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COMPUTER NETWORK USE AND FIRMS' PRODUCTIVITY PERFORMANCE:

THE UNITED STATES VS. JAPAN

by

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Abstract

This paper examines the relationship between computer network use and firms' productivity performance, using micro-data of the United States and Japan. To our knowledge, this is the first comparative analysis using firm-level data for the manufacturing sector of both countries. We find that the links between IT and productivity differ between U.S. and Japanese manufacturing. Computer networks have positive and significant links with labor productivity in both countries. However, that link is roughly twice as large in the U.S. as in Japan. Differences in how businesses use computers have clear links with productivity for U.S. manufacturing, but not in Japan. For the United States, the coefficients of the intensity of network use are positive and increase with the number of processes. Coefficients of specific uses of those networks are positive and significant. None of these coefficients are significant for Japan. Our findings are robust to alternative econometric specifications. They also are robust to expanding our sample from single-unit manufacturing firms, which are comparable in the two data sets, to the entire manufacturing sector in each country, as well as to the wholesale and retail sector of Japan.

1. Introduction

Are computer and other information technologies (IT) a driving force of the recent productivity upward shift observed in the United States and other counties? Oliner and Sichel (2000) show that about two thirds of the 1.5% U.S. productivity revival after 1995 can be attributed to the growth in IT investment. Gordon (2000) argues that the growth in U.S. labor productivity is not a structural shift but simply a pro-cyclical movement. In that view, productivity growth is observed only in the sectors that produce IT, while sectors that use IT cannot take advantage of their often substantial IT investments. After the IT bubble burst, U.S. economic growth did slow, but labor productivity continued to be strong. Baily (2002) suggests that the IT investment surge explains a significant portion of the post-1995 productivity revival in the United States.

In contrast, the Japanese economy of the 1990s was mired in unfavorable conditions following the collapse of the bubble economy in the early 1990s. Japan's GDP growth rate averaged 1.4% in 1990s, in contrast to 4.1% in 1980s. This sluggish Japanese economy is puzzling because Japanese firms also heavily invested in information technology.

Jorgenson and Motohashi (2003) conduct growth accounting exercises to compare the role of IT in economic growth in the two countries. They find that IT capital services make similar contributions to economic growth in both countries during the late 1990s. They also find that TFP grows more rapidly in Japan in the second half of 1990s than the first half. As a result, the slow pace of recent Japanese economic growth comes mainly from the negative contribution of labor inputs to GDP growth.

While growth accounting gives a global view on the relationship between IT investments and economic growth, it shows only a snapshot of what happened. Behind the aggregated data in growth accounting lie productivity and IT use at the firm level. Several studies use establishment and firm-level (micro) data to study these questions separately for the United States and Japan (such as Atrostic and

Nguyen 2005 and 2004, for the United States; and Motohashi 2001 and 2003, for Japan). One micro data study conducts a comparative analysis of the effects of IT on productivity in the U.S. and Japan (Jarmin and Motohashi 1999), but looks only at the presence of IT. A more recent analysis (Atrostic, Boegh-Nielson, Motohashi, and Nguyen 2004) compares the relationship between productivity and computer networks for Denmark, the United States, and Japan, but the data cover different sectors, the minimum unit sizes differ, and econometric specifications differ. No studies have used comparably defined data sets and econometric specifications to examine directly how specific technologies such as the presence of computer networks or different ways of using computer networks affect productivity in the two countries.

This paper is unique in that it uses new firm-level data for the manufacturing sectors of the United States and Japan to test the hypothesis that IT is a multi-faceted technology, where different uses of computer networks are different technologies that shift the production function. Each data set contains information on both the presence of a network in a firm and the specific ways firms use those networks to conduct their business processes. We focus on single-unit firms because those are the most comparable between the two data sets. For each country, we find evidence that computer networks are a general-purpose technology that is used in a variety of applications across industries, such as flexible manufacturing systems and product delivery logistics. Within a firm, IT applications are varied, ranging from financial accounting systems to inventory control systems and human resource management systems. We find positive and significant links between computer networks and labor productivity in both countries. However, the links between productivity and specific uses of those networks differ between the United States and Japan. Most uses of computer networks in the United States have positive and significant links with productivity, while there are no statistically significant links between specific uses of computer networks and productivity in Japan. The broad findings for single-unit manufacturing firms are similar to those for the manufacturing sector in both countries, and our findings are robust to alternative econometric specifications.

2. The Relationship Between Computer Networks and Productivity

Computers may affect productivity when used directly as a specific form of capital inputs to the production process. This is the approach taken in many national and industry-level studies, as well studies at the plant or business level (*e.g.* McGuckin *et al.* 1998, Brynjolfsson and Hitt (2000), and Dunne *et al.* (2000). Consider a steel mill. Computers and automated processes are used to control production processes in modern steel mills. Many supporting business processes can also be computerized. For example, computers can be used to maintain a database of customers or shipments, or to do accounting or payroll. Computers may substitute for paper-based systems without changing the underlying business processes.

But computers may also be used to organize or streamline the underlying business processes. When these computers are linked into networks, they facilitate standard business processes such as order taking, inventory control, accounting services, and tracking product delivery, and become electronic business processes (or e-business processes). These e-business processes occur over internal or external computer networks that allow information from different processes to be readily exchanged. Shipments may be tracked on-line, inventories may be automatically monitored, and suppliers notified when pre-determined levels are reached.

Adopting e-business processes automates and connects existing business processes. It can also change the way companies conduct not only these processes but also their businesses. The surge of interest in supply chains exemplifies the potential for computers to affect productivity growth outside of the manufacturing sub-sectors that produce them. These effects are thought to occur through organizational changes. Many core supply chain processes are widely cited as examples of successful e-business processes that, in turn, are expected to shift the location of the process the participants in the supply chain. Brynjolfsson and Hitt (2000) argue that the effects of organisational changes may rival the effects of changes in the production process.

Viewed this way, computer networks are a productivity-enhancing technology. Bresnahan and Greenstein (1997) hypothesize that computer networks are a general-purpose technology. General-purpose technologies are sector-specific but are diffused widely across industries, and used in a variety of ways within an industry or firm. A characteristic of general-purpose technologies is facilitating complementary investments. In the case of IT, these complementary investments may include reorganizing or streamlining existing business processes. The IT and complementary investments together yield computers linked into networks that further facilitate reorganizing and streamlining business processes.

3. Data and Sources

Until recently, a lack of information on business-level uses of IT limited most micro data studies to exploring the links between productivity and simple indicators of the presence of IT. Japan was a leader in producing data on both the presence of computer networks and how businesses use them, beginning in 1991. Statistical agencies in many countries, including the United States, recently developed new data that permit micro-level analyses of links between productivity and how businesses use IT.[1] This study is the first comparative analysis using these data for Japan and the United States.

2.1. Japan

[1] For a review of these studies, see Pilat (2004)

The data for Japan come from the Basic Survey of Business Structure and Activities (BSBSA), which collects data on productivity and information network use. The BSBSA is the Ministry of Economy, Trade, and Industry's (METI) firm-level survey for all firms with no fewer than 50 employees and no less than JPY 30 million in capital. The BSBSA is the basis for various kinds of firm level surveys by METI in the sense that firm level surveys for special issues, including the information and communication technologies (ICT) Workplace Survey, use the BSBSA firm list as their sample base. BSBSA is an extensive survey for all firms over a certain size so that even long panel data have enough observations for analysis. In each year, it covers over 25,000 firms, and about half of them are manufacturing firms. The survey items include a broad range of firm activities, such as R&D, overseas production, and outsourcing. It also contains financial statement information that allows productivity calculations. The most recent data available as of December 2004 are for 2002, which were collected in the 2003 survey. Summary data and detailed description of BSBSA are available in METI (2004a).

IT network use variables are available in BSBSA for 1991, 1994, 1997 and 2000. In 1991 and 1994, firms were asked whether they used intra firm or inter firm networks, and were asked about specific network applications such as inventory control, logistics management, and customer relationships. In 1997, firms were asked whether they used intra firm and inter firm networks, but not about specific IT network applications. Instead, other items were collected, such as use of electronic data interchange (EDI), computer assisted design or manufacturing (CAD/CAM), and e-commerce (EC), as well as the number of personal computers per worker. In 2000, survey items were modified again, and focused on collecting data about e-commerce activities, as well as the use of intra firm and inter firm networks. Motohashi (2002) looked at the impact of information network use by type of e-business process, based on cross-section data from the 1991 BSBSA. This paper uses BSBSA data only for 2000.

