

E-business and labour productivity in manufacturing and services

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New firm level analysis based on data from e-commerce surveys has shown the value of using Information and Communication Technologies (ICT) to link business processes on labour productivity.

Earlier work in this area focused on e-commerce (buying and selling over electronic networks). More recent surveys have broadened the use of electronic business processes. They show that the use of e-commerce by firms, after high levels of initial trial and error, has begun to stabilise.

While adoption of e-business processes is now widespread among larger firms, their labour productivity effects vary by sector.

This article summarises work based on the 2001/02 surveys. It outlines a research programme on other ICT indicators and their impacts, whose results will be reported later.

Introduction

Analysis of Office for National Statistics (ONS) micro-data suggests firms with automatic links between their e-commerce networks and operating business processes enjoy higher labour productivity. However this is not true for all process links, and depends on firm size and sector.

Previous ONS work in this area has been limited to narrower analysis of e-commerce, the buying or selling of goods via electronic networks (Crisciolo and Waldron, 2003). However the potential of electronic networks lies in how they can transform the operations of an enterprise, not just its transactions, and e-commerce is increasingly seen as just one of many specific applications of e-business.

International work in this area includes a study by Atrostic and Nguyen (2002). They show, using the 1999 US Bureau of Census Computer Network Use Survey (CNUS), that:

- computer networks in firms have a positive impact on Total Factor Productivity (TFP)
- only half such networks were used for buying or selling.

Growing case evidence suggests that integration of business processes through computer networks, with organisational and human capital investments, promotes gains in labour productivity (Brynjolfsson and Yang, 1999). The concept of a firm with integrated systems linking production, distribution, procurement and sales functions making operations more efficient is supported by international case studies. Automatic processing and sharing of such information may help improve labour productivity if the technology is applied appropriately

Up to now, statistical analysis of these effects has been limited by lack of large sample surveys, and also by rapid changes in ICT use by firms. Both these limitations are addressed in this article.

E-business Process Measurement

Questions on electronic business processes have been included in the ONS e-commerce surveys to business in both 2001 and 2002. In both years the questions:

- focus on links between internal business process types (for example, logistics) and buying / selling, and on links to customers' and suppliers' e-enabled business processes
- cover both open systems (usually one-to-many) such as the internet, and closed systems (usually one-to-one).

Closed electronic business links predate the development of the Internet, and are often known as Electronic Data Interchange (EDI). Such systems are usually set up by firms to organise procurement or order handling and involve dedicated business to business links. Many of these systems are now migrating to the Internet, although they remain ‘closed’ in the sense that they are owned by one firm, which selects the customers or suppliers that can do business through them.

The business process questions included in the 2002 survey are shown below.

On the last working day of 2002

27. did your electronic ordering systems link automatically to electronic systems either within or outside of your business?

(please put a cross in the box that applies)

Yes No 180 → If no, go to question 29

28. did your business’s electronic ordering, sales or purchasing systems link automatically, within your business to:

(for each category, please place a cross against either yes or no)

	Yes	No	
your production or service operating systems	<input type="checkbox"/>	<input type="checkbox"/>	185
your logistics or delivery systems	<input type="checkbox"/>	<input type="checkbox"/>	186
your invoicing or payment systems	<input type="checkbox"/>	<input type="checkbox"/>	184
your marketing or customer relationship management systems	<input type="checkbox"/>	<input type="checkbox"/>	187
your other internal operating systems	<input type="checkbox"/>	<input type="checkbox"/>	188
your suppliers’ ordering or business systems	<input type="checkbox"/>	<input type="checkbox"/>	181
your customers’ ordering or business systems	<input type="checkbox"/>	<input type="checkbox"/>	183
other links to external businesses’ systems	<input type="checkbox"/>	<input type="checkbox"/>	189

These questions are based on a model of business processes developed by Michael Porter (Porter, 1985), and which forms the basis for the US survey. This list of processes is largely based on manufacturing firms and may be less applicable to firms providing services. This has given rise to some difficulties for respondents, particularly smaller firms in the service sector, and discussions have been held with other statistics offices to develop improved survey approaches. For the time being surveys based on this type of business model are being tried in a number of countries.

The analysis which follows:

- explores e-business process use in the 2002 E-commerce Inquiry
- shows the decreasing level of turbulence in e-commerce activity among UK firms
- examines associations between e-business process integration and labour productivity
- outlines econometric work still under way to determine statistical significance, and the relationship between these and other indicators of ICT use.

