Cusumano, M., A. MacCormack, C. K. Kemerer and W. Crandall, "A Global Survey of Software Development Practices," MIT, MIT ebusiness Working Paper no. 178 (2003).
- Ehrlich, I., G. Gallais-Hamonno, Z. Liu and R. Lutter, "Productivity Growth and Firm Ownership: an analytical and empirical investigation," *Journal of Political Economy* 102:5 (1994), 1006-1038.
- Fraumeni, B. M., "The Measurement of Depreciation in the U.S. National Income and Product Accounts," *Survey of Current Business* July (1997), 7-23.
- Fujimoto, T., "Japanese-Style Supplier Systems and Modularization – A Case of the Automobile Industry," in Aoki, M and H. Ando (Eds.), *Modularization* (Tokyo: Toyo Keizai, 2002). (in Japanese).
- Fukao, K., and H. U. Kwon , "Productivity and Economic Growth in Japan: Industry-Level and Firm-Level Empirical Analysis," Economic and Social Research Institute, Cabinet Office, Government of Japan, ESRI Discussion Paper Series No. 66 (2003). (in Japanese).
- Fukao, K., T. Miyagawa, H. Kawai, T. Inui, X. Yue, Y. Okumoto, K. Nakamura, M. Hayashida, K. Nakata, T. Hashikawa, N. Okumura, Y. Murakami, S. Hamagata, Y. Yoshizawa, T. Maruyama, and S. Yamauchi, "Industry-wise Productivity and Economic Growth: 1970-1998," Economic and Social Research Institute, Cabinet Office, Government of Japan, Economic Analysis 170 (2003). (in Japanese).
- Gort, M. and N. Sung, "Competition and Productivity Growth: the case of the US telephone industry," *Economic Inquiry* 37:4 (1999), 678-691.
- Hall, R. E., "Invariance Properties of Solow's Productivity Residual," in P. Diamond (Ed), *Growth / Productivity / Unemployment* (MIT Press, 1990).

- Hayashi, F., and E. Prescott, "The 1990s in Japan: A Lost Decade," *Review of Economic Dynamics* 5 (2002), 206-235.
- Honma, M., N. Atoda, F. Hayashi and K. Hata, "Equipment Investment and Corporate Tax Systems," Economic Planning Agency, Institute of Economic Studies, Research Series 41 (1984). (in Japanese)
- Hulten, C. R., "Introduction" in Hulten, C. R. (Eds), *New Development in Productivity Analysis* (Chicago: The University of Chicago Press, 2001).
- Im, K., H. Pesaran and Y. Shin, "Testing for Unit Roots in Heterogeneous Panels," *Journal of Econometrics* 115 (2003), 53-74.
- Jorgenson, D. W., "Information Technology and the U.S. Economy," *American Economic Review* 91:1 (2001), 1-31.
- Koyama, Y., and Y. Takeda, "Process Structure of Computer Software Development: Its Characteristics and Problems," in Fujimoto, T., A. Takeishi and Y. Aoshima (Eds), *Business Architecture* (Tokyo: Yuuhikaku, 2001). (in Japanese).
- Levin, A., and C. F. Lin, "Unit root tests in Panel Data: Asymptotic and Finite-sample Properties," University of California, San Diego, Unpublished manuscript (1993).
- Maddala, G. S., *Introduction to Econometrics* (New York: John Wiley & Sons Inc., 2001).
- Maddala, G. S. and S. Wu, "A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test: Evidence From Simulations and the Bootstrap," *Oxford Bulletin of Economics and Statistics* 61 (1999), 631-652.
- Ministry of International Trade and Economy, Industrial Policy Bureau, Research and Statistical Division, *Survey of Selected Service Industries, Information Service Industry Volume* (1991-1999).
- Nakajima, T., *Productivity Analysis of the Japanese Economy* (Tokyo: Nihon Keizai Shinbunsha, 2001).
- Nishimura, K. G., K. Minetaki, M. Shirai, and F. Kurokawa, "Industry Transformation: Is "New Economy" Present in Japan?," in Okuno-Fujiwara, M., A. Takemura and J. Shintaku (Eds.), *Electronic Society and Market Economy* (Tokyo: Shinseisha, 2002). (in Japanese).
- Nishimura, K. G., and M. Shirai, "Can Information and Communication Technology Solve Japan's Productivity-Slowdown Problem?," *Asian Economic Papers* 2:1 (2003), 85-139.
- Nishimura, K. G., T. Nakajima and K. Kiyota, "Does Natural Selection Mechanism Still Work in Severe Recessions? – Examination of the Japanese Economy in the 1990s –," University of Tokyo and Keio University, mimeo (2003), a revised version will appear in *Journal of*

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Economic Behavior and Organization.

OECD, "The Software Sector: Growth, Structure and Policy Issues," OECD, DSTI/ICCP/IE(2002)/8, (2002).

Sano, Y., "Outsourcing and the Role of 'SHAIN (Regular Full-time Workers)' in Information Service Industries," in H. Sato (Ed.), *Employment Systems in Information-Technology Age* (Tokyo: Nihon Hyoron Sha, 2001), 93-116. (in Japanese).

Shintani, M., "Quantitative Analysis of Information Service Industries Based on Micro Data," available at <http://www.seinan-gu.ac.jp/~shintani/b1.htm>, (1998). (in Japanese).

