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IT, Productivity and Growth in Enterprises: Evidence from new international micro data

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Abstract

The relationship between information technology (IT), productivity, and growth has been established at the aggregate level. However, the mechanisms through which the effect operates at the level of specific businesses remains unclear. Statistical agencies have developed indicators of businesses' readiness to use IT (e.g. the IT infrastructure, diffusion of specific technologies), and some indicators on actual usage (e.g., purposes, frequency of use). The next phase is developing estimates of the impact of IT use. A recent OECD study addressed this question using aggregate data for OECD countries, and micro data for Germany and the U.S. A second phase of the OECD study envisions a series of two- and three-country studies making use of newly available micro data for roughly a dozen countries. This paper outlines one such study, a three-country project addressing the impact of IT use in Denmark, Japan, and the U.S. Each country recently collected new data at the level of specific businesses on the use of IT by businesses, and has conducted preliminary analyses of its own data. Each country also has different underlying market and institutional structures. The next phase of this project will be to develop estimates of the impact of IT use based on these new micro data, developing and testing hypotheses that acknowledge differences among the countries in market and institutional structures.

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1. Introduction

The development of statistics on the Information Society – understood as a structured and coherent statistical framework – has been ongoing since the mid-nineties. The statistical framework can be described as a set of building blocks in order to ensure flexibility and adaptability. At the moment the international statistical framework developed by the OECD countries is consisting of the following categories: 1) ICT investments, 2) ICT infrastructure, 3) ICT sector, 4) access to and use of ICT by households and individuals, 5) access to and use of ICT by enterprises, 6) access to and use of ICT by the public sector, 7) e-commerce and 8) skills and education.

It is a characteristic of statistics on the Information Society that due to the continuous development of the ICT technology and in the diffusion and usage of this technology into all corners of economies and societies, the contents of the statistical coverage is never fully developed but under constant redesigning. Existing indicators might get outdated related to user needs and new indicators on emerging technologies have to be developed to satisfy the needs of the users. A recent example is the adoption of the eEurope2005 action plan, challenging the statistical offices of the EU member states to develop indicators related to policy areas as e-learning or e-health[1].

If we look at the statistics monitoring the usage of ICT, the development of statistical indicators has taken its starting point in the measurement of readiness, followed by intensity indicators and finally the creation of impacts indicators. At the moment we have a relatively good coverage in terms of indicators and countries covered concerning statistics on the *readiness* (infrastructure, penetration) and partly also on *usage* (purposes, frequencies, barriers, etc.).[2] We are now entering the phase of developing statistics on the *impact* of ICT usage.

Measuring the electronic economy touches on almost every aspect of the economy. No single statistical agency has the resources and technical expertise to independently resolve all the measurement issues and fill all the information gaps associated with measuring the electronic economy. Cooperation across statistical agencies is required. This paper describes some initial initiatives in the development of measuring impact of ICT usage in enterprises taken by the statistical offices in Denmark, Japan and United States. The paper outlines a common project as part of the second OECD micro data project on IT and growth.[3]

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[1] European Commission: eEurope 2005, KOM(2002)263final

[2] For instance for 29 OECD countries information about telecommunication networks (access paths per 100 inhabitants are available and for 17 countries countries information about internet penetration by industry, cf. OECD: DSTI/ICCP/IE(2002)8

[3] The first OECD microdata project is described in Bartlesman *et al.* That study used harmonized macro and sectoral data for OECD, a unique cross-country dataset developed for the OECD Growth Project with firm turnover and related measures at the sectoral level (see Colecchia and Schreyer 2001), and establishment level micro data for the U.S. and German manufacturing sectors. The first microdata project addressed questions of differential uptake of technologies among countries, and differences in aggregate productivity patterns. It explored whether underlying differences among countries in market conditions and institutional frameworks affected their use of technologies, and the effects of that use on growth. The microdata comparison of the German and U.S. manufacturing sectors led to the conclusion that U.S. manufacturing establishments are more likely to experiment with different ways of conducting business than their German counterparts, and U.S. businesses choose a higher mean, higher variance strategy in adopting new technology. This second OECD project follows from the success of the first OECD microdata study, and seeks to build and expand on the first study. The micro data studies complement the many studies based on aggregate data that studied the link between IT use and growth (e.g., Colecchia and Schreyer 2001, Jorgenson and Stiroh 2000, Oliner and Sichel 2000, Triplett and Bosworth 2000). With the relationship between IT and productivity and growth established in aggregate data, attention turned to determining whether the relationships held for individual businesses units, and then, to estimating the size of the IT impact and possible causality. The first OECD microdata study examined only data for the U.S. and German manufacturing sectors. One facet of the second OECD micro data project on IT and growth expands the comparative microdata analyses to include nearly a dozen countries. The expanded analyses are taking place through a series of collaborations, with a small number of countries involved in each collaboration. Each group is developing its own way of reconciling the differences in each country's existing micro data that are important to comparative studies, such as the sectors covered, the scope of businesses included in each sector, and the specific questions asked.

This paper describes the collaboration among Denmark, Japan, and the U.S. The three countries differ geographically and in the size of their populations and economies. Denmark is a small European economy, but was a leader among the European Union in collecting data on the use of IT by businesses, with much of its survey serving as the foundation for the model survey adopted by OECD. Japan is a large economy and a major IT producer. The strong growth of the U.S. economy in the late 1990s, widely associated with IT, attracted world-wide interest in the relationship between IT and growth (e.g., Colecchia and Schreyer 2001 and Bartlesman 2002). What all three countries have in common, and the reason for participating in this joint micro data study, is that all three just collected detailed data on the use of IT in one or more major sectors of their economies.