Results for e-business in 2002 survey

Responses to the E-commerce survey in 2002 show business process links are reasonably common, with 40 to 50 per cent incidence among large firms (over 250 employees), but under 10 per cent incidence among firms with less than 20 employees. For micro businesses (under 10 employees) use of electronically linked businesses processes is reported at 1–2 per cent. These results are shown in Table 1 below, overall and for specific types of process links.

The data shows that internal integration is more common than direct links with customers or suppliers’ business systems, and that integration in the financial area (sales or procurement to invoicing or payment) is the most widespread form of linkage. There is also evidence that external links to suppliers are somewhat more common than links to customers; this is broadly consistent with earlier analysis of the use, and benefits, of electronic procurement (Criscuolo and Waldron, 2002).

The populations of firms by size band are also shown in Table 1 and make clear that although incidence of e-business links is low in micro-businesses, the population is many times greater than the largest group. This means that there are many more micro businesses with linked processes (over 30,000) than there are among firms in the largest size category.

The ONS survey does not ask, as US surveys have, about use of Enterprise Resource Planning (ERP) by firms. ERP entails the use of integrated, IT based controls across the firm, and so ERP enabled firms are usually those with multiple business processes links. We can assess this by identifying firms whose responses show they have linked some, or most, processes in Table 1.

Table 2 shows, by comparison, the proportion of firms with differing levels of multiple links. It indicates that a majority of firms, across all size bands, that have linked one process to procurement or sales have linked at least three. So multiple linking is common for those firms that have made a start. But the proportion of firms that are heavily integrated and answer ‘yes’ to five or more questions, is less than half of the firms that have some form of e-linked processes.

In theory the integration of electronic business processes should offer firms improved efficiency, productivity and hence profitability. The results of the 2002 E-commerce survey show that firms are investing in and applying such technologies. Assuming firms are rational economic agents,

Table 1
Percentage of businesses with electronic integration of different types of business processes

Employment size band (numbers)	Per cent				
	0 to 9	10–49	50–249	250–999	1,000+
With integrated processes in some form (overall question)	2	8	20	40	51
- integrated production or service operating systems	1	3	11	25	31
- integrated logistics or delivery systems	1	2	8	25	33
- integrated invoicing or payment systems	1	5	14	32	43
- integrated marketing or customer relationship management (CRM) systems	1	2	5	11	18
- integrated other internal systems	1	4	9	23	33
- integrated with suppliers' ordering or business systems	1	3	5	15	24
- integrated with customers' ordering or business systems	:	1	5	16	20
Number of businesses in UK population	1,621,499	184,048	31,435	5,541	1,608

Source: E-commerce survey 2002

Table 2
Percentage of businesses multiple linking of electronic business processes

Employment size band (numbers)	Per cent				
	0–9	10–49	50–49	259–999	1,000+
With integrated processes in some form (Table 1)	2	8	20	40	51
- with 3 + linked processes	1	4	12	30	39
- with 5 + linked processes	:	1	4	15	19

Source: E-commerce survey 2002

improved performance should be their goal. Later in this article we attempt to discover whether such investments are associated with higher productivity at firm level.

Changes in e-commerce use

Previous analysis in ONS (Clayton and Waldron, 2003) has shown considerable levels of turbulence, defined as entry and exit to and from e-commerce activity, between 2000 and 2001. Many firms in 2001 had either stopped using e-commerce or had only recently started. This meant it was very difficult to identify statistically significant effects in any productivity impact work. The following section summarises previous findings and replicates the analysis for 2001 to 2002 to discover whether behaviour is more settled, and so improved performance effects more likely to be evident.