Van Ark, B., Inklaar R. and R. H. McGuckin, "Changing Gear, Productivity, ICT and Service Industries: Europe and the United States," Groningen Growth and Development Center, Research Memorandum GD-60 (2002).

i There has been a sizable literature on productivity growth or technological progress. Hayashi and Prescott (2002) examine the movement of the TFP (total factor productivity) growth relying on neoclassical framework and argue that declined supply of labor coupled with declined TFP growth is one of the culprits of disappointing economic growth of Japan. Fukao et al. (2003), based on detailed industry-wise data as well as macro data, reveal a sharp decline in the TFP growth rate in aggregates and in many industries.

ii In the same token, Ark et al. (2002) show that the labor-productivity growth in Japanese IT-producing industries in the late 90s is 19.5%, which is roughly in line with 23.7% in the United States and 13.8% in EU.

iii In fact, US wholesale and retail trade sectors contribute greatly to overall productivity. Basu et al. (2003) claim that almost 70% of the overall TFP growth of the United States can be explained by the TFP growth of the wholesale and retail trade sectors.

iv However, Fukao and Kwon (2003) report that when they adjust quality of labor inputs and utilization of capital stocks in the traditional growth accounting framework, TFP growth rates in manufacturing sectors are rather low compared with rather high TFP growth rates in service sectors. They attribute rather good performance to deregulation in service industries. However, their procedure of “adjustment” seems inconsistent with basic assumptions of the growth accounting framework, notably perfect utilization, so that their result should be evaluated cautiously.

v Ahn (2001) touches service industries briefly in his survey of empirical results in productivity based on firm dynamics. He points out several problems in productivity analysis of service industries such as appropriate measurement of outputs, although importance of service industries is obvious in viewing its large share in GDP.

vi The JSIC (Japanese Standard Industry Classification) System was revised substantially in March 2002 (called 11th Revision). Before this revision, information service industries were classified to service industries, but after the revision, they now belong to a new 1-digit industry classification called “Information and Communication Industries”.

vii Most prominent is IBM. IBM’s divisional revenues now reveal that revenues from software and information service divisions exceed those from hardware divisions. IBM’s move prompts several Japanese firms to follow it.

viii CMM evaluates maturity or capability of software development in five levels. See Conference for Improving Software Development and Procurement Processes (2001).

ix Ahn (2001) and Bartelsman and Doms (2000) survey firm-level empirical analyses. Ahn examines non-manufacturing industries extensively.

x Sano (2001) examined the effect of outsourcing on information service industries based on case studies. Koyama and Takeda (2001) investigated software-development productivity, with special emphasis on modularization, referring to various cases in the industry.

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

xii See Aoki and Okuno (1996) for an example of Japanese academic writing emphasizing this collaboration positively.

xiii Here “modularization” is 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.

xiv API (application programming interface) is a part of 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.

xv This is a clear warning against common practices that estimate the value of software products by wage times man-hours of programmers and system engineers who engage in developing these software products.

xvi See <http://www.elysiuminc.com/>.

xvii See <http://www.armonicos.co.jp/english/>.

xviii ASP is included if they develop software themselves.

xix This is based on the data set supplied by the Statistics Bureau for our empirical study.

xx There are other notable characteristics. First, the Survey asks the headquarters of firms to report the total fixed capital stocks and the total operating expenses (and their breakdowns) of information service

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

activities of the firms as a whole. This is very convenient in our constructing firm-level information-service activities' value-added and capital stocks. However, categorized information-service activities' labor input data (such as the number of system engineers) are available only at the establishment level. Thus, it is necessary to construct firm-level data of information-service activities' labor input data from establishment data.

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

xxii Labor hours are estimated by multiplying the number of workers by the average work hours in information service industries, using the Monthly Labor Survey.

xxiii As for weights, we use those in the 1995 Input-Output Tables' fixed-investment matrix data.

xxiv Unfortunately however, we do not have an individual firm's building and structure rent data directly. 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 are not different from the average.

xxv Here we follow Hall (1990).

xxvi The effective tax rates and the discounted value of future depreciation are calculated by 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 of Homma et al. (1984).

xxvii Here we follow the method of the White Paper of the Cabinet Office. However, this five-year criterion might be too restrictive, so that we plan to relax this assumption in the future.

xxviii Although we have information about SE's in establishments, we cannot aggregate them to get firm-level SE's since the Survey does not collect information about what firm a particular establishment belongs to. Consequently, we are obliged to assume that the ratio of SE's to the total work force at the headquarters is on the average its ratio for the firm as a whole. In particular, the firm-level number of SE's in our study is calculated by multiplying the firm's total number of information service workers by the ratio of SE's to the information-service work force at the headquarters. The firm-level ratio of SE's to the total information-service workers is calculated by using this figure.

xxix In addition, we show in Tables 2-3, Table 2-4 and Table 2-5 differences in averages for subcategories of our samples (custom software, prepackaged software, system management and administration, online database service) for different thresholds. To make comparison comparable, we results about single establishments in these tables.

xxx Firms that do not conform to any of four types are excluded from segment-wise estimations in the following empirical analysis.

xxxi We tried the number of programmers and that of research scientists in our preliminary analysis, but they did not have any significant effects on TFP. Thus, we excluded them in the present analysis.

xxxii See footnotes in Section 3.4 for the way these variables are constructed.

xxxiii In firm-level panel cases, we can estimate the TFP level using Caves et al (1982) or Good et al (1997) approach of estimating productivity differentials across the panel. Nishimura et al. (2003) estimate the TFP level and examine entry-exit dynamics of Japanese manufacturing firms by using a firm-level panel data based on the Basic Survey of Business Structure and Activities. However, we start here with first differences for analytic simplicity.

xxxiv In this way, we implicitly assume that TFP levels are non-stationary, which are likely since TFP changes are in many cases permanent technological changes. However, even if TFP-levels are stationary, OLS estimators of equation (2) (or (3)) remain consistent. See Maddala (2001).

xxxv There might be a possibility that lagged x_{ij} may influence TFP in (1) (or (2), (3)). We estimate correlation matrices of dependent variables and independent variables including lags to check this point. Estimated correlation matrices, however, suggest that TFP at t is correlated mostly with independent

variables at the same period. Furthermore, preliminary estimation results including these lags show insignificant coefficients for lagged variables in most cases, so that we ignore them in our baseline empirical results.