2.2. United States

The Computer Network Use Supplement (CNUS) data used in this study are part of a Census Bureau measurement initiative to fill some data gaps on the growing use of electronic devices and networks in the economy that is described in Mesenbourg (2001). The 1999 CNUS supplement to the 1999 Annual Survey of Manufactures (ASM) provides the first large-scale picture of the presence of computer networks, and how businesses use them, in U.S. manufacturing. Over 38,000 plants responded to the CNUS survey, with a response rate of 82 percent. More information about the survey can be found at U.S. Census Bureau (2004).

CNUS data on computer networks can be linked to data in the 1999 ASM and prior years, such as the value of shipments, employment, and materials. The CNUS and ASM data responses can also be linked to the Census of Manufactures (CM), which is conducted every five years. Atrostic and Nguyen (2005) provide more information about these data.

2.3. Data Used in This Study

The BSBSA is a firm-level survey covering both manufacturing and non-manufacturing sectors of Japan. The CNUS is an establishment-level survey that covers only the manufacturing sector of the United States. Although it is possible to identify establishments that belong to the same firm in the CNUS, there is no information about units in the firm that are outside the manufacturing sector. We select for this study the subsamples of the BSBSA and CNUS that are comparable: single-unit manufacturing firms. These firms have only one plant. We include only firms that have more than 50 employees, the minimum size for BSBSA. There are about 5,000 single-unit manufacturing firms in the CNUS, and about 4,000 in the BSBSA.

Each dataset is analyzed separately, and only by the researcher(s) from that country, because of the confidentiality provisions governing the use of these data.

3. Descriptive Statistics

In both the United States and Japan, manufacturing businesses with computer networks are bigger and more productive than those having no networks. Table 1 shows that the relative employment ratio is 2.25 in Japan and 2.17 in the United States. Relative productivity measured by either gross output or value added ranges from 19 to 29 percent higher for manufacturing firms that have networks.

Table 1. **Relative labour productivity of network users in Japan and the United States**

	Japan (2000) (manufacturing)		United States (1999) (all manufacturing plants)	
	With networks	Without networks	With networks	Without networks
Sales/employment	1.29	1	1.28	1
Value added/employment	1.19	1	1.29	1
Employment	2.25	1	2.17	1

Computer networks appear to be general-purpose technologies in both countries. They are widely diffused among manufacturing industries, occurring in about 88 percent of U.S. manufacturing plants responding to the survey (Census 2004) and about 78 percent of Japanese manufacturing firms (Table 2). Specific applications, such as monitoring production or inventory control, are found across all industries in both countries, and there are striking similarities in the specific industries that are most and least likely to have networks. However, the penetration of networked processes is much higher in U.S. manufacturing. This section presents basic comparative statistics about the diffusion of computer networks and specific network applications in both countries.

3.1. Japan

In the 2000 BSBSA, information on several kinds of network variables are available. Survey items include whether a firm uses intra firm network and/or inter firm networks. In addition, a detailed questionnaire on e-commerce (EC) is prepared, and the data on EC by type of e-business process, i.e., sales, production control, inventory control, design, procurement as well as logistics, are collected.[2] In Table 2, the diffusion rate of various types of information networks is calculated from the 2000 BSBSA data and presented by industry at 3-digit NAICS industry.

About 80% of firms introduced any type of network, but this share varies by industry. The share of networked firms is higher in computer and electrical industries (86 percent and 82 percent), as well as petroleum (83 percent). On the other hand, in wood products and leather and allied products, smaller shares of firms (56 and 55 percent) are hooked up with IT network. This pattern generally holds for the shares of inter and intra-firm network.

EC processes have diffused relatively modestly in Japanese manufacturing, with averages ranging from 1.2 percent (EC design) to 14.6 percent (EC sales). A significant variation of network diffusion rate across industry is found in EC for procurement. In computer and electronics components, 13.7% of firms are using e-commerce, while this share for all manufacturing is only 6%. This finding is consistent with EC market estimate by METI, suggesting that more than 40% of total business-to-business transactions occurred in electrical and electronics equipment and components (METI, 2004b) As for EC for sales, the diffusion rate is generally higher for most industries, as compared to that for EC for procurement. Presumably, electronic transactions between manufactures and wholesale/retailers are much common, as compared to within manufacturing transactions.

Cross-industry variation in network diffusion rates may be related to cross-industry variation in labor productivity premiums for firms using networks. Figure 1 shows the relative value added per employee of network users to value-added of non-users by industry. In many industries, the labor productivity of network users is around 20% higher than that of non-users. However, some industries

[2] The definition of EC is electronic transactions inter firms ones through including propriety information network. This corresponds to OECD's broad definition of e-commerce.

show only small differences, such as leather and allied products (lower productivity for net users), paper, petroleum and coal products, and furniture and fixtures.

3.2. The United States

The CNUS data show that U.S. manufacturing plants use networks for much more than on-line sales and orders. Only half of U.S. manufacturing plants reporting that they have a network also report that they accept and/or place orders online (Census 2002). That finding is consistent with the long history of computer network use in the United States which pre-dates e-commerce by decades. The 1999 CNUS data therefore contain information on the use of e-business process by all plants, whether or not they conduct e-commerce.

U.S. manufacturing plants use computer networks in myriad ways, including running complex software that links multiple processes, and conducting specific business processes over their networks. This section presents a few stylized facts about business use of computer networks based on published tabulations (Census 2002).

FIERP Software. Fully integrated enterprise resource planning software (FIERP) is the kind of sophisticated software that links different kinds of business applications (such as inventory, tracking, and payroll) within and across businesses. Figure 2 summarizes information from the CNUS about the presence of FIERP software in U.S. manufacturing in 2000.[3]

FIERP software is found throughout U.S. manufacturing, although it remains relatively rare compared to computer networks. While about 88 percent of manufacturing plants in the CNUS have networks, only 26 percent have this kind of software. The 26 percent average masks variations in use among industries. FIERP was used by fewer than 15 percent of plants in four industries (Apparel; Wood Products; Printing and Related Support Activities; and Nonmetallic Mineral Products), but by at least 33

[3] The CNUS was conducted as a supplement to the 1999 ASM, but the data were collected during 2000, and are thought to reflect usage in 2000.

percent of plants in five others (Chemicals; Machinery; Computer and Electronic Products; Electrical equipment, Appliances, and Components; and Transportation Equipment).

Specific E-Business Processes. The CNUS asks two questions about two sets of such e-business processes. The first set contains information about the presence of seven networked processes: 1) Design Specifications; 2) Product Descriptions or Catalogs; 3) Demand Projections; 4) Order Status; 5) Production Schedules; 6) Inventory Data; and 7) Logistics or Transportation. Plants are asked whether they use these processes to share information with other business units (many U.S. manufacturing plants are part of multi-unit businesses), customers, or suppliers. The second set asks about 28 detailed business processes in five broad groupings: 1) Purchasing; 2) Product Orders; 3) Production Management; 4) Logistics; and 5) Communication and Support. These two groupings are similar, but not identical.

All processes are used in all U.S. manufacturing industries. Each of the seven processes in the first set is used, on average, by at least 24 percent of manufacturing plants, and plants in all 21 manufacturing industries share each kind of process information online (Table 3).

Usage differs across processes. One summary of this usage and its heterogeneity is shown in Figure 3. For each process, the first bar is the average for all manufacturing sectors, followed by a space, then bars for each manufacturing industry. Some processes are much more likely to be shared such as Design Specifications (39 percent, on average) and Product Descriptions or Catalogs (45 percent) than are Demand Projections (24 percent).

Usage differs across industries. Data in Table 3 confirm the visual impression of Figure 3 that sharing is particularly high in Computer and Electronic products (73 percent); Electrical Equipment, Appliances, and Components (65 percent); and Machinery (61 percent). These same industries are among the highest online sharers of several other kinds of e-business process information, such as Design Specifications; Demand Projections; and Order Status.

However, there is less variation among industries for other e-business processes. For example, Inventory Data are shared on-line by 48 percent of plants in Chemicals, 45 percent of plants in Beverage and Tobacco, and 43 percent each in Textile Mills; Paper; Electrical Equipment, Appliances, and Components; and Transportation Equipment.