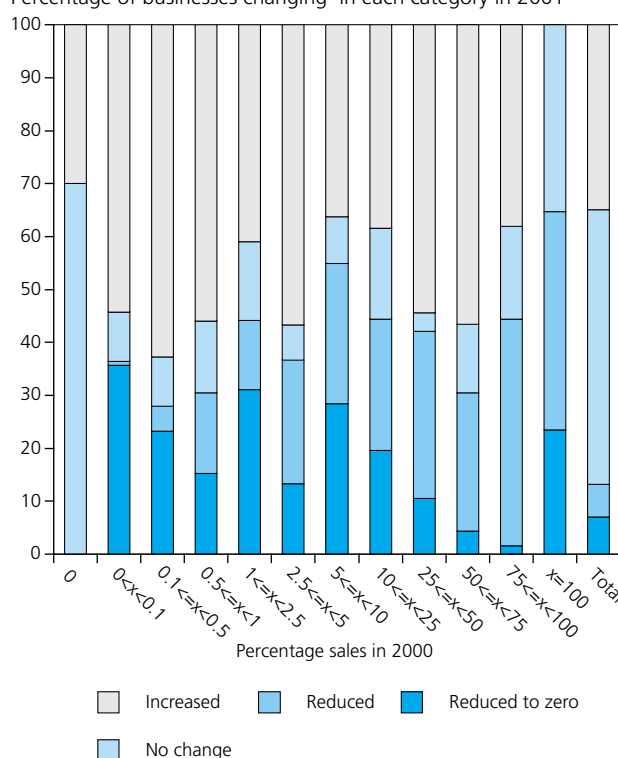
The new analysis uses two linked samples of firms that responded to the E-commerce survey in two consecutive years – 2000 to 2001 and 2001 to 2002. These provide an insight into the levels of turbulence in e-commerce (via the internet and other networks) by comparing firm responses on the value of their transactions with their response in the previous year. Clearly the overlap excludes firms which ceased trading in the dot.com crash of 2000/01, and so our estimate understates the degree of change in the overall market.

Figure 1 compares the 'percentage of firm sales via e-commerce' for each firm in the 2000–01 overlap to their response in the previous year and identifies whether it is in the same range, higher, lower but still positive, or if it has reduced to zero. The comparison shows relatively high numbers of firms – especially among those which had over 5 per cent sales from e-commerce in 2000, which had reduced their dependence on electronic trading by 2001.

Among firms that reported less than 2.5 per cent of sales via e-commerce in 2000, the proportion reporting ceasing e-trading altogether by 2001 is high. In the lowest category, over 30 per cent had ceased to be active in e-commerce selling.

Figure 1
Changes in values of e-commerce sales – all network, 2000–01

Percentage of businesses changing in each category in 2001

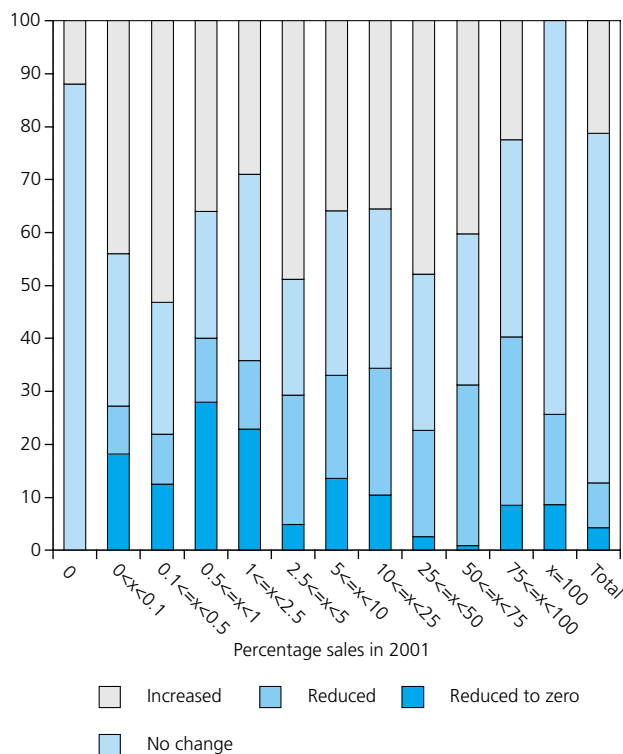


Source: E-commerce Inquiry 2000, 2001

Figure 2 below makes the same comparison between 2001 and 2002. There is certainly less flux between 2001 and 2002 than in the previous year. For instance, only 4 per cent of all responding firms exited e-commerce in 2001–02, compared to 7 per cent in 2000–01. The data shows that this is especially true of firms for which e-commerce represented a significant proportion of sales.

Figure 2
Changes in values of e-commerce sales – all networks, 2001–02

Percentage of businesses changing in each category in 2002



Source: E-commerce Inquiry 2001, 2002

It is also clear that in total more firms gave a 'no change' response in 2002 than in 2001 (66 per cent compared to 52 per cent), and fewer reported increased sales via e-commerce (22 per cent compared to 35 per cent). As well as reduced exit, there appears to be a decreasing rate of entry into e-commerce activity between the two periods. Of the firms reporting zero e-commerce activity in 2000, 30 per cent had started e-selling in 2001. The comparable figure for 2001–02 is 12 per cent.