2. How IT May Affect Productivity and Growth in Enterprises

Computers may affect productivity and growth in enterprises in at least two ways. Computers may be used directly as inputs to the production process, as a specific form of capital. 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), Dunne *et al.* (2000), Motohashi 2001, and Atrostic and Nguyen 2002). Consider a steel mill. Computers and automated processes are used to control production processes in modern steel mills. Many supporting business processes also can 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 (e-business processes; Atrostic, Gates, and Jarmin (2000)). These e-business processes occur over internal or external computer networks that allow information from processes to be exchanged readily. 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 this potential for computers to affect productivity growth outside of the manufacturing subsectors that produce them. These effects are thought to occur through organizational change. 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 among the participants in the supply chain. Brynjolfsson and Hitt (2000) argue that the effects of organizational changes may rival the effects of changes in the production process. Viewed this way, computer networks are a productivity-enhancing technology.

Although the theoretical literature makes clear that IT is a multi-faceted input, the emphasis in much of the literature has been on the IT producing industry, and on relatively simple indicators of whether or not businesses use IT. Relatively few studies (e.g., Greenan and Mairesse 1996 for France, Motohashi 2001 for Japan, Atrostic and Nguyen 2002 for the U.S., and Bartlesman *et al.* 2002 for the U.S. –German comparison) examine how businesses use IT. Many studies focused on one use of IT, e-commerce.

3. From measuring e-commerce to measuring e-business processes

In the mid-nineties there was tremendous interest devoted to e-commerce and its expected considerable growth and influence on the future forms of conducting business and especially trading across existing national borders. As a consequence, the OECD received in 1998 a mandate to define and measure electronic commerce (Ottawa OECD Ministerial). In 2000 the OECD Member countries endorsed two definitions of electronic transactions (electronic orders) based on a narrower and broader definitions of the communications infrastructure. According to the OECD definitions, it is the method by which the order is placed or received, not the payment or the channel of delivery, which determines whether the transaction is an Internet transaction (conducted over the Internet) or an electronic transaction (conducted over computer-mediated networks).[4]

Table 1. Estimates of Web, Internet and electronic commerce transactions. Percentage of total sales or revenues

BROADER ↑	Web commerce	Internet commerce	Electronic commerce (BROADER →)
Business sector		**2.04%** (UK, 2000) **0.40%** (Canada, 2000) **0.40%** (Australia, 1999-2000)	**5.83%** (UK, 2000)
Business sector (excluding finance and insurance)	**0.90%** (Denmark, 2000) **0.70%** (Finland, 2000)	**0.94%** (UK, 2000)	**5.95%** (UK, 2000)
Retail sector	**0.10%** (France, 1999)	**1.04%** (UK, 2000) **0.40%** (Canada, 2000) **0.30%** (Canada, 1999)	**1.39%** (UK, 2000) **0.91%** (USA, 1st Q 2001) **0.70%** (USA, 1st Q 2000) **0.63%** (USA, 1st Q 1999)

Source: OECD: Science, Technology and Industry Scoreboard 2001.

It is obvious that comparisons of the level of e-commerce across countries are heavily influenced by the definition used, cf. table 1. Comparisons of electronic commerce transactions are hampered by the use of different definitions across countries as by differences in the survey coverage.[5] But table 1 shows that e-commerce has until now been relatively small in many countries. Nor has it experienced the growth expected, so the justification of the focus on e-commerce can be questioned.

At the same time, studies consistently found that computers were associated with strong economic growth, particularly in the United States in the late 1990s. How do computers affect economic activity? It seems unlikely that the primary effect of computers to date is through the relatively small amounts of e-commerce over the Internet, or over other networks. Businesses use computers, and computer networks, in many other ways, such as managing production, refining supply chains, and conducting back office operations such as accounting. Relatively little is known about these other uses, and the focus of policy-makers, scientists and statistical offices have been directed towards the measurement of e-business. This chapter describes different approaches of measurement taken by the statistical offices of Denmark, Japan and United States.

3.1 Denmark

Statistics Denmark has since 1998 been conducting an annual survey on ICT usage in enterprises using a questionnaire nearly identical with the model questionnaire on ICT usage in enterprises approved by OECD member states in October 2001.[6] The questionnaire is intended to provide guidance for the

[4] See OECD: DSTI/ICCP/IIS(2001)1/REV1

[5] While e-commerce is 0.9 percent of U.S. retail trade sales in 2000, it is 18.4 percent of Manufacturing shipments and 7.7 percent of Merchant Wholesale Trade sales, assuming that all manufacturing and wholesale e-commerce is entirely B-to-B, and that all retail e-commerce is business-to-consumer. Most B-to-B e-commerce in the U.S. is conducted over Electronic Data Interchange networks rather than the Internet. In 2000, 88 percent of merchant wholesalers' e-commerce sales were over EDI. Manufacturing plants primarily using EDI networks for accepting on-line orders accounted for two-thirds of e-commerce shipments of plants responding to the 2000 Annual Survey of Manufactures, while plants primarily using Internet networks accounted for only 5 percent of e-commerce shipments (*E-commerce 2000*, www.census.gov/estats).