An alternative view of the same information is given in Figure 4, which groups the processes by industry. Manufacturing industries clearly differ in their use of on-line business processes. Some industries make scant use of them. For example, usage ranges from 14 percent to 29 percent in Wood products, from 18 to 36 percent in Apparel, and from 16 to 35 percent Nonmetallic Metals. Others industries, on the other hand use most of these processes. Usage ranges from 24 to 61 percent in Machinery, from 33 to 73 percent in Computer and Electronic Products, and from 35 to 65 percent in Electrical Equipment. The use of a few processes is widespread within those industries. Design Specifications are shared by at least 56 percent of plants in these three industries, and Product Descriptions or Catalogs are shared by at least 61 percent.

4. Empirical Implementation

The above figures are descriptive statistics, which do not take into account other factors that may affect firms' productivity. For this reason, we turn to a regression analysis that allows us to establish a relationship between computer network use and productivity while controlling for the effects of factors such as firms' characteristics. We base our empirical work is based on a Cobb-Douglas production function that we extend to take account of the features of our data. First, we estimate the relationship between firms' labor productivity and conducting business processes over computer networks. We begin with an intensity measure to get a broad picture of whether a relationship exists between productivity and e-business processes, and then turn to measures of the presence of specific e-business processes. Second, we test the robustness of the empirical results in several ways. We use alternate measures of networked business processes in our core specification. We estimate country-specific alternative specifications. Estimates for single-unit firms in each country are compared to assess how well our findings for single-unit firms generalize.

4.1. Empirical Model

We employ the same productivity equation used in Atrostic and Nguyen (2005) in which labor productivity is specified as a function of input intensity and firms' specific characteristics. That is,

$$(1) \quad \text{Log}(Q/L) = \beta_0 + \textstyle\sum_k \beta_{kj}\, \text{EBProcess}_{kj} + \alpha_1 \log(K/L) + \alpha_3 \log(M/L) + \sum \alpha_{4i}\,(\text{SIZE}_i)$$

$$+ \alpha_5 \log(\text{MIX}) + \textstyle\sum \gamma_i \text{IND}_i + \varepsilon$$

Equation (1) relates the use of various electronic business processes (EBProcess) to (log) labor productivity. In what follows, we describe in detail the variables incorporated in equation (1).

E-business process variables. The parameters of interest are the coefficients of the e-business processes, the β_{kj}, which we model as technological shifts in the production function. Each group of e-business processes is entered in a separate regression. The first group of e-business processes is the presence of a computer network. The second group is the use of FIERP software (for the United States), or using the network to communicate within the firm or externally (i.e., intra or inter firm networks for Japan). The third group is a measure of the intensity of network use, entered as a set of dummy variables corresponding to the use of one, two, three, etc., processes.

The fourth group examines the effect of detailed e-business processes: five processes for the United States and six for Japan. We examine these processes in two ways. First, we enter dummy variables for all five processes in a single equation. The coefficients in such a regression show the independent impact of a process, controlling for the presence of other processes. Second, we enter a dummy variable for only one process. This coefficient shows the impact of using a specific process compared to not using it.

Standard production function variables and plant characteristics. The dependent variable in equation (1), Q/L, is gross output labor productivity, measured as the value of shipments (Q) divided by total employment (L). For the United States, both values come from the 1999 ASM. For Japan, both values come from the 2000 BSBSA.

The first group of explanatory variables is the standard production function variables. K is the book value of capital, measured relative to total employment (L). For the United States, both values come from the 1997 CM, and have the "97" subscript[4]. For Japan, both values come from the 2000 BSBSA. Materials inputs, M, are measured relative to total employment in the 1999 ASM for the United States, and in the 2000 BSBSA for Japan. The U.S. measure of materials includes business and contract services and energy used at the plant, as well as physical materials inputs. The Japanese measure may include expenses not directly related to production, such as advertising and communications.

The second group of explanatory variables characterizes the firm. MIX is the ratio of non-production to production workers, a proxy for skill mix, and IND represents the firm's industry, coded in both data sets to the North American Industry Classification System (NAICS). $SIZE_i$ is a set of employment size classes. Details of the construction of these variables are given in Atrostic and Nguyen (2005) and Motohashi (2004).

[4] Book value of capital (K) is collected only in Economic Census years such as 1992 and 1997.

5. Empirical Findings for Network Use: The United States vs. Japan

Our empirical results show that the relationship between computer network use and productivity differ between U.S. and Japanese manufacturing firms. Computer networks have positive and significant links with firms' labor productivity in both countries. However, while we find positive and significant links between specific ways that businesses use networks in U.S. manufacturing, we do not find any statistically significant links for Japan.

5.1. Computer Networks

Computer networks are linked to productivity in both the United States and Japan. We report in Table 4 results for identical productivity specifications for single-unit manufacturing firms in both countries (column 2 for the United States and column 4 for Japan). These regressions explain 66 percent of the variance in productivity for U.S. single-unit firms, and 94 percent of the variance for Japanese single-unit firms. While network coefficients are positive for both the United States and Japan, the U.S. network coefficient of 0.048 is almost twice the coefficient of 0.029 for Japan. This difference is interesting because the diffusion rates are similar for both countries, reflecting the long use of networks in their manufacturing processes. Thus, differences in how those networks are used in each country may contribute to the difference in coefficients.

Differences in complementary investments between Japan and the United States may also contribute to differences in the relative productivity impact of networks. A large literature suggests that these complementary investments may take several forms (e.g. Bresnahan and Greenstein (1997)). Co-invention may be required to put networks in place and make them effective. Organizational changes may also be required, such as adopting innovative work practices, supply chain management, and customer relationship management. However, further organizational capital also may be required for such changes to have a productivity impact. Otherwise, simply adopting an application such as supply chain management would not automatically make any business as productive as an industry leader (Motohashi 2004). Japanese firms conduct fewer such organizational changes, compared to U.S. firms, when they introduce new IT systems (e.g., Motohashi 1999 and 2004).

5.2. Estimated Productivity Functions.

Productivity functions for single-unit manufacturing firms differ in the two countries. Coefficients for these firms in the United States and Japan are shown in columns 2 and 4 of Table 4. The materials elasticity of 0.728 for Japanese firms outpaces the elasticity of 0.461 for the United States firms. The U.S. capital elasticity of 0.090 is more than twice the Japanese elasticity of 0.037. Worker mix, the ratio of non-production to production workers, is positive and statistically significant at the 1 percent level in both countries, consistent with capital deepening. However, the economic importance of worker mix on productivity is much higher in the United States compared to Japan (coefficients of 0.070 vs. 0.012).

5.3. Specific E-business Processes.

The way U.S. single-unit firms use networks affects their productivity, by any of our measures of use. In contrast, only one way of using networks is associated with the productivity of Japanese single-unit firms.

United States. Plants running FIERP software over a network have productivity that is about 5.3 percent higher in than plants without a network (column 1 of Table 6). This productivity gain is greater than the gain from only running a network (about 5 percent).

Intensity of use matters. Higher intensity is associated with higher productivity impacts (column 2).[5] Running a single process over a network yields about a 1 percent productivity gain that is

[5] Previous work (Atrostic and Nguyen 2004b) analyzes both sets of e-business process variables, but the estimates in this paper use only the second set. The set of single-unit firms is much smaller than all manufacturing plants (roughly 5000

significant at the 1 percent level. Plants running two or three processes are about 4 percent more productive than plants with no networked processes, significant at the 5 percent level. The most intensive uses are associated with even higher productivity of 7.1 percent for 4 processes and 5.7 percent for all 5 processes, both significant at the 1 percent level.

The links between specific processes and productivity for the United States depend on how we specify the processes. When all five e-business processes (purchasing, product orders, production management, logistics, and communication and support) are entered into the productivity function together, only the coefficient for production management of 0.031 is positive and significant at the one percent level (column 3 of Table 6). This result stands in contrast to our prior research (Atrostic and Nguyen 2004), where we found a negative coefficient for production, and positive and significant coefficients for supply-chain activities such as logistics, inventory, and order tracking.

Japan. Productivity is about 3 percent higher in single-unit firms using networks (column 1, Table 5). However, the presence of e-commerce networks generally has no statistically significant relationship with firm labor productivity.