The pattern for internet sales only (excluding EDI) is similar. Only 3 per cent of firms selling via internet ceased trading electronically and 82 per cent reported 'no change' in 2001 to 2002. The same figures for 2000 to 2001 were 11 per cent and 72 per cent respectively.

Internet purchasing is another activity with less turbulence in 2001 to 2002 than there had been previously. In particular fewer firms had stopped placing orders via the Internet (7.4 per cent in 2001–02 compared to 10.6 per cent in 2000–01). This was particularly notable among firms for which internet purchases were a relatively small part of overall procurement.

The pattern of evidence suggests that after a period of experimentation more firms are finding an equilibrium and trading electronically at a level suited to them. This is supported by electronic sales value data which has stabilised. If this is a correct interpretation of the data, it increases the likelihood that productivity advantages for firms employing e-commerce and e-business processes may also have stabilised, and that they may be more amenable to analysis.

Labour productivity and e-business use

This section examines whether labour productivity is related to the way firms use ICT to implement business processes. Data were produced by linked firm responses to the E-Commerce survey and Annual Business Inquiry (ABI) in 2001 and 2002. Labour productivity data is taken from the ABI and calculated using 'Gross Value Added at basic prices' (GVA), excluding firms for which GVA was either negative or zero. All firms are weighted equally and all analysis was conducted after trimming 5 per cent at each end of the GVA distribution in each broad industry classification (2 digit SIC).

Due to the size of the sample it only proved possible to separate firms according to whether they are in broad production or service sectors. However, given earlier comments on the applicability of the business process questions to the service sector, it was important to do this.

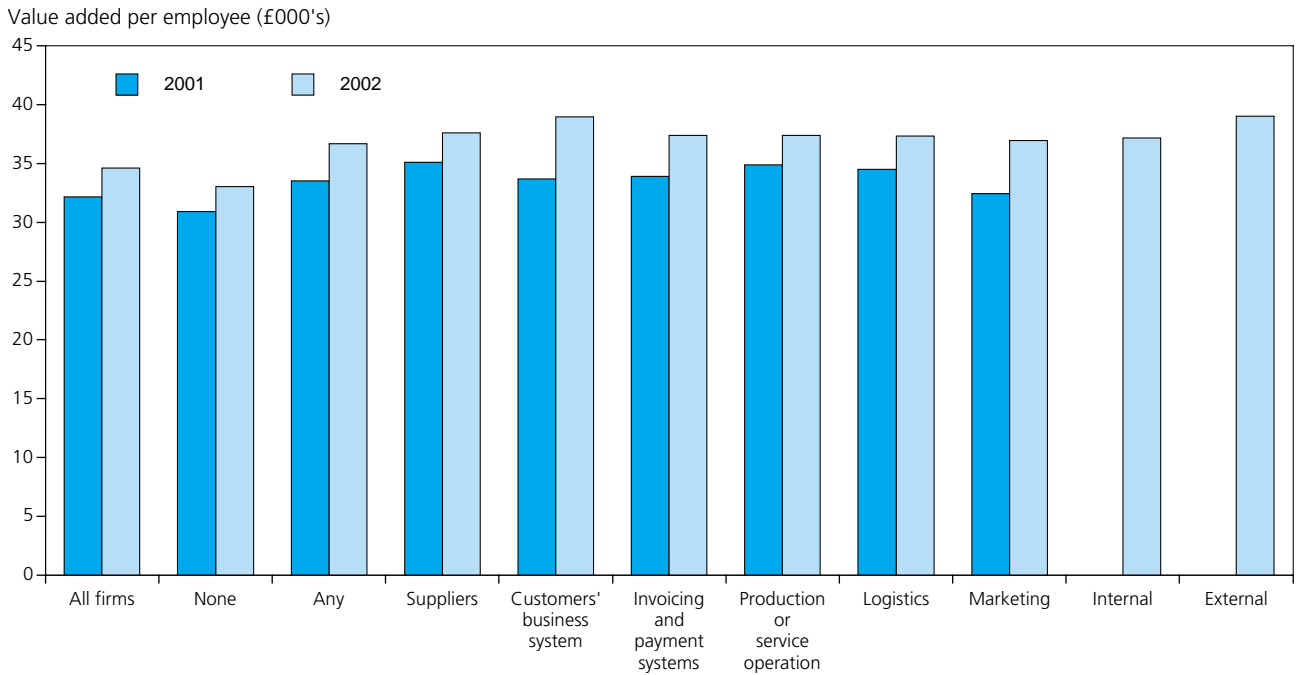
Results and Analysis

Figure 3 shows value added per employee for firms across all sectors related to use of linked e-business processes. It indicates that firms with automatic links between certain processes and their e-commerce activity have higher average labour productivity than firms without such links, and also higher than the average for the whole sample. The most productive firms have multiple linkages that include suppliers or customers.