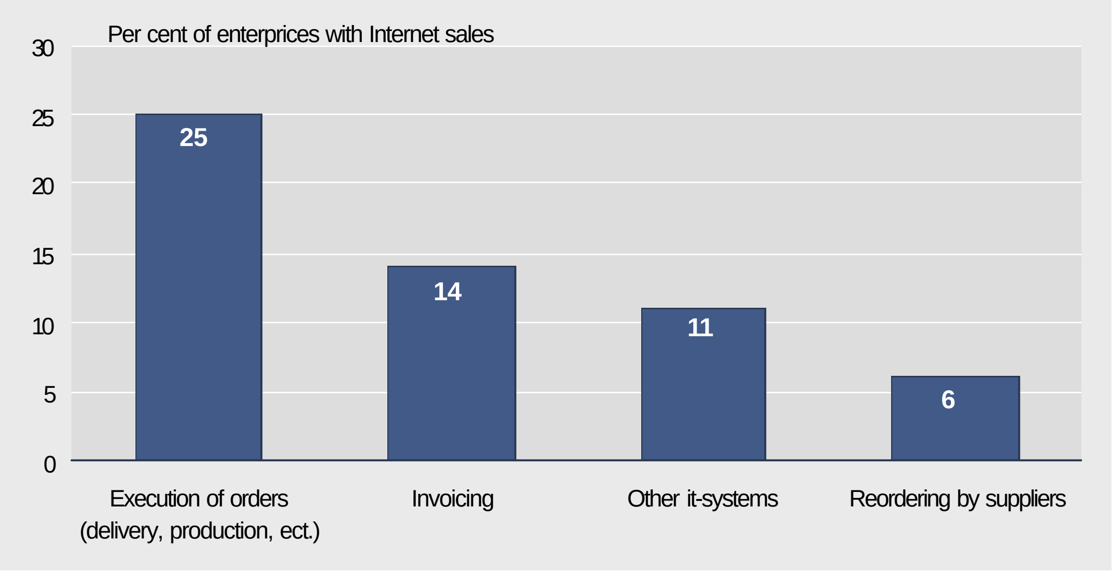
[6] See OECD: DSTI/ICCP/IIS(2001)1/REV1

measurement of indicators of ICT, Internet use and electronic commerce and is composed of separate, self-contained modules to ensure flexibility and adaptability to a rapidly changing environment. While the use of "core" modules allows the measurement on an internationally comparable basis, additional modules can be added to respond to evolving or country specific policy needs in this area.

In 2001, Statistics Denmark added a country specific module on integration of internet sales with it systems, The reasoning was that the possible automatisation of business processes is the core element of e-commerce and the basic reason for focusing on this issue having potential implications for the ways for enterprises to organise and for job creation as well.

The results show that every third enterprise with internet sales in Denmark has integrated the sales with at least one type of it system, cf. figure 1. By integration is meant that the receipt of orders via the homepage is automatically connected to one or more it systems.[7]

Figure 1. Integration of internet sales with it systems. Denmark 2001



Source: Statistics Denmark. Statistiske Efterretninger. Serviceerhverv 2002:16

25 per cent of the enterprises with internet sales has integrated the receipt of the order with systems effecting the order, i.e. delivery, production. The second frequent type is integration with billing systems (14 per cent) and reordering of products with suppliers (6 per cent). 11 per cent has integration with other it systems as booking systems, mail systems, etc.

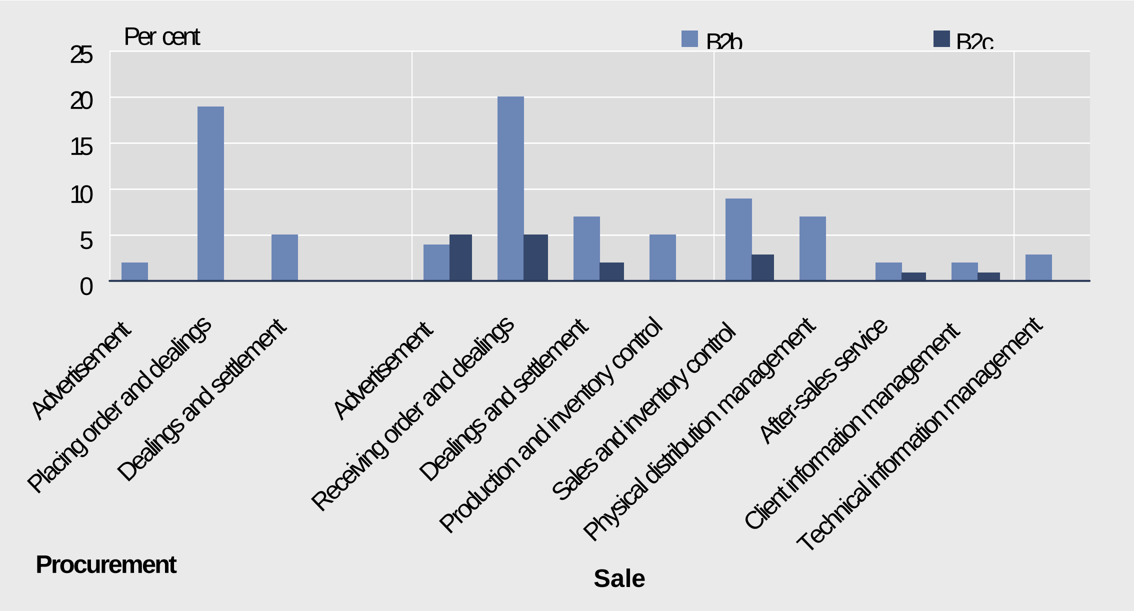
3.2 Japan

In Japan, METI has been conducting the annual ICT Workplace Survey since the 1970's. This is a firm level survey for about 9,500 computer users in Japan. The survey items cover everything from conditions of the costs of information processing of different types, such as hardware, software, and information processing services, penetration of computers for workplace, and conditions of use of information processing networks, etc. As part of the plan to augment IT statistics in Japan, this survey was expanded and the 2001 version includes new survey items on e-commerce and e-business processes. The survey for e-commerce is conducted by using both "broad" and "narrow" definitions of e-commerce by OECD. Data

[7] The results are presented in Danmarks Statistik. Statistiske Efterretninger. Serviceerhverv 2002:16

on the uses of e-commerce for each category of B2B buying and selling, and B2C are collected by the type of e-business process. Figure 2 shows the rate of firms using B2B or B2C e-commerce for each type of e-business application, and it separates the usage of B2B e-commerce for procurement from the one for selling.

Figure 2 Firms using B2B or B2C EC by type of e-business process. Japan 2001



It is found that "placing and receiving orders" is the most typical business application for B2B e-commerce, and "sales and inventory management" comes next. It should be noted that B2B e-commerce includes transactions via traditional EDI networks, and the diffusion rate of e-commerce via Internet into Japanese firms is much smaller. It can be shown in the figure 2 that B2C e-commerce, conducting via Internet, is not so popular among Japanese firms.