It should be noted that the Japanese data show only the diffusion of e-commerce by type of e-business. Therefore, the diffusion rates of network by e-business are very small as compared to those of the United States. Low diffusion rates lead to lower variance in productivity data between network users and non-users, which make it more difficult to evaluate the impact of networks. Even after setting aside such limitation in Japanese data, we can conclude that intensity of network use is not associated with higher productivity in Japan, in contrast to the United States. Neither of two measures of intensity (the number of processes used, and a series of dummy variables that index the number of processes used,

compared to the 27,000 plants analyzed in Atrostic and Nguyen 2004b) so we find more noise in the data when analyzing the set of seven processes.

parallel to the U.S. measure) has a significant coefficient. The coefficients are reported in column 2,. Table 5.

The BSBSA data do not show links between specific processes and productivity for the Japan, regardless of on how we specify the processes. When the six processes are entered together (column 7 of Table 5), none of the coefficients is significant. Nor are there any significant coefficients for any specific process.

Table 7 presents the results for Japanese whole sale and retail firms. The productivity impact of network is about 1% and statistically significant, while e-commerce shows no significant impact on labor productivity. As with the results for manufacturing, e-commerce intensity does not register any significant relationship with firm labor productivity. As for specific e-commerce processes, only sale processes have a significantly positive relationship with labor productivity with an estimated coefficient of 0.008.

6. Discussion

A strength of our study is that our data contain similar measures of key production variables such as capital and computer networks, business characteristics, including the same industry classifications, and the key technology variables of interest: computer networks and how they are used. These similarities make us more confident that the differences we find reflect actual differences between the economies of the United States and Japan.

This section assesses the robustness of our estimates for U.S. and Japanese manufacturing. It discusses how likely our estimates for single-unit manufacturing firms are to generalize to the manufacturing sector of each country, and to other sectors. Finally, we note some data gaps that temper our conclusions.

6.1. Alternative Specifications.

For the United States, we estimate but do not report a number of alternative econometric specifications. One set of estimates includes dummy variables indicating whether a plant is new since 1997 as a proxy for possible technology and managerial vintage effects. Another set includes a measure of the firm's economic performance in a prior period. The third set includes both the dummy for new plants and the prior period performance measure, and is the preferred specification in prior research for U.S. manufacturing (Atrostic and Nguyen 2004). The coefficients and statistical significance of the computer network and e-business process variables, and the production function variables, are stable across these alternative econometric specifications.

6.2. Sample Size.

For the United States, estimates of the effects of detailed e-business processes appear to be somewhat sensitive to sample size. Diffusion rates for detailed processes are higher in the United States than in Japan, but even in the CNUS data, average diffusion rates of 24 percent for these processes are sparse compared to the 88 percent diffusion rate for computer networks.We also find that using the alternate group of seven e-business processes leads to fewer significant coefficients for those processes. This finding, too, may reflect the relatively small sample size for single-unit firms with more than 50 employees. Prior research using data for all manufacturing firms (Atrostic and Nguyen 2004) found that both sets of e-business process measures had stable coefficients, and that supply-chain processes generally were statistically significant.

6.3. Economic Performance in Prior Periods.

Prior research for the United States (Atrostic and Nguyen 2005) uses two-stage estimations to address potential endogeneity. In contrast to standard findings that estimated effects in two-stage estimates are smaller in magnitude and less likely to be significant than OLS coefficients, we find that the effects are significant and roughly twice as high in the two-stage estimates. We also find that neither including a dummy variable to control for new plants (perhaps more innovative or able to purchase the newest technology) nor a variable to control for relative productivity in the prior period changes the general level or broad pattern of significant e-business process coefficients.

Motohhashi (2004) addresses the effect of unobservable firm-specific factors behind productivity performance by estimating fixed-effect models based on panel data. He finds that the effect of intra firm and inter firm networks are both positive, but not statistically significant. This is consistent with the cross section-regression in this paper that find weak explanatory powers for network variables for Japanese manufacturing firms.

6.4. Findings Generalize Beyond Single-unit Manufacturing Firms.

The key coefficient of interest, computer networks, appears to generalize from single-unit manufacturing firms to the manufacturing sector for each country. The coefficients reported in Table 4 of 0.044 and 0.048 for U.S. all manufacturing plants and single-unit plants are similar, as are the parallel coefficients of 0.019 and 0.029 for Japan. Capital and materials coefficients also are similar for single-unit firms and all firms. One variable whose coefficient changes markedly is the worker mix variable, the ratio of non-production to production workers. For the United States, the coefficient drops from 0.070 for single-unit plants to 0.037 for all plants, but remains significant at the 1 percent level. For the Japan, the coefficient of 0.012 is significant at the 1 percent level for single-unit firms. That coefficient drops to 0.000 for all manufacturing firms, and is not statistically significant.

7. Conclusions

This research explores the relationship between productivity and the use of computer network technologies in the manufacturing sectors of the United States and Japan. The key contribution of our work is that ours is the first firm-level analysis to explore the link between productivity and the specific ways that businesses use computer networks in both countries. We find that using networks in general is positively linked to productivity in both countries. However, other results differ between the two countries. For the United States, we find clear productivity increases associated with many networked processes, including production management, order status, logistics, communication, and support, but not for Japan. For Japan, only the presence of computer networks, and not different uses of those processes, is positively associated with productivity. These findings are robust to a variety of econometric specifications. They also generalize beyond the single-unit manufacturing firms in both countries, holding for the entire manufacturing sector of both countries and for the wholesale and retail sectors of Japan.

What explains the difference between the two countries? The available data may limit our ability to estimate the relative roles of computer networks and their uses in both countries. One key concept, computer networks, is the same for both countries. However, information is collected on e-business processes used in all phases of business activity for the United States, but only for e-business processes conducted as part of e-commerce for Japan. Diffusion rates for most of these e-business processes are much lower in Japan than for the broader set of processes measured in the United States, making it difficult to estimate their impact in Japan. Without data for multiple periods for both countries, we are not able to address questions of whether well-managed, productive businesses adopt computer networks, or whether using computer networks and conducting business processes over them makes a business more productive.

Differences between the two countries may also derive from the way each implements this general-purpose technology. The general-purpose technology literature stresses the need not just for using technology, but using that technology together with complementary investments, innovation, process change, and other facets of organizational capital. Motohashi (2004) addresses this question by testing the complementarity of information and business networks for productivity growth, and finds some evidence for such a relationship. Firms conducting joint production and R&D activities may be superior for networking activities with other firms, which will be one of the factors needed to make efficient use of information networks. In addition, it is found that high performance work practices and decentralized organizational structures are important to achieving higher productivity performance (Black and Lynch 2001 and 2003, Bresnahan and Greenstein 1999). There is some evidence showing that there are fewer such organizational changes and co-inventions in Japan than in the United States. This may be one of reasons why we find that the impact of IT network on productivity is relatively weak in Japan. This is one of our future research directions to understand the difference between Japan and the United States.

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Table 2a
Japan: Presence of Computer Networks by Industry and Specific Applications