xxxvi However, non-stationarity of the data may not be so problematic. Phillips and Moon (1999) argue that even if the unit root tests fail to reject the null hypothesis, usual pooled time series and cross section regression models yield useful information concerning long run regression relationship.

xxxvii Here we should distinguish between unit root tests for panels with large time dimensions and those for panels with small time dimensions, and between unit roots tests applicable balanced panels and unbalanced ones. For panel unit root tests with small time dimensions, see Bond et al. (2002). Several major panel unit root tests, such as those of Levin and Lin (1993) and Im et al. (2003), are not directly applicable for unbalanced panel data like our samples. For unbalanced panel unit root tests, see Maddala and Wu (1999).

xxxviii Bond et al. (2002) point out that t-tests based on OLS estimation results provide simple robust tests with high power in Monte Carlo simulations, in the case that the variance of the unobserved heterogeneity is relatively small, and in the case of panels with relatively small time series.

xxxix That is,

$$E(e_{i,t}) = 0$$

$$E(e_{i,t}^2) = \text{Var}(e_{i,t}) = \sigma_e^2$$

$$E(e_{i,t+r}e_{j,t+s}) = \text{Var}(e_{i,t+r}, e_{j,t+s}) = 0 \text{ for } i \neq j, r \neq s$$

xl In Table 5, random effect models are selected by the Hausman test.

xli One may argue there might be simultaneity between TFP growth and first differences of explanatory variables. To take this in mind, we conducted an instrument variable estimation and found qualitatively the same results as in reported Tables 5 through 10. The results of instrumental variable estimation results are reported in Table 11.

xlii Data are available between 1991 and 1999. However, we take first differences so that we lose one year. In addition, we lose one more year in the case of employment adjustment costs to calculate ADJUST variables.

xliii The Wald test leads to the rejection of heteroscedasticity for all Groups in FGLS.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

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

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

**Table 2-1 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	0.0311 (0.4931)	-8.0988	8.4861	7610	32060
Outsourcing to Sales Ratio	0.1378 (0.1577)	0.0000	1.0000	10866	38746
Number of SE	31.7126 (142.3801)	0.0000	9425.2220	10866	38746
SE to Total Work Force Ratio	0.2839 (0.2567)	0.0000	1.0000	10866	38746
Profit to Operating Cost Ratio	0.2827 (1.7481)	-0.9608	161.0000	10846	38715
# of Workers	96.2852 (324.0208)	1.0000	23668	10866	38746

Notes:

Standard deviations in parenthesis. "# of firms" column reports the number of firms with sufficient information enabling the calculation.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Table 2-2 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	0.0417 (0.3516)	-4.1931	4.2479	1106	6117
Outsourcing to Sales Ratio	0.1482 (0.1442)	0.0000	0.8898	1106	6117
Number of SE's	79.3533 (231.8276)	0.0471	#####	1106	6117
SE to Total Work Force Ratio	0.3789 (0.2247)	0.0031	1.0000	1106	6117
Profit to Operating Cost Ratio	0.2332 (1.3172)	-0.6533	89.5953	1106	6117
# of Workers	193.2424 (479.3581)	1.0000	9430	1106	6117

Notes:

Standard deviations in parenthesis.

Table 2-3 Differences in Averages among Subcategories in Single Establishments:**Case of 90% Criterion**

Firms whose particular segment's sales share exceeds more than 90% of their total information service sales

Variable	Sales Share > 90%			
	Custom Software	Prepackaged Software	System Management and	Online Data Base Service
TFP growth	0.0341 (0.3962)	0.0644 (0.5534)	-0.1051 (1.1670)	-0.0545 (0.2027)
Labor Productivity Growth	0.0457 (0.3177)	0.0471 (0.4748)	0.1365 (1.0241)	0.0638 (0.1124)
Outsourcing to Sales Ratio	0.1626 (0.1502)	0.0725 (0.1071)	0.0546 (0.0760)	0.0635 (0.0492)
Number of SE's	42.4845 (140.5637)	9.9575 (25.1370)	10.2602 (20.3217)	3.0500 (2.4582)
SE to Total Work Force Rati	0.4912 (0.2160)	0.3918 (0.2428)	0.3546 (0.2009)	0.1921 (0.0637)
Profit to Operating Cost Rat	0.1473 (0.4017)	0.4267 (0.6632)	0.4897 (0.6779)	0.0075 (0.1306)
# of Workers	69.3514 (170.7314)	24.7377 (38.2829)	21.4444 (32.3246)	16.9000 (14.8208)
# of Firms	363	52	6	4
# of Firm-Year's	1255	122	9	10

Notes:

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Table 2-4 Differences in Averages among Subcategories in Single Establishments:

Case of 70% Criterion

Firms whose particular segment's sales share exceeds more than 70% of their total information service sales

Variable	Sales Share > 70%			
	Custom Software	Prepackaged Software	System Management and	Online Data Base Service
TFP growth	0.0281 (0.3987)	0.0436 (0.5782)	-0.0592 (0.6637)	0.0612 (0.4613)
Labor Productivity Growth	0.0464 (0.3182)	0.0265 (0.4522)	0.0980 (0.5967)	0.0398 (0.2270)
Outsourcing to Sales Ratio	0.1620 (0.1575)	0.0805 (0.1126)	0.1127 (0.1472)	0.0509 (0.0517)
Number of SE's	37.3376 (124.3926)	12.1866 (30.0798)	21.0377 (44.3199)	3.0213 (2.2421)
SE to Total Work Force Rati	0.4687 (0.2164)	0.3836 (0.2385)	0.2948 (0.2249)	0.1685 (0.0710)
Profit to Operating Cost Rati	0.1774 (0.5150)	0.4620 (0.7313)	0.2234 (0.4262)	0.2670 (0.8301)
# of Workers	64.4387 (153.3472)	27.0452 (40.2962)	100.7742 (136.4685)	19.3889 (13.3907)
# of Firms	458	74	18	10
# of Firm-Year's	1680	177	31	18