In general the presence of any of the links surveyed is associated with higher average labour productivity. (Questions on 'other Internal and External links' were not asked in 2001). However causation cannot be assumed, since successful integrated business processes are more common among large productive firms, with their greater resources and economies of scale.

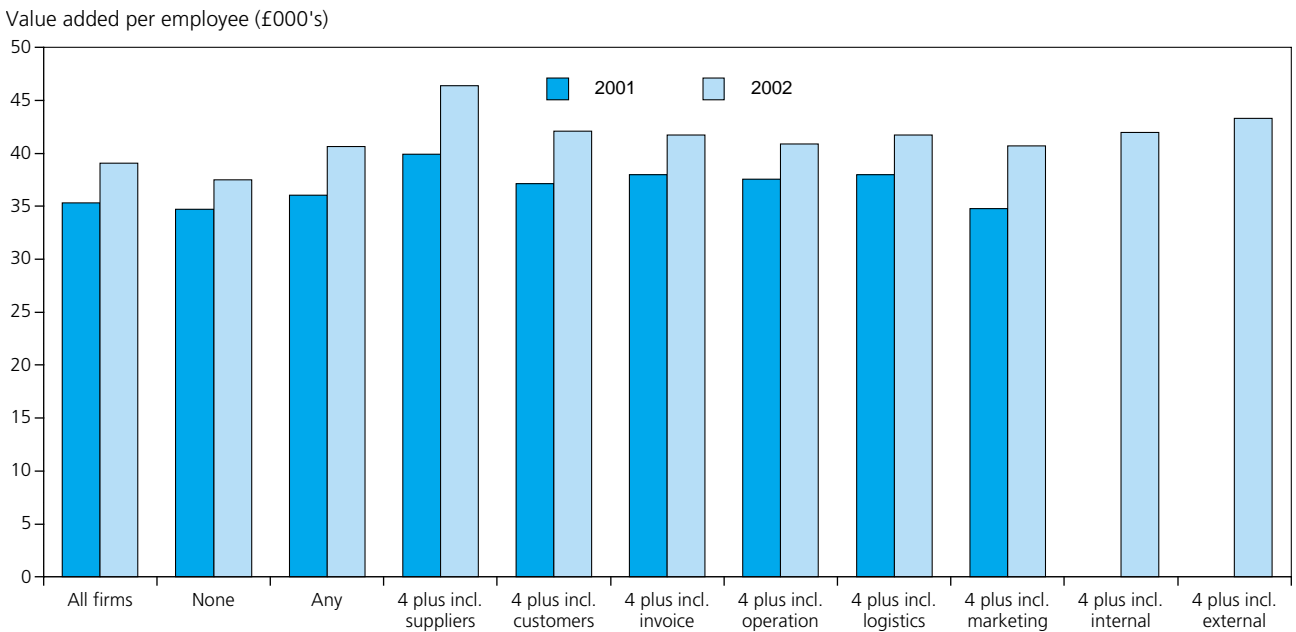
Figure 4 shows a similar analysis, for firms in the production sectors only, but with a focus on firms that have at least four business processes linked electronically. The data suggests firms with any type of link have higher labour productivity than those without, and that firms with multiple links enjoy even greater benefits. The links that appear to be associated with highest productivity levels in production are those with suppliers or some other external system. This is consistent with previous analysis showing productivity gains for those manufacturing firms employing e-procurement (Crisuolo and Waldron, 2003).