NAI CS	Industry	N	Any network	Inter firm	Intra firm	EC sales	EC production	EC inventory	EC design	EC procurement	EC logistics
	All manufacturing firms	**13,219**	**78.3%**	**34.9%**	**67.4%**	**14.6%**	**3.7%**	**2.7%**	**1.2%**	**6.0%**	**2.7%**
311	Food manufacturing	1,462	70.7%	27.9%	61.1%	16.8%	1.4%	1.9%	0.1%	2.5%	2.4%
312	Beverages and tobacco	160	81.3%	35.0%	73.8%	29.4%	3.8%	4.4%	0.6%	5.6%	8.8%
313	Textiles and fabrics	141	67.4%	31.9%	51.1%	4.3%	6.4%	5.7%	0.7%	0.7%	4.3%
314	Textiles mill products	192	78.1%	34.4%	65.6%	11.5%	1.6%	3.1%	0.0%	2.6%	3.6%
315	Apparel and accessories	355	68.2%	29.0%	56.3%	11.0%	3.7%	2.8%	0.8%	1.1%	4.2%
316	Leather and allied products	40	55.0%	22.5%	45.0%	10.0%	7.5%	0.0%	0.0%	2.5%	0.0%
321	Wood products	160	56.3%	21.9%	47.5%	6.9%	2.5%	0.6%	0.6%	2.5%	0.6%
322	Paper	440	73.2%	32.3%	63.0%	14.3%	2.0%	1.8%	0.2%	3.0%	2.0%
323	Printing, publishing etc	825	77.6%	25.7%	70.9%	14.7%	3.0%	2.3%	0.5%	2.8%	1.6%
324	Petroleum and coal products	55	83.6%	40.0%	69.1%	16.4%	1.8%	3.6%	1.8%	5.5%	7.3%
325	Chemicals	944	81.1%	30.0%	72.9%	16.2%	1.5%	2.9%	0.6%	4.4%	4.4%
326	Plastics and rubber products	831	78.5%	38.5%	65.7%	16.6%	3.1%	2.6%	1.1%	5.4%	2.8%
327	Nonmetallic mineral products	554	69.0%	25.6%	58.1%	8.1%	1.3%	1.6%	0.5%	2.0%	1.1%
331	Primary metals	739	78.9%	39.9%	66.2%	17.1%	3.0%	2.7%	1.1%	6.2%	1.8%
332	Fabricated metals	1,001	78.8%	31.7%	68.6%	13.3%	3.7%	2.5%	1.3%	3.8%	2.2%
333	General machinery	1,703	81.1%	31.6%	71.7%	10.0%	3.8%	1.8%	1.8%	7.1%	1.8%
334	Computer and electronic products	1,445	86.6%	45.9%	73.3%	18.3%	6.2%	4.4%	1.7%	13.7%	2.8%
335	Electrical appliances and components	780	82.6%	42.8%	69.1%	15.9%	3.7%	3.2%	0.8%	10.4%	1.5%
336	Transportation equipment	1,121	81.4%	48.8%	68.2%	15.1%	8.5%	3.2%	4.4%	8.5%	4.5%
337	Furniture and fixtures	181	77.9%	28.2%	68.5%	12.7%	5.5%	2.8%	1.1%	2.8%	2.8%
339	Other manufacturing	90	84.4%	31.1%	76.7%	17.8%	3.3%	3.3%	0.0%	12.2%	2.2%

Table 2b

Japan: Presence of Computer Networks by Industry and Specific Applications

	Single-establishment firms	N	Any network	Inter firm	Intra firm	EC sales	EC production	EC inventory	EC design	EC procurement	EC logistics
	All manufacturing	**3,896**	**75.5%**	**37.8%**	**61.2%**	**9.0%**	**4.3%**	**2.7%**	**0.8%**	**4.8%**	**1.7%**
311	Food manufacturing	437	62.9%	28.4%	49.0%	9.2%	1.1%	1.1%	0.0%	0.9%	1.1%
312	Beverages and tobacco	38	78.9%	36.8%	65.8%	18.4%	7.9%	5.3%	0.0%	0.0%	7.9%
313	Textiles and fabrics	78	67.9%	33.3%	47.4%	1.3%	6.4%	5.1%	0.0%	0.0%	3.8%
314	Textiles mill products	70	77.1%	48.6%	54.3%	8.6%	1.4%	1.4%	0.0%	0.0%	2.9%
315	Apparel and accessories	146	61.6%	28.8%	43.8%	6.2%	4.1%	4.1%	1.4%	1.4%	2.7%
316	Leather and allied products	17	35.3%	11.8%	35.3%	11.8%	5.9%	0.0%	0.0%	0.0%	0.0%
321	Wood products	59	45.8%	16.9%	40.7%	1.7%	3.4%	1.7%	1.7%	0.0%	0.0%
322	Paper	124	69.4%	29.0%	54.0%	9.7%	0.8%	1.6%	0.0%	1.6%	0.0%
323	Printing, publishing etc	232	75.4%	25.4%	67.7%	10.8%	2.2%	1.7%	0.4%	2.2%	0.9%
324	Petroleum and coal products	7	71.4%	57.1%	42.9%	14.3%	0.0%	14.3%	0.0%	0.0%	0.0%
325	Chemicals	119	79.8%	32.8%	63.0%	5.0%	0.8%	1.7%	0.0%	1.7%	1.7%
326	Plastics and rubber products	219	80.8%	43.8%	63.9%	11.9%	4.6%	2.7%	0.5%	3.2%	1.8%
327	Nonmetallic mineral products	103	62.1%	30.1%	44.7%	3.9%	1.9%	2.9%	1.0%	3.9%	1.0%
331	Primary metals	209	70.8%	34.0%	59.3%	11.0%	2.4%	1.9%	0.5%	4.8%	1.0%
332	Fabricated metals	269	76.6%	36.1%	62.1%	8.6%	4.8%	2.2%	0.7%	3.7%	1.9%
333	General machinery	473	83.5%	38.7%	71.9%	7.2%	5.1%	1.7%	1.5%	5.7%	1.5%
334	Computer and electronic products	545	85.0%	49.0%	69.5%	10.6%	6.6%	5.1%	1.1%	11.7%	2.8%
335	Electrical appliances and components	253	80.2%	46.6%	66.4%	9.9%	5.5%	3.6%	1.2%	9.5%	0.8%
336	Transportation equipment	407	78.4%	46.7%	61.4%	9.8%	6.9%	3.4%	2.0%	5.7%	2.2%
337	Furniture and fixtures	67	77.6%	34.3%	65.7%	10.4%	6.0%	1.5%	0.0%	3.0%	3.0%

Source: Motohashi tabulations of BSBSA 2000.

Table 3
United States: Percentage of Manufacturing Plants that Share Information Online with Customers or Suppliers, By Type of Information

NAICS Code	Description	6a Design Specifications	7a Product Descriptions or Catalogs	8a Demand Projections	9a Order Status	10a Production Schedules	11a Inventory Data	12a Logistics or Transportation
	All Manufacturing	39%	45%	24%	35%	30%	33%	28%
311	Food products	22%	31%	22%	32%	28%	34%	31%
312	Beverage and tobacco	20%	29%	32%	37%	34%	45%	37%
313	Textile mills	32%	36%	29%	39%	36%	43%	32%
314	Textile product mills	34%	46%	25%	40%	29%	32%	30%
315	Apparel	26%	36%	18%	34%	29%	30%	27%
316	Leather and allied products	23%	46%	17%	32%	24%	25%	24%
321	Wood products	23%	29%	14%	24%	19%	26%	18%
322	Paper	43%	36%	26%	42%	34%	43%	33%
323	Printing and related support activities	39%	44%	16%	35%	27%	26%	24%
324	Petroleum and coal products	30%	32%	28%	27%	31%	38%	30%
325	Chemicals	36%	49%	34%	43%	40%	48%	42%
326	Plastics and rubber products	43%	46%	28%	38%	32%	36%	32%
327	Nonmetallic mineral products	27%	35%	16%	23%	21%	26%	20%
331	Primary metals	38%	44%	28%	40%	34%	38%	32%
332	Fabricated metal products	39%	42%	20%	30%	26%	25%	22%
333	Machinery	56%	61%	24%	36%	30%	28%	24%
334	Computer and electronic products	61%	73%	35%	45%	37%	41%	33%
335	Electrical equipment, appliances, and components	57%	65%	35%	46%	40%	43%	38%
336	Transportation equipment	55%	49%	41%	48%	46%	43%	42%
337	Furniture and related products	34%	42%	16%	27%	23%	23%	22%
339	Miscellaneous	36%	53%	20%	31%	23%	25%	25%

Source: Atrostic and Nguyen' tabulations, based on U.S. Census Bureau, *1999 E-business Process Use by Manufacturers Final Report on Selected Processes* (March 1, 2002), www.census.gov/estats.