The ICT Workplace Survey looks not only at e-commerce and e-business process activities, but also at an extensive variety of firm level IT related activities, such as hardware and software investment, IT usage by employees and use of communication technology for business. However, it has to be lined up with the Basic Survey of Business Structure (BSBSA) to study productivity and information network use. The BSBSA is the METI's firm level census survey for all firms with no less than 50 employees and no less than 30 million yen capital amount. It serves as a lynchpin of various kinds of METI's firm level surveys in a sense that firm level surveys for special issues including the ICT Workplace Survey use a BSBSA's firm list, as a sample base. The BSBSA itself also provides data on firm's performance, globalization activities, R&D and other innovation related variables.

3.3 United States

The U.S. Census Bureau collected plant-level data on computer networks in U.S. manufacturing plants through the Computer Network Use Supplement (CNUS) to the 1999 Annual Survey of Manufactures (ASM). The CNUS surveyed some 50,000 manufacturing plants about their use of on-line purchasing and ordering, the presence of computer networks, the kind of network (EDI, Internet, both), about 25 business processes (such as procurement, payroll, inventory, etc., conducted over computer networks; "e-business processes"), and whether those networked processes are used to interact internally, or with the manufacturing plant's customers or suppliers. The CNUS focused on the use of computer networks, rather than the presence of computers alone. Early findings were released in an analytic report in June 2001, based on the responses of over 38,000 U.S. manufacturing plants. Detailed tabulations were released in March 2002 (for both releases, see www.census.gov/estats). Because the CNUS were collected as a supplement to the ASM, we can link CNUS data to current and previous information for the same plant collected in the 1999 ASM and the 1997 and 1992 Census of Manufactures (CM). These linkages allow us to examine relationships between the plants' economic behaviour and their use of computer networks.

The preliminary findings show that manufacturing plants responding to the CNUS were "wired" in mid-2000. Almost 90 percent had a computer network in place. While over 80 percent of responding plants had Internet access at the plant, there were opportunities for further integration of e-business processes. Almost half of the plants that accepted orders online did not place orders online. Focusing only on e-shipments and e-purchases excludes a large part of manufacturing plants' use of e-business processes.

Table 2. E-shipments and e-purchases in mid-2000 at U.S. manufacturing plants responding to CNUS survey

Status of e-purchases	Status of e-shipments			
	All plants	Make e-shipments	Do not make e-shipments	Unknown
All plants	38,985	12,069	26,462	454
Make e-purchases	13,233	6,063	7,061	109
Do not make e-purchases	25,237	5,901	19,203	133
Unknown	515	105	198	212

Source: Table B, *Manufacturing 1999 and mid-2000*, www.census.gov/estats, June 8, 2001.

4. New insights on how IT affects productivity and growth

Different methods of obtaining information about impact of IT on growth and business performance are expected to be introduced in the coming years. One method is the enlargement of the existing model survey with modules on electronic business processes or the design of questions addressing the issue of perceived benefits of using IT. Especially the reliability of the last type of questions can be questioned and another way to proceed is by linking the ICT usage survey data with economic data from other surveys at the firm-level.

As mentioned above, the OECD has launched such a project for reporting in 2003. This paper describes an initiative taken by the statistical offices in Denmark, Japan and United States to utilise existing survey data in order to obtain new insight into the question of how IT affects business performance. The project is in its initial phase and the first step has been the identification of a number of key variables. The availability of these variables in each country is given in table 3. As the statistical registers used are not harmonized across countries, it is difficult to conduct comparable analysis for all three countries. However, in order to deepen the understanding of cross country differences and similarities, pair-wise comparisons or even separate analysis in each countries, to be presented in this section, are useful.

	Denmark	Japan	U.S.
I. Basic Statistics			
Data Source and coverage of year	ICT survey (1998-2001) Accounts Stats (1995-1999)	BSBSA (1991,94-99) ICTWP survey (2000)	CM,ASM (1992,97,99) CNUS (1999)
Coverage of sector	All sectors	All sectors	Manufacturing
Unit of analysis (minimun size)	Firm (20+)	Firm (50+)	Plant (5+)
Number of observations	1.8K	20K (BSBSA) 2K(+ICTWP)	38K
Industry clasification	NACE	JSIC	NAICS
Productivity Variables			
Total shipments/sales/revenues	yes	yes	yes
# of employment	yes	yes	yes
Value Added	yes	yes	yes
Other major variables			
Skill or worker mix	no	yes	yes
ICT investment	no	yes	yes
Number of workers with access to			
computers	yes	yes (in 1997)	no
Internet	yes	no	yes
II. E-statistics			
Number with E-activity:			
E-commerce (yes/no; year)			
OECD broad definition	yes/2000-	yes/2000	yes
OECD narrow definition	yes	no	yes
Networks (kind of network)			
Wireless	no	yes/2000	no
Internet	yes	yes/2000	yes
Intranet, EDI-"lite"	yes (intranet)	no	yes
EDI	yes	yes/1997	yes
Other (specify)	LAN	LAN, WAN	LAN, "other"
Relevant Software, e.g. Fully Integrated Resource Planning Software	no	no	yes
E-Business Processes	no	yes/91,94	yes
Value of E-Commerce			
per unit, per workers	yes/2000-	yes/2000	yes
by type of network			
Internet	yes/2000-	no	no
EDI	yes/2000-	no	no

Table 3. Data Availability in Denmark, Japan, and the U.S

4.1 Data

In Denmark, Statistics Denmark is establishing a database including data from 3 statistical registers, see also annex for more detailed description:

- The 1998 questionnaire on the enterprises use of IT. Including 1,832 enterprises.
- The account statistics 1995-1999. Including all enterprises with more than 10 employees in manufacturing industry, construction and retail trade.
- The Integrated Database for Labour Market Research (IDA) containing detailed information about each employee and their personal background

The scope of the project is firstly to profile the enterprises which can be characterised as the first group of users of internet, intranet, extranet and carrying out e-commerce. Can we identify any links between the use of internet, extranet, e-commerce and business performance or characteristics of the employees at micro level? The Danish project is certainly hampered by the fact that no data on IT investments are available and instead information about use of internet, extranet have to be used as indicators for the e-maturity of the enterprise.