Table 2-5 Differences in Averages among Subcategories in Single Establishments:**Case of 50% Criterion**

Firms whose particular segment's sales share exceeds more than 50% of their total information service sales

Variable	Sales Share > 50%			
	Custom Software	Prepackaged Software	System Management and	Online Data Base Service
TFP growth	0.0250 (0.4040)	0.0362 (0.5632)	0.0810 (0.7895)	-0.0010 (0.4833)
Labor Productivity Growth	0.0425 (0.3202)	0.0264 (0.4457)	0.0765 (0.4346)	0.0541 (0.2134)
Outsourcing to Sales Ratio	0.1542 (0.1500)	0.0894 (0.1219)	0.1266 (0.1243)	0.0487 (0.0553)
Number of SE's	35.8617 (115.4218)	9.9708 (24.8576)	19.5121 (35.1353)	3.0284 (2.2996)
SE to Total Work Force Rati	0.4532 (0.2154)	0.3440 (0.2243)	0.2686 (0.2179)	0.1723 (0.1109)
Profit to Operating Cost Rat	0.1834 (0.5186)	0.3748 (0.6261)	0.2191 (0.5663)	0.4587 (1.5229)
# of Workers	64.9219 (144.3840)	25.4161 (35.6407)	103.2206 (133.3655)	19.8184 (12.6948)
# of Firms	527	113	35	13
# of Firm-Year's	2010	274	68	27

Note:

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Table 3 Differences in Averages Among Different Organizational Changes: 1991-1998

	All	Group 1(Single)	Group 2(Multi)	Group 3(Expanded)	Group 4(Shrunk)
TFP growth	0.0197 (0.4631)	0.0179 (0.4164)	0.0261 (0.4139)	0.0239 (0.5017)	0.0051 (0.5198)
Labor Productivity Growth	0.0417 (0.3516)	0.0403 (0.2972)	0.0433 (0.3079)	0.0510 (0.4273)	0.0189 (0.3943)
Outsourcing to Sales Ratio	0.1482 (0.1442)	0.1309 (1.4703)	0.1769 (0.1508)	0.1549 (0.1465)	0.1325 (0.1276)
Number of SE's	79.3533 #####	19.7731 (38.2180)	174.3493 #####	112.1807 (308.3249)	34.6971 (81.3331)
SE to Total Work Force R	0.3789 (0.2247)	0.3848 (0.2268)	0.3699 (0.2160)	0.3713 (0.2314)	0.3639 (0.2170)
Profit to Operating Cost R	0.2332 (1.3172)	0.2048 (0.6716)	0.2215 (0.6480)	0.3755 (3.0485)	0.2095 (0.6760)
# of Workers	193.2424 #####	50.0860 (69.6813)	445.6522 #####	258.7119 (584.3632)	94.4569 (160.6008)
# of Firm-Year's	6117	1732	1294	899	788

Notes:

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period,

Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3:

firms that start as single establishments and become multi-establishment firms by the end of the

sample period, Group 4: firms that start as multi-establishment firms and become single

establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

Table 4 Unit Root Test: First Difference

	TFP Growth	d-OUT	d-SE	d-SE-RATIO	d-PROFIT	d-ADJUST
BM	0.6264 *** (0.0180)	0.5368 *** (0.0138)	0.7763 *** (0.0111)	0.5402 *** (0.0138)	-0.1946 *** (0.0147)	0.9805 ** (0.0083)
OLS1	-0.3467 *** (0.0116)	-0.2135 *** (0.0132)	-0.1920 *** (0.0108)	-0.2982 *** (0.0126)	-0.4896 *** (0.0124)	-0.0375 *** (0.0055)
OLS2	-0.6734 *** (0.0259)	-0.3474 *** (0.0233)	-0.3758 *** (0.0218)	-0.5020 *** (0.0245)	-1.6247 *** (0.0350)	-0.3809 *** (0.0214)

Notes

"d-" denotes the first difference. The null is that there is a unit root and "***", "**", and "*" denote significance at 1%, 5%, and 10%, respectively, under the null. Standard deviations are in parenthesis. BM is the unit root test of Breitung and Meyer (1994). OLS1 and OLS2 are those in Bond et al. (2002), where OLS1 is without differenced lags, and OLS2 with differenced lags. We test OLS1 and OLS2 both with and without time-dummies, but results are qualitatively similar. Thus we report here only the results with time dummies.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Table 5 Estimation Results (PANEL OLS): 1991-1998

dependent variable: TFP growth

	All	Group 1(Single)	Group 2(Multi)	Group 3(Expanded)	Group 4(Shrunk)
d-OUT	-0.8310 *** (0.0670)	-0.2803 ** (0.1223)	-0.6004 *** (0.1351)	-1.2221 *** (0.1807)	-0.4295 ** (0.1846)
d-SE	-0.1008 *** (0.0129)	-0.0727 *** (0.0274)	-0.1685 *** (0.0298)	-0.0809 *** (0.0305)	-0.2527 *** (0.0344)
d-SE-RATIO	0.2838 *** (0.0547)	0.3445 *** (0.0974)	0.2181 * (0.1157)	0.2939 ** (0.1378)	0.6840 *** (0.1577)
d-PROFIT	0.0753 *** (0.0030)	0.1998 *** (0.0121)	0.1417 *** (0.0139)	0.0494 *** (0.0035)	0.1704 *** (0.0139)
d-D1992	0.1325 *** (0.0320)	0.0003 (0.0553)	0.1902 *** (0.0663)	0.2909 *** (0.0805)	-0.3861 *** (0.0887)
d-D1993	0.0989 ** (0.0313)	0.0102 (0.0540)	0.0914 (0.0640)	0.2179 *** (0.0785)	-0.2886 *** (0.0902)
d-D1994	0.0402 (0.0294)	-0.0652 (0.0505)	0.0789 (0.0593)	0.1341 * (0.0741)	-0.2836 *** (0.0873)
d-D1995	0.0745 *** (0.0267)	0.0318 (0.0455)	0.0844 (0.0534)	0.1305 * (0.0682)	-0.2235 *** (0.0796)
d-D1996	0.0869 *** (0.0235)	0.0593 (0.0396)	0.0668 (0.0466)	0.1047 * (0.0604)	-0.1343 * (0.0704)
d-D1997	0.0630 *** (0.0196)	0.0483 (0.0327)	0.0512 (0.0384)	0.1620 *** (0.0514)	-0.1386 ** (0.0582)
d-D1998	0.0396 *** (0.0142)	0.0216 (0.0234)	0.0537 * (0.0277)	0.0976 *** (0.0378)	-0.0317 (0.0417)
Constant	0.0380 *** (0.0067)	0.0227 ** (0.0115)	0.0512 *** (0.0134)	0.0611 *** (0.0176)	-0.0531 *** (0.0193)
Hausman Test	15.7500	9.3400	12.6300	1.9000	6.2800
p-value	0.1508	0.5905	0.3185	0.9988	0.8543
fixed or random	random	random	random	random	random
LM	##### ***	##### ***	66.9396 ***	##### ***	70.3953 ***
# of Firms	1106	318	231	156	143
# of Firm-Year'	6117	1732	1294	899	788