Data are based on the North American Industry Classification System (NAICS).
Column heading refers to questionnaire item number

Table 4
OLS Regression Results for U.S. and Japanese Manufacturing Sectors: Computer Networks

Dependent variable: Log of gross output labor productivity

(t-statistics in parentheses)

	United States[a]		Japan[b]	
	All Plants	Single-Unit Firms	All Firms	Single-Unit Firms
Log (M/L)	0.532	0.461	0.769	0.729
	(182.57)**	(79.38)**	(415.61)**	(199.86)**
Log (K/L)	0.099	0.090	0.040	0.037
	(37.60)**	(17.09)**	(29.61)**	(14.52)**
Computer Network	0.044	0.048	0.019	0.029
	(3.95)**	(2.86)**	(6.10)**	(4.47)**
Log (Mix)	0.037	0.070	0.001	0.012
	(9.65)**	(9.00)**	(1.00)	(3.37)**
100 < L ≤ 200	-0.008	-0.017	0.013	0.015
	(-1.21)	(-1.54)	(3.90)**	(2.45)*
200 < L ≤ 1000	-0.008	-0.032	0.034	0.055
	(-1.24)	(-2.36)*	(10.05)**	(6.77)**
L > 1000	0.070	-0.027	0.077	0.141
	(5.24)**	(-0.34)	(12.97)**	(4.07)**
Constant	2.608	2.861	0.900	1.035
	(126.50)**	(79.90)**	(135.49)**	(76.75)**
Industry dummy	yes	yes	yes	yes
Observations	22,431	5,033	13,278	3,816
R-squared	0.74	0.66	0.95	0.94

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Sources:
a Atrostic and Nguyen calculations of CNUS data; plants with more than 50 workers.
b Motohashi calculations of METI data

Table 5
Japan: OLS Regression Results for Single-Unit Manufacturing Firms, 2000,
Type of Computer Network, Intensity of Business Process Use, and Network Uses
Dependent variable: Log of gross output labor productivity

(absolute value of t-statistics in parentheses)

	1	2	3
Log (M/L)	0.729	0.729	0.729
	(199.83)**	(197.17)**	(197.14)**
Log (K/L)	0.037	0.037	0.037
	(14.53)**	(14.48)**	(14.52)**
Log (Mix)	0.011	0.012	0.012
	(3.17)**	(3.41)**	(3.41)**
Network	0.031		
	(4.57)**		
E-commerce	-0.008		
	(0.94)		
Number of network processes =1		0.006	
		(0.09)	
Number of network processes =2		0.008	
		(0.13)	
Number of network processes =3		-0.013	
		(0.19)	
Number of network processes =4		0.004	
		(0.06)	
Number of network processes =5		0.021	
		(0.30)	
Number of network processes =6		0.004	
		(0.05)	
Sales			-0.009
			(0.84)
Production			-0.023
			(1.31)
Inventory			0.035
			(1.53)
Design			0.016
			(0.50)
Procurement			0.007
			(0.47)
Logistics			-0.010
			(0.43)
Constant	1.053	1.048	1.054
	(81.76)**	(76.12)**	(81.75)**
Observations	3,816	3,816	3,816
R-squared	0.94	0.94	0.94

Notes:
Regressions include industry dummies and firm size dummies
1 both inter and intra included
2 ec=1 if any type of EC, 0 otherwise
3 netsum: number of EC types (0-6, there are EC for sales, production, inventory, design, logistics)
4 net=1,2,3,4,5,6: dummy variables for the number of EC types, net=0 as a base
5 each type of EC included all together

Source: Motohashi calculations of BSBSA 2000.

Table 6
U.S.: OLS Regression Results for Single-Unit Manufacturing Firms, 1999,
Type of Computer Network, Intensity of Business Process Use, and Network Uses
Dependent variable: Log of gross output labor productivity

(t-statistics in parentheses)

	1	2	3
Log (M/L)	0.457	0.461	0.462
	(74.92)**	(79.43)**	(79.48)**
Log (K/L)	0.095	0.090	0.090
	(17.11)**	(16.97)**	(16.92)**
Log (Mix)	0.066	0.068	0.068
	(8.22)**	(8.73)**	(8.72)**
Network	0.049		
	(2.79)**		
FIERP & Network	0.053		
	(2.79)**		
Number of network processes=1		0.016	
		(0.82)**	
Number of network processes =2		0.043	
		(2.44)*	
Number of network processes =3		0.043	
		(2.48)*	
Number of network processes =4		0.071	
		(4.09)**	
Number of network processes =5		0.057	
		(3.09)**	
Purchasing			-.001
			(-0.09)
Product Orders			0.009
			(0.82)
Production Management			0.031
			(2.54)**
Logistics			0.001
			(0.82)
Communication and Support			0.014
			(0.96)
Observations	4,640	5,033	5,033
R-squared	0.66	0.66	0.66

significant at 10 %* significant at 5%; ** significant at 1%

Note: Number of observations in column 1 differs from number of observations in columns 2 and 3 because column 1 estimates omit plants with inconsistent responses to question about FIERP

1 FEIRP and Network included

2 Regressions include industry and size dummies.

4 net=1,2,3,4,5: dummy variables for the number of E-Business processes used, net=0 as a base

5 All e-business processes included

Source: Motohashi's calculations of BSBSA 2000

Table 7

Productivity regressions for Japanese Wholesale and Retail Firms, 2000

Dependent Variable: Log Gross Output Labor Productivity

(t-statistics in parentheses)

	1	3	4
Log (M/L)	0.902 (731.44)**	0.902 (732.55)**	0.902 (732.77)**
Log (K/L)	0.004 (6.56)**	0.004 (6.51)**	0.004 (6.49)**
Log (Mix)	-0.006 (2.16)*	-0.006 (2.09)*	-0.006 (2.01)*
Network	0.008 (3.39)**		
E-commerce	0.002 (0.96)		
EC=1		-0.054 (1.04)	
EC=2		-0.053 (1.00)	
EC=3		-0.047 (0.90)	
EC=4		-0.051 (0.96)	
EC=5		-0.038 (0.70)	
EC=6		-0.006 (0.10)	
Sale			0.008 (2.87)**
Inventory			0.001 (0.11)
Design			0.005 (0.24)
Procurement			-0.004 (0.97)
Logistics			0.000 (0.03)
Constant	0.504 (100.38)**	0.563 (10.70)**	0.509 (104.40)
Observations	9,832	9,832	9,832
R-squared	0.99	0.99	0.99

Note: * significant at the 5% level, ** significant at the 1% level
EC = E-commerce
Regressions include size dummies and industry dummies.

Source: Motohashi calculations of BSBSA 2000.

Figure 1

Productivity premia of firms using computer networks in Japan, 2000, by NAICS 3-digit industry