The work carried out has consisted of establishing a longitudinal database covering the period 1995 –1999. The starting point is the 1 800 enterprises included in the ICT usage survey 1998, being matched with the register of accounts statistics 1995 – 1999 at the firm-level. Out of the 1,832 enterprises 853 enterprises can be found in the account statistics 1995-1999 as the account statistics only covers manufacturing, construction and retail trade.

In Japan, the data for productivity analysis of information network in Japan are the combination of ICT Workplace Survey and Basic Survey of Business Structure and Activity (BSBSA). However, the relationship between these two data sources is a bit complicated. BSBSA is an extensive survey for all firms with certain cut-off points so that even long panel data have enough observations for analysis. In each year, it covers around 30,000 firms, and panel data from 1994 to 1998 have about 18,000 observations. However, the latest data point as of December 2002, is 1999, and 2000 data will be available soon. The survey items include broad range of firm activities, such as R&D, overseas production and outsourcing. It contains financial statement information which allows productivity calculations, and information network variables are available in 1991, 94 and 97. Therefore, it is possible to conduct firm level analysis of information network use by using only BSBSA data. Motohashi (2002) looks the impact of information network use by type of e-business, based on cross section data of 1991 BSBSA.

ICT Workplace Survey provides more detailed and up-to-date information on firm level IT related activities. Data from this annual survey for 2000 are available already, with detailed variables on IT investments and e-business process, as is mentioned in section 3.2. However, since significant changes in sampling framework for the 2000 survey have been implemented, the construction of panel data is difficult. The number of observations in the 2000 survey is around 5,000, but linkage with the previous year gives only 1,000 or less observations. When it is linked with BSBSA panel data from 1994 to 1998, the number of linked firm becomes nearly 3,000. Therefore, ICT Workplace Survey data can be used as a complement to BSBSA panel data, in a sense that it supplements up-to-date and detail information on IT.

In this paper, BSBSA panel data from 1994 to 1999 are used, since ICT Workplace Survey in 2000 give only IT use variables but not performance variables.

In the United States, results reported in this section are mainly from Atrostic and Nguyen 2002 and are based on U.S. manufacturing plants that responded to the 1999 U.S. CNUS survey. These results are not weighted, and do not reflect the entire U.S. manufacturing sector; totals are more likely to be representative of the larger plants in manufacturing (see *Manufacturing 1999 and mid-2000* at www.census.gov/estats). In addition, the CNUS data are linked to observations for the same plant in the Annual Survey of Manufactures for 1999, and to the Economic Census for 1992 and 1997.

4.2 Cross section analysis of network use and productivity

Table 4 shows that labor productivity difference between network users and non-users in Japan and U.S. It should be noted that the definition of value added for both countries are different, due to the difference of the unit of observation. In addition, the timing of observation is different. However, it is interesting to see that manufacturing firms/plants with networks are higher in labor productivity in both countries. Moreover, it is found that the firms/plants with networks were much larger than those without networks.

Table 4. Labor productivity for network users and non-users in Japan and the Unites States

	JAPAN(1997)		US(1999)	
	With Networks	Without Networks	With Networks	Without Networks
Sales/Employment	36.15	32.22	284.79	222.39
Value Added/Employment	7.48	7.14	133.65	103.29
Employment	829.70	363.59	235.70	118.64

To look at the relationship between network use and productivity, the regression analysis is conducted for Japan and the United States. Table 5 shows the regression coefficients of network use dummies in production function estimates, using 1997 BSBSA data for Japan. In the 1997 survey of BSBSA, variables on the use of IT network by type, such as intra and inter firm network, POS/EOS, CAD/CAM, EDI and e-commerce, are available. The Cobb Douglas production function with value added as an independent variable, and usual factor inputs such as employment and capital stock, as well as a network use dummy variable as dependent variables is estimated by each type of IT network. In addition, each regression is conducted by controlling for the industry and size class of each firm.

Table 5 shows the penetration rate of each type of network, as well as estimated coeffic ients and p-values for network use dummies in regression results by type of network. It is found that use of both intra firm and inter firm network is positively correlated with TFP level at the firm level. In terms of network type, the positive and statistically significant coefficients are found in “open network (Internet)”, “CAD/CAM” and “EDI”. The lower panel of Table 5 shows the results from the same regression analysis, but only for a group of firms with inter firm network, in order to show the relative significance of IT’s productivity impact by network type. It is found that use of “CAD/CAM” has a positive impact on TFP level as compared to other type of network, while use of “POS/EOS” has a negative impact.

Table 5. Cross section regression of TFP and network use (Japan, 1997)

Type of network	Penetration rate	Reression coef. (p-value)
(For all firms)		
Intra firm network	59.8%	0.080 (0.0%)
Inter firm network	28.3%	0.018 (5.1%)
open network	3.4%	0.039 (8.6%)
POS/EOS	18.5%	-0.014 (18.8%)
CAD/CAM	48.3%	0.052 (0.0%)
EDI	20.3%	0.026 (1.4%)
EC	0.9%	-0.049 (25.0%)
(For firms with inter-firm newtork)		
open network	10.6%	0.030 (18.4%)
POS/EOS	28.0%	-0.028 (6.6%)
CAD/CAM	53.6%	0.053 (0.1%)
EDI	38.0%	0.022 (14.8%)
EC	2.1%	-0.052 (28.1%)

The same type of regression analysis is conducted for the US data. The ordinary least squares (OLS) regressions reported in Table 6 show the effect of controlling for other plant characteristics (columns 1 – 3), and to controlling for prior conditions at the plant (column 4). Estimates based on this measure (columns 1 and 3) show that labor productivity in U.S. manufacturing plants with networks is about 5 percent higher than in plants without networks. Estimates based on the value-added labor productivity measure (column 2) show that labor productivity is about 11 percent higher in plants with networks. These OLS estimates are robust to alternative specifications of the underlying Cobb-Douglas production function model.