Notes:

"d-" denotes the first difference. D-year is a year dummy.

"***", "**", and "*" denote significance at 1%, 5%, and 10%, respectively.

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period, Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3: firms that start as single establishments and become multi-establishment firms by the end of the sample period, Group 4: firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

LM is joint LM test for serial correlation and random effects. See Baltagi (1995).

Table 6 Estimation Results (PANEL-Random effects with AR1): 1991-1998

dependent variable: TFP growth

	All	Group 1(Single)	Group 2(Multi)	Group 3(Expanded)	Group 4(Shrunk)
d-OUT	-0.8499 *** (0.0679)	-0.2765 ** (0.1232)	-0.6086 *** (0.1359)	-1.2614 *** (0.1826)	-0.4255 ** (0.1850)
d-SE	-0.1162 *** (0.0132)	-0.0894 *** (0.0278)	-0.1919 *** (0.0306)	-0.0784 ** (0.0311)	-0.2686 *** (0.0348)
d-SE-RATIO	0.3221 *** (0.0553)	0.3841 *** (0.0982)	0.2611 ** (0.1167)	0.2946 ** (0.1389)	0.7199 *** (0.1580)
d-PROFIT	0.0740 *** (0.0030)	0.2006 *** (0.0119)	0.1464 *** (0.0141)	0.0495 *** (0.0034)	0.1726 *** (0.0139)
d-D1992	-0.1849 *** (0.0409)	-0.0035 (0.0702)	-0.2999 *** (0.0837)	-0.3672 *** (0.1023)	0.4848 *** (0.1118)
d-D1993	-0.2090 *** (0.0412)	-0.0871 (0.0702)	-0.2135 ** (0.0851)	-0.3777 *** (0.1039)	0.3929 *** (0.1123)
d-D1994	-0.1132 *** (0.0407)	0.0883 (0.0690)	-0.1926 ** (0.0841)	-0.3011 *** (0.1016)	0.4519 *** (0.1118)
d-D1995	-0.1376 *** (0.0402)	0.0162 (0.0680)	-0.2173 *** (0.0832)	-0.3195 *** (0.1013)	0.4785 *** (0.1097)
d-D1996	-0.1730 *** (0.0402)	-0.0225 (0.0680)	-0.2155 *** (0.0832)	-0.2383 *** (0.1003)	0.3863 *** (0.1114)
d-D1997	-0.1736 *** (0.0404)	-0.0391 (0.0686)	-0.1972 ** (0.0833)	-0.3595 *** (0.1011)	0.4972 *** (0.1116)
d-D1998	-0.1891 *** (0.0405)	-0.0330 (0.0685)	-0.2536 *** (0.0835)	-0.3908 *** (0.1010)	0.4202 *** (0.1117)
cosntant	0.1875 *** (0.0377)	0.0345 (0.0642)	0.2513 *** (0.0783)	0.3557 *** (0.0940)	-0.4434 *** (0.1020)
AR1 Coefficient	-0.1273	-0.0991	-0.1454	-0.1107	-0.0869
# of Firms	1106	318	231	156	143
# of Firm-Year'	6117	1732	1294	899	788

Notes:

d- denotes the first difference. D-year is a year dummy.

***, **, and * denote significance at 1%, 5%, and 10%, respectively.

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period, Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3: firms that start as single establishments and become multi-establishment firms by the end of the sample period, Group 4: firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

Assuming that the disturbances follow an AR(1) process

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Table 7 Estimation Results (FGLS): 1991-1998