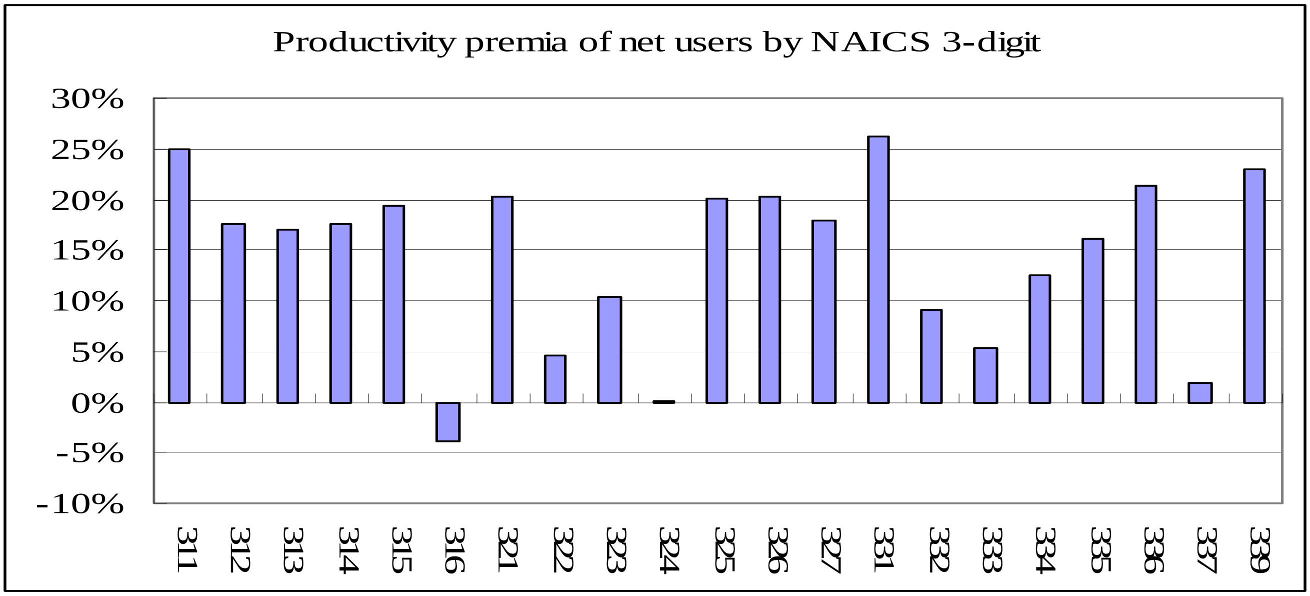
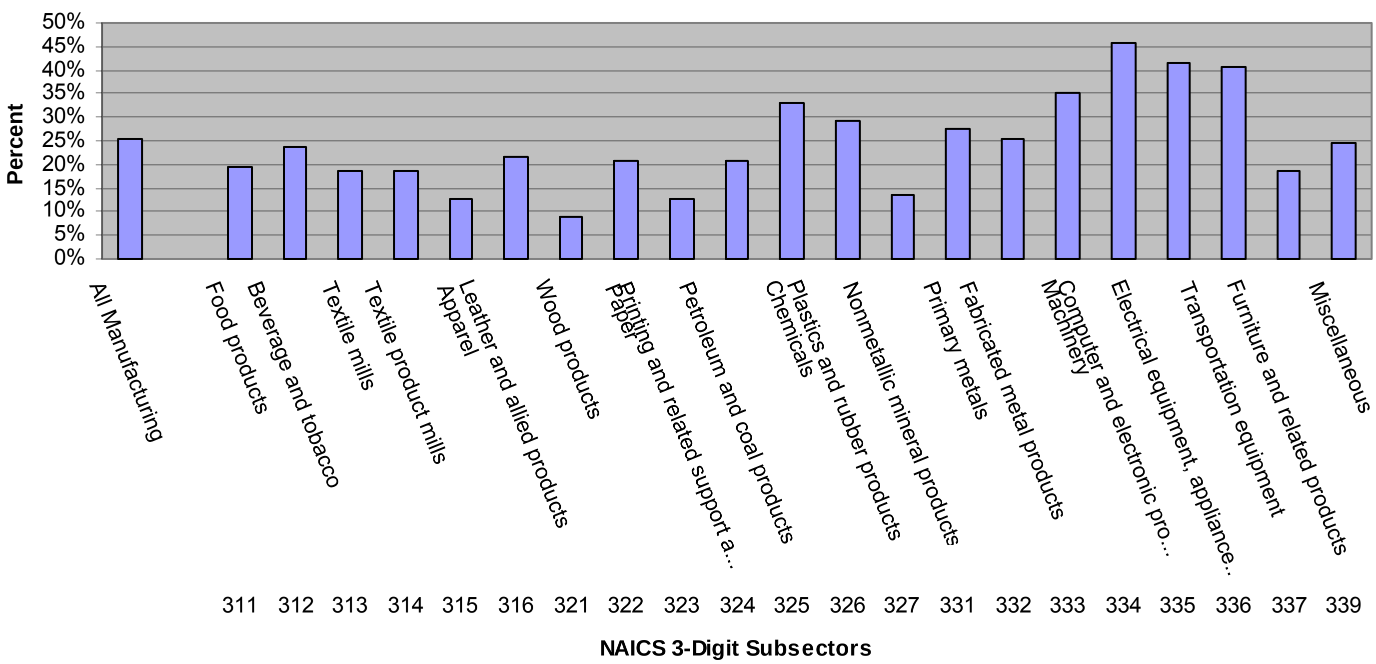


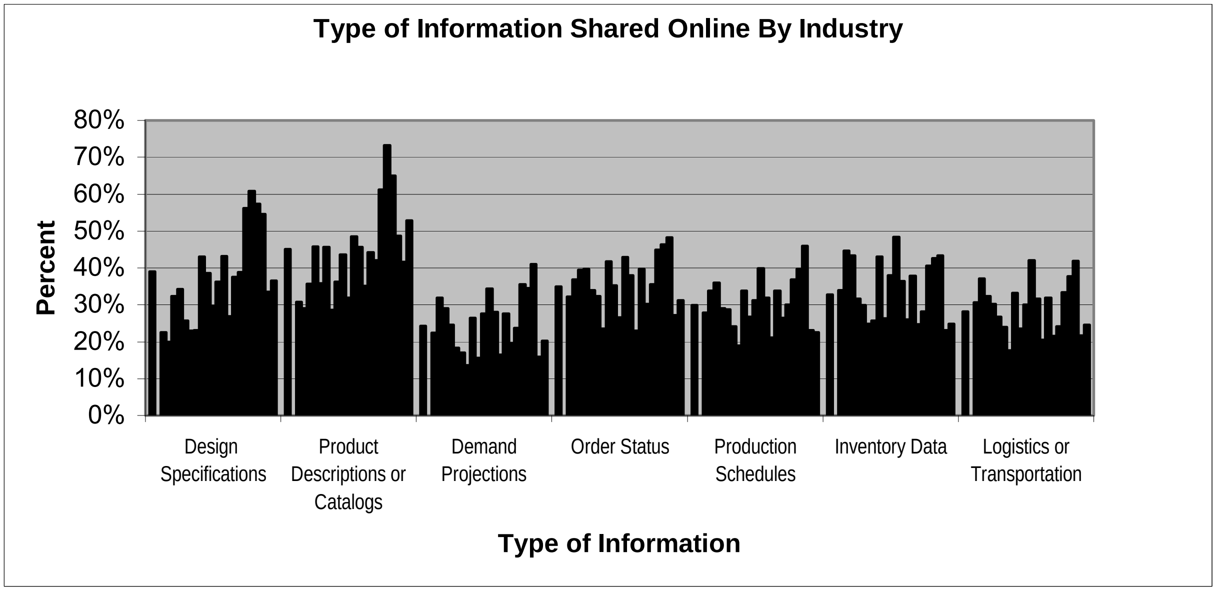
Figure 2

Fully Integrated Enerprise Resource Planning (FIERP) Software is Used in All Manufacturing Sectors in 2000



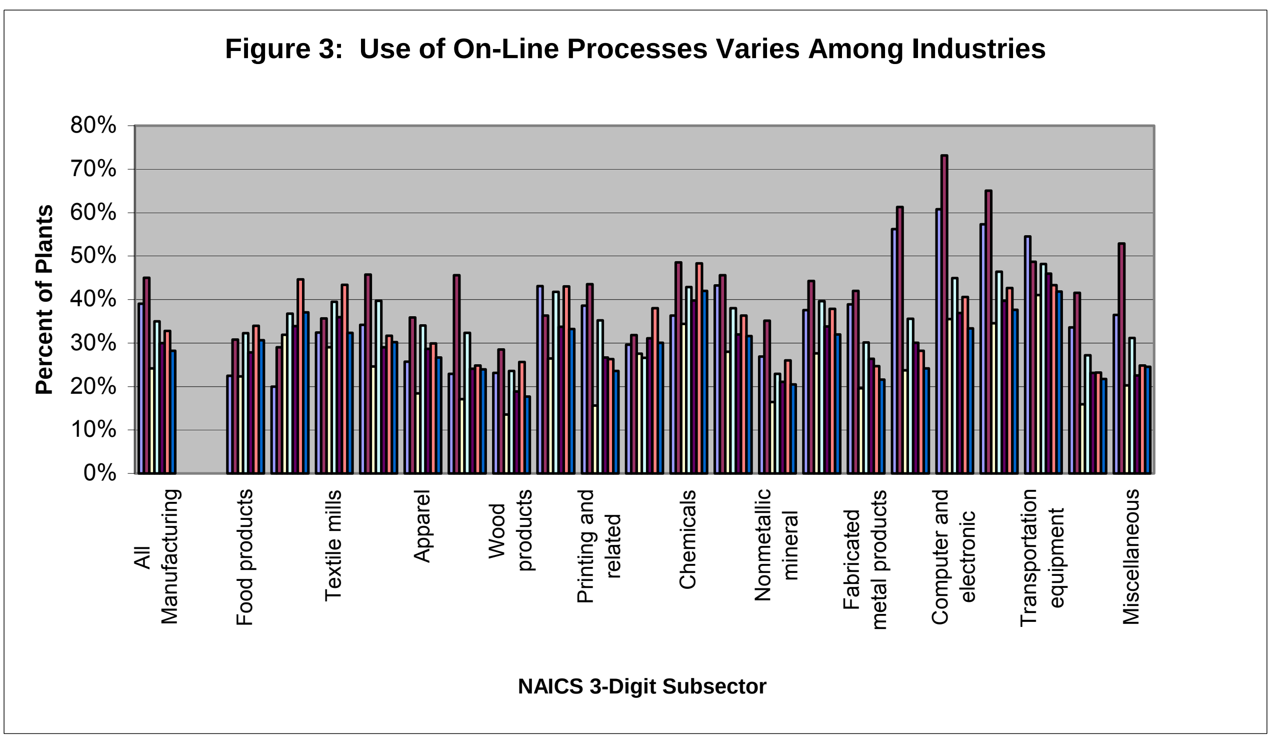
Source: Atrostic and Nguyen calculations based on U.S. Census Bureau 2002

Figure 3: Some Kinds of Information Are More Likely to Be Shared On-line



Source: Atrostic and Nguyen calculations based on U.S. Census Bureau 2002

Figure 4 – need to retitle figure



Source: Atrostic and Nguyen calculations based on U.S. Census Bureau 2002.