Estimates in column (4) control for prior conditions at the plant, and use the predicted probability of having a computer network in 1999 (Pr (CNET)) instead of the actual presence or absence of a network in 1999 (CNET). The coefficients of CNET and Pr (CNET) are not directly comparable. One way to interpret the two-stage estimates is to compare the productivity impacts of computer networks on plants at two points in the predicted probability of having a computer network. An example close to our data compares plants at the 10th and 90th percentiles of the estimated probability of having a computer network. (Recall that about twelve percent of the plants in our sample do not have a computer network.) The respective estimated probabilities of these plants adopting a computer network (based on probit regressions not reported here) are 0.8422 and 0.9671.Using the estimated coefficient for the "Pr (CNET)" of .505 from the probit regression (Column 4 of Table 2), we can calculate the expected productivity difference between the two plants: 0.505(0.9671 - 0.8422) = 0.0631. The productivity difference means that a plant moving from the 10th percentile (less likely to have a computer network) to the 90th percentile (more likely to have a computer network) would increase its labor productivity by 6.31 %. Many studies find that controlling for prior conditions substantially lessens the estimated impact of IT. However, in this case, the estimate controlling for prior conditions is about 2 percentage points above the estimates obtained from the OLS models.

Table 6 Labour Productivity Regression Results. US

Dependent Variable: Labor Productivity
(T-statistics in parentheses)

	OLS Estimates			Two-stage Estimates
	Gross Output	**Value-Added**	**Gross Output**	**Gross Output**
Independent Variables	(1)	(2)	(3)	(4)
Intercept	2.678 (159.95)	3.736 (144.57)	2.830 (119.48)	2.357 (32.50)
CNET	.046 (5.76)	.105 (7.85)	.033 (3.00)	(--)
Pr (CNET)	(--)	(--)	(--)	.505 (6.41)
SKILL	.043 (12.28)	.084 (14.12)	.039 (8.40)	.037 (8.12)
Log(K/L97)	.091 (39.86)	.186 (49.91)	.088 (28.81)	.084 (26.61)
MULTI	.114 (19.30)	.236 (24.17)	.101 (12.58)	.039 (3.31)
Log(M/L)	.515 (206.74)	(--)	.505 (148.93)	.506 (150.48)
Size2	-.055 (7.92)	-.049 (4.13)	-.052 (5.52)	-.047 (5.09)
Size3	-.084 (12.43)	-.077 (6.72)	-.079 (8.88)	-.073 (8.35)
Size4	-.092 (11.25)	-.097 (6.96)	-.083 (7.77)	-.071 (7.37)
Size5	-.090 (8.74)	-.107 (6.19)	-.070 (5.23)	-.065 (4.88)
Size6	-.017 (1.21)	.012 (0.53)	-.008 (0.460	-.004 (0.22)
Industry (3-digit NAICS)	Yes	Yes	Yes	Yes
R^2	.756	.261	.750	.756
Number of Plants	29,808	29,671**	17,787***	17,787

** The number of observations in column (2) is smaller than that in column (1) because a number of plants have value-added equal to zero.
***The number of observations in columns (3) and (4) are smaller than in column (1) for two reasons. Many plants did not respond to the 1992 computer investment question used to construct the Pr(CNET) measure used in the two-stage regressions of column (4). In addition, the Pr(CNET) measure takes account of the plant's prior condition, and so could be constructed only for plant in existence in both 1992 and 1999.
Source: Atrostic and Nguyen 2002, based on their calculations from the U.S. CNUS data linked to the ASM and CM.

4.3 Use of IT network and productivity growth

The cross section analysis in the previous section shows the positive association between use of IT network and productivity level in both Japan and the United States. In addition, it is also found that the productivity impacts differ by the type of network in Japan. However, there is a problem associated with omitted variables in regression analysis of the previous section. The productivity premium can be explained not only by IT network use, but also by other factors such as managerial abilities, employees' skills and other intangible assets at firm. If these kinds of omitted variables are correlated with network dummy variable (and it is often the case), regression coefficients with network are biased upward. In order to mitigate this kind of problem, there are two standard alternatives. One alternative is to control for prior conditions in a two-stage estimate, as reported in column (4) of the U.S. results. The other alternative is to check the relationship between network use and productivity growth, instead of productivity level. The reason is that taking differences between two periods sweeps out time invariant omitted variables. The tabulations below calculate rates of growth between two periods for selected variables of interest, such as value added, employment, and labor productivity. Tabulations in Tables 7 and 8 are not directly comparable with the regressions presented Table 5 for Japan or Table 6 for the U.S. because the tabulations do not control for factors such as inputs other than computers, or industry or size.

Table 7 shows the difference in labor productivity growth rates between firms with intra firm networks and firm without them in Denmark and Japan. In both countries, the growth rate is calculated for the period of 95-97 and 97-99, which are "before" and "after" the timing of network use in 1997, respectively. In Demark, firms with networks achieved higher growth rate of value added particularly after network introduction, but higher growth rate in employment at the same time, which leads to lower rate of labor productivity growth. In Japan, firms with network use achieved less sharp drop in labor productivity growth after network introduction as compared to non-users.