dependent variable: TFP growth

	All	Group 1(Single)	Group 2(Multi)	Group 3(Expanded)	Group 4(Shrunk)
d-OUT	-0.6283 *** (0.0197)	-0.2063 *** (0.0344)	-0.3336 *** (0.0640)	-1.0684 *** (0.0613)	-0.4127 *** (0.0496)
d-SE	-0.0762 *** (0.0050)	-0.0880 *** (0.0104)	-0.1156 *** (0.0132)	-0.0691 *** (0.0158)	-0.1877 *** (0.0191)
d-SE-RATIO	0.2405 *** (0.0153)	0.4207 *** (0.0371)	0.2165 *** (0.0436)	0.2622 *** (0.0579)	0.5558 *** (0.0637)
d-PROFIT	0.1049 *** (0.0031)	0.2153 *** (0.0052)	0.2058 *** (0.0113)	0.0595 *** (0.0065)	0.2083 *** (0.0099)
d-D1992	0.0811 *** (0.0113)	0.0239 (0.0294)	0.1478 *** (0.0120)	0.1759 *** (0.0411)	-0.2940 *** (0.0441)
d-D1993	0.0512 *** (0.0101)	0.0274 (0.0271)	0.0844 *** (0.0125)	0.1122 *** (0.0365)	-0.2227 *** (0.0424)
d-D1994	0.0193 ** (0.0092)	-0.0350 (0.0237)	0.0624 *** (0.0118)	0.0555 * (0.0308)	-0.2289 *** (0.0365)
d-D1995	0.0601 *** (0.0077)	0.0583 *** (0.0191)	0.0705 *** (0.0104)	0.0682 *** (0.0260)	-0.1795 *** (0.0308)
d-D1996	0.0715 *** (0.0065)	0.0805 *** (0.0150)	0.0471 *** (0.0092)	0.0735 *** (0.0207)	-0.1035 *** (0.0237)
d-D1997	0.0552 *** (0.0050)	0.0543 *** (0.0118)	0.0307 *** (0.0055)	0.1144 *** (0.0163)	-0.1186 *** (0.0184)
d-D1998	0.0302 *** (0.0038)	0.0143 (0.0093)	0.0236 *** (0.0066)	0.0725 *** (0.0136)	-0.0236 * (0.0131)
constant	0.0285 *** (0.0020)	0.0237 *** (0.0050)	0.0439 *** (0.0026)	0.0480 *** (0.0076)	-0.0387 *** (0.0075)
Log likelihood	#####	#####	#####	23.4631	#####
Wald Test : p-val	0.0000	0.0000	0.0000	0.0000	0.0000
# of Firms	1086	315	226	154	139
# of Firm-Year's	6097	1729	1289	897	784

Note:

Δ- denotes the first difference. D-year is a year dummy.

***, **, and * denote significance at 1%, 5%, and 10%, respectively.

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period, Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3: firms that start as single establishments and become multi-establishment firms by the end of the sample period, Group 4: firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

Wald Test is the test statistic asymptotically distributed as chi-square(k) under the null of heteroscedasticity, where k

Table 8 Estimation Results with ADJUST (PANEL): 1991-1997

dependent variable: TFP growth

	All	Group 1(Single)	Group 2(Multi)	Group 3(Expanded)	Group 4(Shrunk)
d-OUT	-0.7918 *** (0.0737)	-0.2750 ** (0.1374)	-0.4778 *** (0.1469)	-1.2134 *** (0.1941)	-0.3968 ** (0.1873)
d-SE	-0.1049 *** (0.0141)	-0.0637 ** (0.0299)	-0.1891 *** (0.0333)	-0.1540 *** (0.0427)	-0.3505 *** (0.0402)
d-SE-RATIO	0.2686 *** (0.0597)	0.3284 *** (0.1062)	0.2789 ** (0.1279)	0.4825 *** (0.1634)	0.9846 *** (0.1672)
d-PROFIT	0.0714 *** (0.0032)	0.1877 *** (0.0128)	0.1992 *** (0.0181)	0.0451 *** (0.0035)	0.2760 *** (0.0191)
d-ADJUST	-0.0231 *** (0.0063)	0.0060 (0.0204)	-0.0482 ** (0.0236)	-0.0274 ** (0.0113)	0.0827 *** (0.0191)
d-D1992	0.0628 * (0.0358)	0.0010 (0.0626)	0.0761 (0.0814)	0.2403 *** (0.0810)	-0.2182 ** (0.0915)
d-D1993	0.0329 (0.0335)	0.0048 (0.0584)	0.0008 (0.0733)	0.1584 ** (0.0770)	-0.1657 * (0.0883)
d-D1994	-0.0215 (0.0301)	-0.0744 (0.0520)	-0.0027 (0.0648)	0.0670 (0.0705)	-0.1660 ** (0.0812)
d-D1995	0.0166 (0.0258)	0.0178 (0.0442)	0.0061 (0.0548)	0.0604 (0.0625)	-0.1428 ** (0.0698)
d-D1996	0.0363 * (0.0209)	0.0422 (0.0354)	0.0011 (0.0431)	0.0359 (0.0520)	-0.0762 (0.0572)
d-D1997	0.0181 (0.0148)	0.0314 (0.0247)	-0.0088 (0.0295)	0.0909 ** (0.0383)	-0.1000 ** (0.0407)
constant	0.0343 *** (0.0080)	0.0267 * (0.0139)	0.0436 ** (0.0171)	0.0694 *** (0.0194)	-0.0314 (0.0213)
Hausman Test	9.8200	5.3000	9.6000	4.5900	2.0900
p-value	0.5469	0.9157	0.5665	0.9493	0.9982
fixed or random	random	random	random	random	random
LM	##### ***	78.7613 ***	31.3115 ***	63.4210 ***	18.5245 ***
# of Firms	1096	318	228	155	140
# of Firm-Year'	5103	1439	1085	752	656

Note:

"d-" denotes the first difference. D-year is a year dummy. ADJUST is the squared rate of change in employment.

"***", "**", and "*" denote significance at 1%, 5%, and 10%, respectively.

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period, Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3: firms that start as single establishments and become multi-establishment firms by the end of the sample period, Group 4: firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

LM is joint LM test for serial correlation and random effects. See Baltagi (1995).