Figure 5: Japan: Networks are diffused among manufacturing industries

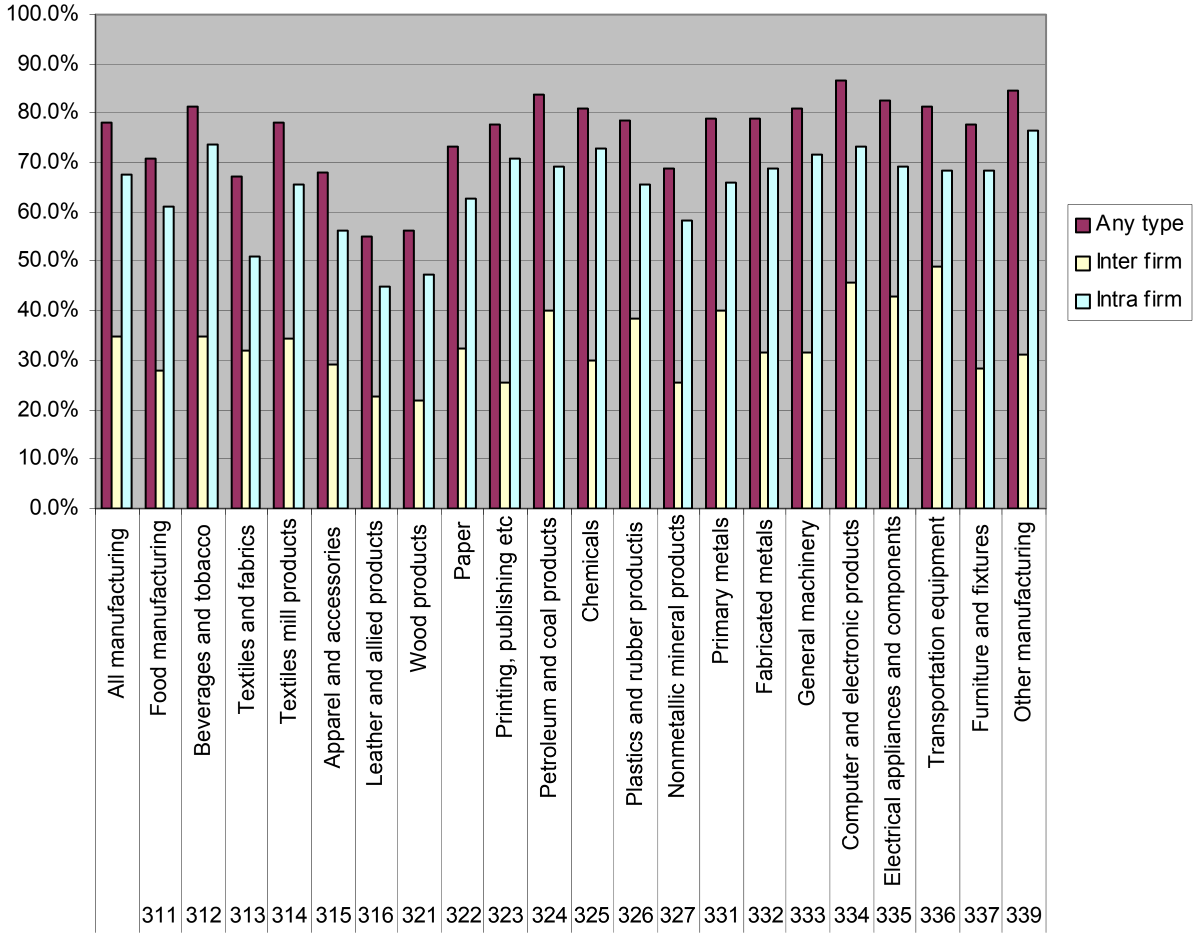


Figure 6: Japan: E-Business Processes Associated with E-Commerce

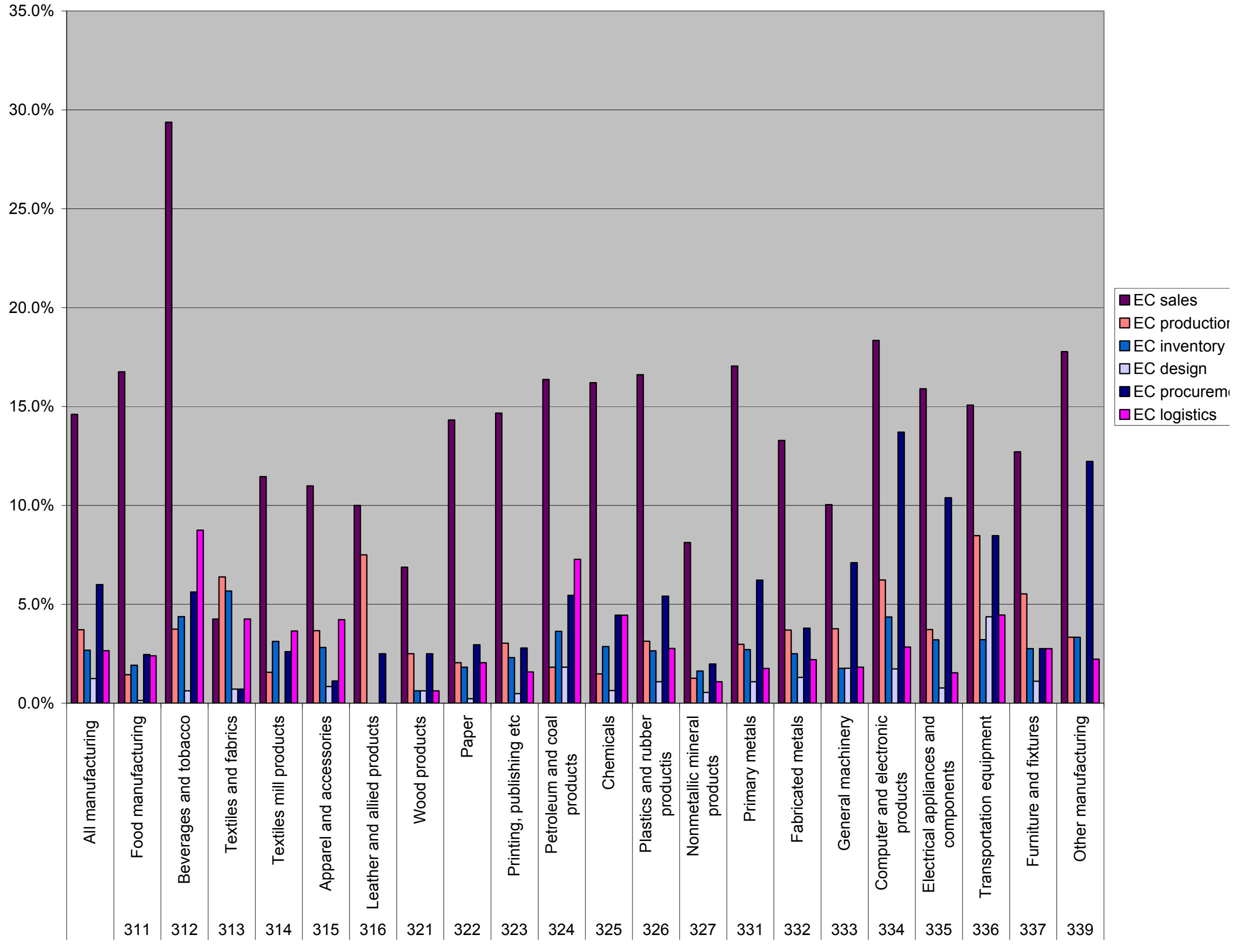


Figure 7
Japan: Diffusion of E-Business Processes in Manufacturing
By Type of Process