Table 7 Labor productivity growth and network use in manufacturing firms

	# of Enterprise	Value Added Growth 95->97	Value Added Growth 97->99	Employment Growth 95->97	Employment Growth 97->99	LP Growth 95->97	LP Growth 97->99
DENMARK		median	median	median	median	median	median
-intranet in 97	568	13.2%	4.3%	3.5%	0.0%	7.0%	5.0%
+intranet in 97	99	15.1%	8.7%	7.1%	2.3%	7.8%	4.2%
Total	668	13.8%	4.8%	3.8%	0.0%	7.1%	4.8%
JAPAN		mean	mean	mean	mean	mean	mean
-intranet in 97	4628	1.1%	-8.8%	-0.9%	-5.3%	1.9%	-3.5%
+intranet in 97	6111	3.0%	-7.5%	0.3%	-4.8%	2.7%	-2.7%
Total	10739	2.2%	-8.0%	-0.2%	-5.0%	2.4%	-3.0%

Table 8 is the same tabulation as Table 7 with different kinds of network for Japanese manufacturing firms. It is interesting to see the difference in the pattern of value added and employment growth. For example, firms with EDI network achieved higher productivity growth after 1997, without higher growth rate of employment, while firms with "EC", "LAN" or "POS/EOS" achieved both higher labor productivity and employment growth. As for "CAD/CAM", the network firms show lower labor productivity growth, but this is caused by the skewed industry distribution of this type of network. That is, firms in machinery industry are main user of this network, and machinery industry got the greatest value added drop in the period of 97 to 99. Therefore, it is important to control for industry effect for this type of IT network. More generally, tables such as these cannot account for important factors such as industry and firm size. Multivariate analyses to control for these factors provide better insights about the relationship between IT and outcomes of interest. In addition, it should be noted that the growth rate of value added and labor productivity is not deflated. A proper treatment of price changes in both countries should be our next step as well.

Table 8 Labor productivity growth and network use by network type in Japan

	# of Enterprise	Value Added Growth 95->97	Value Added Growth 97->99	Employment Growth 95->97	Employment Growth 97->99	LP Growth 95->97	LP Growth 97->99
-EDI	8747	2.0%	-8.5%	-0.2%	-5.0%	2.1%	-3.5%
+EDI	1992	3.1%	-6.3%	-0.3%	-5.1%	3.4%	-1.2%
Total	10739	2.2%	-8.0%	-0.2%	-5.0%	2.4%	-3.0%
-EC	10640	2.2%	-8.1%	-0.2%	-5.0%	2.4%	-3.1%
+EC	99	1.9%	-2.3%	-0.2%	-4.4%	2.2%	2.1%
Total	10739	2.2%	-8.0%	-0.2%	-5.0%	2.4%	-3.0%
-LAN	4134	0.8%	-9.1%	-0.9%	-5.1%	1.7%	-3.9%
+LAN	6605	3.1%	-7.4%	0.3%	-4.9%	2.8%	-2.5%
Total	10739	2.2%	-8.0%	-0.2%	-5.0%	2.4%	-3.0%
-POSEOS	8470	2.5%	-8.7%	-0.2%	-5.1%	2.7%	-3.6%
+POSEOS	2269	1.0%	-5.7%	-0.1%	-4.7%	1.1%	-1.0%
Total	10739	2.2%	-8.0%	-0.2%	-5.0%	2.4%	-3.0%
-CADCAM	6534	0.7%	-6.3%	-0.5%	-4.8%	1.2%	-1.5%
+CADCAM	4205	4.5%	-10.7%	0.3%	-5.3%	4.2%	-5.5%
Total	10739	2.2%	-8.0%	-0.2%	-5.0%	2.4%	-3.0%

5. Conclusion and Next Steps

This paper gives a first description of the project in which each country is developing an analytical database linking its new IT use survey to its underlying core business survey data, and, where relevant, to other statistical registers. With those databases, basic statistics on IT use will be calculated, filling in Table 3 with data as comparable as possible. For example, consider Figure 2 for Japan and Table 2 for the U.S. Figure 2 shows that the most common uses of B-to-B e-commerce in Japan were receiving and placing orders and dealings (about 20 percent of firms did each). Table 2 for the U.S. shows that about 30 to 33 percent of U.S. manufacturing plants used B-to-B e-commerce for e-purchases and e-shipments. Statistics for the Danish and Japanese manufacturing sectors will be calculated in the next phase. Specific analytical metrics will be chosen for the second portion of the table. In this paper, only pair wise tabulations are provided on the relationship between IT network and productivity level/growth. The next step should be tables for all three countries.

Finally, a series of hypotheses about the rate of IT use, and likely variations across industries and sectors in the three countries will be developed. The hypotheses will be based on the comparative summary statistics, and differences among the countries in their market and institutional structures. Multivariate analyses, such as the regression results for Germany and the U.S. presented in the first OECD micro data study, and the U.S. results presented in this paper, will be conducted in as parallel a way as possible for key hypotheses.

Annex Description of the Danish database on IT impacts

1. The 1998 survey on use of ICT by enterprises

The purpose of the survey is to monitor the use of information technology among enterprises, including electronic commerce and barriers to the use of IT. The statistics form part of Statistics Denmark's focus on the information society. The Use of ICT in Danish enterprises 1998 survey was carried out in October 1998 and was published in January 1999. The content of the survey is very similar to the model survey on ICT usage by enterprises later agreed by the WPIIS.

The survey is based on a voluntary postal questionnaire. The sample consists of more than 1.800 enterprises with a minimum of 20 full-time employees. Most of the industries in the private sector are represented in the population. The omitted industries are agriculture, recycling and electricity, gas and water supplies. Industries that are totally exempt from VAT are not included in the test sample. Those are primarily in the financial sector and personal transportation.

As a general rule, the reference year is 1998. However, the enterprises were also asked about expectations regarding 1999, and previous use in 1997 in a number of variables.

Survey variables:
Enterprises with ICT
Share of PC users
Share of enterprises with local network
Barriers to the use of ICT
Share of enterprises with Internet access*
Share of Internet users in enterprise
Share of enterprises with homepage*
Share of enterprises with intranet*
Use of Internet*
Share of enterprises with EDI

*1997 or before, 1998, 1999 exp., Do not know/not relevant

2. The accounts statistics 1995 - 1999

The accounts statistics are intended as an indicator of the activity level and of the structure of the Danish business sector. This means that the statistics should be seen as a primary source of financial data for analytical studies of Danish business enterprises, including data required for the evaluation and conception of government policies and decisions affecting the business community. Moreover, the accounts statistics are an essential input to the Danish national accounts statistics, and they provide the bulk of Denmark's contribution to EUROSTAT's structural business statistics at European level.