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Table 9 Estimation Results with ADJUST (PANEL-Random Effects with AR1): 1991-1997

dependent variable: TFP growth

	All	Group 1(Single)	Group 2(Multi)	Group 3(Expanded)	Group 4(Shrunk)
d-OUT	-0.8119 *** (0.0747)	-0.2701 * (0.1385)	-0.4910 *** (0.1477)	-1.2519 *** (0.1983)	-0.4050 ** (0.1888)
d-SE	-0.1184 *** (0.0144)	-0.0817 *** (0.0305)	-0.2045 *** (0.0340)	-0.1423 *** (0.0431)	-0.3724 *** (0.0410)
d-SE-RATIO	0.3009 *** (0.0604)	0.3723 *** (0.1074)	0.3022 ** (0.1290)	0.4573 *** (0.1646)	1.0293 *** (0.1685)
d-PROFIT	0.0707 *** (0.0031)	0.1879 *** (0.0127)	0.2058 *** (0.0184)	0.0459 *** (0.0035)	0.2708 *** (0.0188)
d-ADJUST	-0.0245 *** (0.0065)	0.0069 (0.0208)	-0.0508 ** (0.0243)	-0.0246 ** (0.0115)	0.0840 *** (0.0197)
d-D1992	-0.1057 ** (0.0459)	-0.0126 (0.0797)	-0.1519 (0.1030)	-0.3291 *** (0.1050)	0.2730 ** (0.1172)
d-D1993	-0.1294 *** (0.0461)	-0.0935 (0.0799)	-0.0798 (0.1020)	-0.3384 *** (0.1071)	0.2179 * (0.1188)
d-D1994	-0.0338 (0.0457)	0.0813 (0.0788)	-0.0663 (0.1016)	-0.2593 ** (0.1052)	0.2536 ** (0.1184)
d-D1995	-0.0551 (0.0454)	0.0103 (0.0780)	-0.0806 (0.1017)	-0.2726 *** (0.1050)	0.2894 ** (0.1161)
d-D1996	-0.0914 ** (0.0454)	-0.0245 (0.0783)	-0.0857 (0.1015)	-0.1936 * (0.1043)	0.2013 * (0.1166)
d-D1997	-0.0927 ** (0.0456)	-0.0464 (0.0784)	-0.0675 (0.1018)	-0.3415 *** (0.1054)	0.3253 *** (0.1181)
constant	0.1085 ** (0.0430)	0.0413 (0.0744)	0.1196 (0.0974)	0.3176 *** (0.0975)	-0.2548 * (0.1092)
AR1 Coefficient	-0.1263	-0.1083	-0.1082	-0.1525	-0.1230
# of Firms	1096	318	228	155	140
# of Firm-Year'	5103	1439	1085	752	656

Note:

"d-" denotes the first difference. D-year is a year dummy. ADJUST is the squared rate of change in employment. "****", "***", and "**" denote significance at 1%, 5%, and 10%, respectively.

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period, Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3: firms that start as single establishments and become multi-establishment firms by the end of the sample period, Group 4: firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

Table 10 Estimation Results with ADJUST (FGLS): 1991-1998

dependent variable: TFP growth

	All	Group 1(Single)	Group 2(Multi)	Group 3(Expanded)	Group 4(Shrunk)
d-OUT	-0.6106 *** (0.0170)	-0.3067 *** (0.0382)	-0.2908 *** (0.0490)	-1.0146 *** (0.0507)	-0.2881 *** (0.0519)
d-SE	-0.0951 *** (0.0030)	-0.0708 *** (0.0099)	-0.1661 *** (0.0145)	-0.1667 *** (0.0209)	-0.3081 *** (0.0151)
d-SE-RATIO	0.2669 *** (0.0137)	0.3764 *** (0.0255)	0.2980 *** (0.0474)	0.5281 *** (0.0475)	0.9632 *** (0.0446)
d-PROFIT	0.0852 *** (0.0025)	0.2146 *** (0.0079)	0.2943 *** (0.0173)	0.0464 *** (0.0057)	0.3653 *** (0.0162)
d-ADJUST	-0.0281 *** (0.0023)	0.0160 (0.0112)	-0.0499 *** (0.0088)	-0.0393 *** (0.0061)	0.1108 *** (0.0127)
d-D1992	0.0101 (0.0106)	0.0331 (0.0305)	0.0487 *** (0.0181)	0.0967 *** (0.0361)	-0.1802 *** (0.0343)
d-D1993	-0.0144 (0.0090)	0.0340 (0.0268)	0.0085 (0.0166)	0.0366 (0.0325)	-0.1118 *** (0.0340)
d-D1994	-0.0465 *** (0.0074)	-0.0391 * (0.0220)	0.0009 (0.0149)	-0.0262 (0.0269)	-0.1091 *** (0.0294)
d-D1995	-0.0014 (0.0058)	0.0419 ** (0.0170)	0.0163 (0.0127)	-0.0168 (0.0204)	-0.0919 *** (0.0219)
d-D1996	0.0259 *** (0.0039)	0.0657 *** (0.0118)	0.0010 (0.0093)	-0.0070 (0.0144)	-0.0388 ** (0.0153)
d-D1997	0.0091 *** (0.0028)	0.0467 *** (0.0079)	-0.0086 (0.0072)	0.0572 *** (0.0101)	-0.0763 *** (0.0110)
constant	0.0281 *** (0.0019)	0.0303 *** (0.0053)	0.0396 *** (0.0038)	0.0494 *** (0.0075)	-0.0252 *** (0.0070)
Log likelihood	#####	#####	#####	67.5614	91.2821
Wald Test: p-val	0.0000	0.0000	0.0000	0.0000	0.0000
# of Firms	1066	310	220	151	137
# of Firm-Year's	5073	1431	1077	748	653

Note:

"d-" denotes the first difference. D-year is a year dummy. ADJUST is the squared rate of change in employment.

"***", "**", and "*" denote significance at 1%, 5%, and 10%, respectively.