The statistics of business accounts cover construction and retail trade from the reference year 1994 at enterprise level (i.e. for legal units, such as corporations and sole traders) and from the reference year 1995 at establishment (workplace) level. The coverage was extended to manufacturing industries from 1995, to wholesale trade from 1998, and to the remaining part of the service industries from 1999. Prior to the reference year 1999 another type of accounts statistics was published as well (the SLS-E based accounts statistics).

The statistics are essentially aggregations of items of the annual accounts of business enterprises, notably items of the profit and loss account, the balance sheet and the statement of fixed assets. Thus, a wide range of subjects are covered, e.g. turnover, purchases, expenses, profits, assets, liabilities and investment. The statistical register includes more than 100 variables. Results are compiled and published at both enterprise and establishment level, including distributions according to kind of activity, form of ownership, size group and region.

The data collected from all sources are combined in such a way that a complete set of accounting items is computed for each business enterprise and its component units (establishments) in the survey population. The accounts statistics are a reliable indicator of the activity level and of the structure of the Danish business sector. The highest data quality is achieved at the enterprise level, primarily because the firms prepare their annual accounts at that level.

3. The Integrated Database for Labour Market Research (IDA)

The purpose of the Integrated Database for Labour Market Research (IDA) is to provide access to coherent data about persons and establishments at the level of individual persons and individual establishments. The database is suitable for a large number of research projects concerning the labour market, e.g. research into labour force mobility and job creation.

The distinctive feature of the database is that it enables you to connect persons with companies. It is thus possible to characterize persons on the basis of information about the companies, in which they are employed and correspondingly you can describe companies on the basis of information about the employees. There are more than 200 variables in the database, including a vast number of background variables related to the population. Moreover, both persons and companies can be monitored over time. The database contains information about the entire Danish population and all companies with employees

IDA contains information from the following statistical registers at Statistics Denmark:

The Central Database on Salary Information (COR) administered by the Central Customs and Tax Administration
The Register of Population Statistics
The Educational Classification Module (UKM) / The Register of Education and Training Statistics
The Employment Classification Module (AKM)
The Register of Income Statistics
The Register-based Statistics of Establishments and Employment (EBS)
The Register-based Labour Force Statistics (RAS)
The Register of Unemployment Statistics

As the database contains more than 200 variables, we have not made a list of them here. The headlines for variables in the data sets for persons, jobs and establishments/firms are:

Persons

Gender, age etc.
Family and household
Education
Employment and work experience
Unemployment
Income

Jobs

Job/occupation - full-time/part-time
Hourly labour earnings
Seniority
Change in appointments: Recruitments/resignations

Establishments and firms

Year of establishment
Sector, address etc.
Employees and level of labour earnings
Identity over time (existing, closed down, newly established)

Annex describing U.S. data

Annual Survey of Manufactures Computer Network Use Supplement.

The Annual Survey of Manufactures (ASM) is designed to produce estimates for the manufacturing sector of the economy. The manufacturing universe is comprised of approximately 380,000 plants. Data are collected annually from a probability sample of approximately 50,000 of the 200,000 manufacturing plants with five or more employees. Data for the remaining 180,000 plants with less than five employees are estimated using information obtained from administrative sources.

The 1999 Annual Survey of Manufactures Computer Network Use Supplement was mailed to the plants in the ASM sample. The supplement asked about the presence of computer networks, and the kind of network (EDI, Internet, both). It also collected information about manufacturers' e-commerce activities and use of e-business processes. The questionnaire asked if the plant allowed online ordering and the percentage of total shipments that were ordered online. Information on online purchases were also asked. In addition, information was collected about the plant's current and planned use of about 25 business processes conducted over computer network (such as procurement, payroll, inventory, etc., "e-business processes") and the extent to which the plant shared information online with vendors, customers, and other plants within the company. Approximately 83 % of the sampled plants responded to this supplement. All CNUS data are on the NAICS basis. See www.census.gov/estats for further details.

Linking the CNUS data to current and previous information for the same plants collected in the 1999 ASM, and the 1997 and 1992 Census of Manufactures (CM), allows us to examine many plant-level relationships among economic variables.

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The study uses survey data to analyze the determinants of enterprise innovation in Ethiopia using a multivariate probit (MVP) model. For this study, enterprises were grouped into four categories: all-sized, large-sized, medium-sized, and micro- and small-sized enterprises.Â Most business enterprises in developing countries like Ethiopia are small- andÂ Strategic relation behavior of the enterprises would help them with whom to make collaboration in international and national entities. This would help enterprises advance their business. Enterprises that use foreign inputs and that have collaboration with foreign are interrelated (Avermaete et al.Â Empirical evidence shows that the most important factor of innovation is R & D activity though findings are mixed. Positive productivity growth in the case of the high-productivity firms in the sample was largely due to increased output amid a flat or rising staffing level. According to the findings of the survey, the tighter competition in the economy needed to boost labour productivity growth will push inefficient, low-productivity firms from the market and help re-allocate labour to more productive firms.Â The survey data reveal significant inter- and intra-industry dispersion in labour productivity per worker. For instance, the highest average industry productivity level in the sample population in 2016 was observed in chemicals, the lowest in textiles, wearing apparel and leather (excluding other manufacturing), with an almost fourfold gap between the two industries. It, productivity and growth in enterprises: Evidence from new international micro data. The Economic Impact of ICTâ€"Measurement, Evidence and Implications. Barnes, S. and B. Hunt (2013). E-commerce and V-business. Routledge. BÃ©langer, F. and L. Carter (2008). Trust and risk in e-government adoption. The Journal of Strategic Information Systems.