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period, Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3: firms that start as single establishments and become multi-establishment firms by the end of the sample period, Group 4: firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

Wald Test is the test statistic asymptotically distributed as chi-square(k) under the null of homoscedasticity, where k

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis

Table 11 Estimation Results (IV Method, Random Effects Model): 1992-1998

dependent variable: TFP growth

	All	Group 1(Single)	Group 2(Multi)	Group 3(Expanded)	Group 4(Shrunk)
d-OUT	-1.3809 *** (0.3041)	0.3045 (0.7727)	-1.2141 ** (0.4942)	-2.4283 ** (1.1603)	-0.9453 (0.9589)
d-SE	-0.8234 *** (0.1059)	-1.4139 *** (0.3643)	-1.0901 *** (0.2339)	-0.0282 (0.3808)	-1.6316 *** (0.3120)
d-SE-RATIO	2.0495 *** (0.3161)	3.8917 *** (1.0640)	2.2545 *** (0.6611)	0.2646 (1.1460)	4.0471 *** (0.9808)
d-PROFIT	0.0404 *** (0.0074)	0.2062 *** (0.0436)	0.1083 *** (0.0347)	0.0404 *** (0.0138)	0.2163 *** (0.0742)
d-D1993	-0.0910 ** (0.0289)	-0.1432 ** (0.0641)	-0.0723 (0.0665)	-0.0477 (0.0556)	-0.1925 * (0.1087)
d-D1994	-0.1632 (0.0312)	-0.2358 *** (0.0688)	-0.1497 ** (0.0688)	-0.1085 (0.0716)	-0.2985 ** (0.1322)
d-D1995	-0.1100 *** (0.0301)	-0.1467 ** (0.0676)	-0.1380 ** (0.0662)	-0.0626 (0.0744)	-0.2435 ** (0.1192)
d-D1996	-0.0700 *** (0.0268)	-0.1170 * (0.0615)	-0.1153 ** (0.0580)	-0.0487 (0.0750)	-0.2050 * (0.1105)
d-D1997	-0.0255 (0.0211)	-0.0191 (0.0423)	-0.0521 (0.0444)	0.0534 (0.0592)	-0.1296 (0.0863)
d-D1998	-0.0079 (0.0151)	-0.0320 (0.0314)	0.0130 (0.0308)	0.0590 (0.0411)	0.0186 (0.0607)
Constant	0.0218 ** (0.0089)	0.0288 * (0.0157)	0.0263 (0.0342)	0.0159 (0.0197)	-0.0154 (0.0341)
# of Firms	1086	315	226	153	139
# of Firm-Year'	5346	1535	1108	786	700

Notes:

"d-" denotes the first difference. D-year is a year dummy.

"***", "**", and "*" denote significance at 1%, 5%, and 10%, respectively.

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period, Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3: firms that start as single establishments and become multi-establishment firms by the end of the sample period, Group 4: firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

Instruments are the first lags of explanately variables.

Table 12 The Government-Dependency Dummy (FGLS): 1991-1998

dependent variable: TFP growth

	Gov_Dummy = 1 If Gov Share>20%	Gov_Dummy = 1 If Gov Share>30%	Gov_Dummy = 1 If Gov Share > 40%	Gov_Dummy = 1 If Gov Share > 50%
d-OUT	-0.6113 *** (0.0201)	-0.6011 *** (0.0208)	-0.6072 *** (0.0202)	-0.5986 *** (0.0210)
d-SE	-0.0780 *** (0.0050)	-0.0789 *** (0.0050)	-0.0784 *** (0.0050)	-0.0787 *** (0.0050)
d-SE-RATIO	0.2481 *** (0.0154)	0.2494 *** (0.0155)	0.2484 *** (0.0154)	0.2497 *** (0.0155)
d-PROFIT	0.1067 *** (0.0032)	0.1075 *** (0.0032)	0.1071 *** (0.0032)	0.1077 *** (0.0032)
d-D1992	0.0828 *** (0.0113)	0.0836 *** (0.0113)	0.0839 *** (0.0114)	0.0831 *** (0.0114)
d-D1993	0.0517 *** (0.0101)	0.0526 *** (0.0101)	0.0528 *** (0.0101)	0.0523 *** (0.0101)
d-D1994	0.0203 ** (0.0092)	0.0210 ** (0.0091)	0.0211 ** (0.0092)	0.0207 ** (0.0092)
d-D1995	0.0580 *** (0.0077)	0.0578 *** (0.0077)	0.0584 *** (0.0077)	0.0575 *** (0.0077)
d-D1996	0.0678 *** (0.0065)	0.0673 *** (0.0065)	0.0680 *** (0.0065)	0.0674 *** (0.0065)
d-D1997	0.0510 *** (0.0051)	0.0499 *** (0.0052)	0.0508 *** (0.0051)	0.0497 *** (0.0052)
d-D1998	0.0269 *** (0.0039)	0.0263 *** (0.0039)	0.0268 *** (0.0039)	0.0261 *** (0.0039)
Gov Dummy	-0.0174 *** (0.0039)	-0.0191 *** (0.0048)	-0.0216 *** (0.0040)	-0.0141 ** (0.0056)
Constant	0.0304 *** (0.0020)	0.0306 *** (0.0020)	0.0302 *** (0.0020)	0.0299 *** (0.0020)
Log likelihood	610.1253	609.8844	612.0432	610.3230
Wald Test: p-val	0.0000	0.0000	0.0000	0.0000
# of Firms with Gov_Dummy = 1	111	78	60	44
# of Firms	1086	1086	1086	1086
# of Firm-Year's	6097	6097	6097	6097

Note:

"d-" denotes the first difference. D-year is a year dummy. Gov_Dummy is a dummy that indicates large share of sales to government.

***, **, and * denote significance at 1%, 5%, and 10%, respectively.

The table shows breakdowns of firms with well-established information service activities. Standard deviations are in parenthesis.

All: all in our samples, Group 1: firms that remain single establishments throughout the sample period, Group 2: firms that have headquarters and branch offices throughout the sample period, Group 3: firms that start as single establishments and become multi-establishment firms by the end of the sample period, Group 4: firms that start as multi-establishment firms and become single establishments by the end of the sample period.

Because our samples are an unbalanced panel, the number of firms each year is not equal.

Wald Test is the test statistic asymptotically distributed as chi-square(k) under the null of heteroscedasticity, where k denotes the number of firms.

Total Factor Productivity in Japanese Information Service Industries: Firm-Level Analysis