Figure 3
Average labour productivity for all firms, by type of e-business link



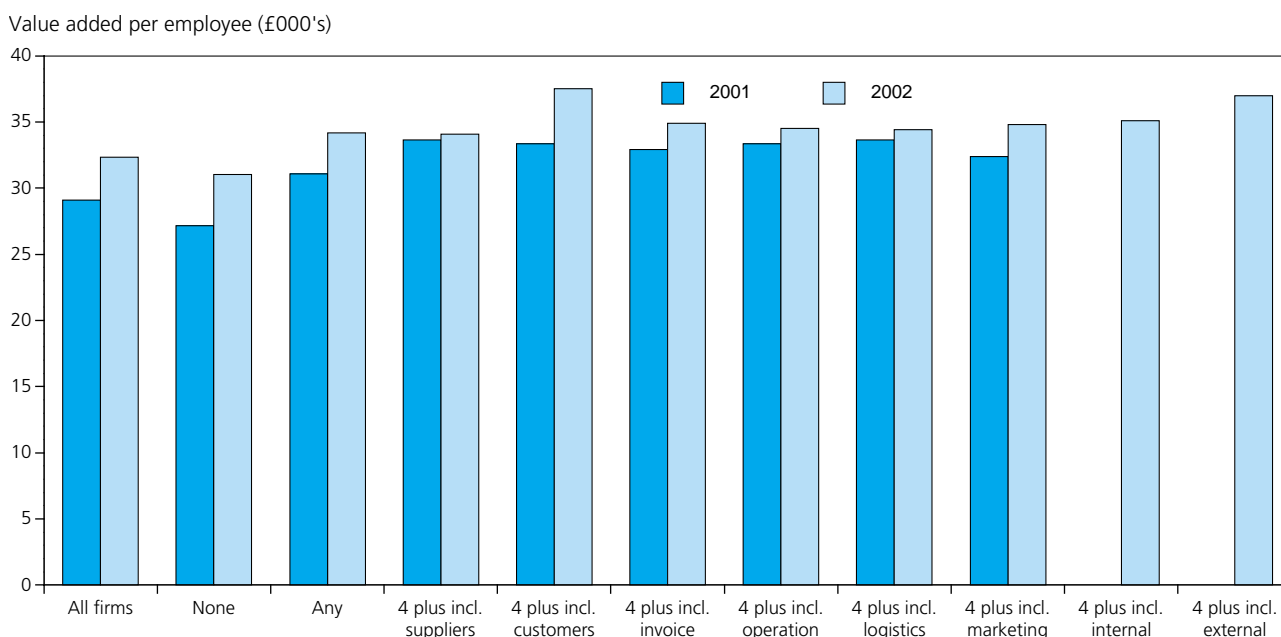
Source: E-commerce Inquiry and Annual Business Inquiry, 2001/02 (ABI 2002 provisional)

Figure 4
Average labour productivity in Production, by type of e-business link



Source: E-commerce Inquiry and Annual Business Inquiry, 2001/02 (ABI 2002 provisional)

Figure 5
Average labour productivity in Services, by type of e-business link



Source: E-Commerce Inquiry and Annual Business Inquiry, 2001/02 (ABI 2002 provisional)

These results, and those for services in Figure 5, suggest firms in both sectors gain from the integration of business processes, particularly multiple integration. Despite difficulties in surveying such concepts for services, it appears firms in services have as much to gain from e-business as manufacturers.

Implications

One notable difference between the production and services results is that in services the most productive firms are those with multiple links including customers, logistics or external operations. In manufacturing, the most productive firms are those with supplier links. We have already related the manufacturing result to earlier work which showed procurement / supply chain management advantages from ICT. Is there a comparable rationale for the service-sector results?

In a recent OECD workshop, attention was drawn to the differences in value creation between manufacturing and services. In manufacturing it occurs at various points through the 'value chain,' and additional value can accrue to a firm either through greater internal efficiency, or via effective outsourcing. However in services value is often added at the point where customer needs and firm capability interact. ICT, on this view, can increase productivity in services by enabling firms to draw on their capabilities – often in the form of knowledge – to meet individual customer needs.

The labour productivity results obtained for production and services from linking the first two years of e-business survey data to the ABI are consistent with this view of different economic structures. These results also suggest the integration of marketing processes can have greater advantages in services; again this is consistent with the idea that in services value is added at the point of customer contact.

Taken together, the results indicate that:

- benefits from electronic integration of business processes at least partly depend on industry sector
- benefits depend on firms' choice of the processes integrated.

The data does also suggest that gains may be easier to achieve for larger firms but this is likely to be related to other causal factors discussed earlier. Larger and more productive firms are more likely to have invested earlier in integrated electronic processes, and to have undergone more 'learning' in their use.

The evidence shown here suggests that there is no general 'ICT productivity effect', and that in seeking to analyse ICT impacts on firm performance it is necessary to look both at the investments firms make, and how they are used. Firms that enjoy better performance will be those that select appropriate technology, integrate the processes most relevant to their operation and implement the organisational change necessary to make it work.

Work now under way is looking to integrate analysis of ICT investment, the use of electronic business processes, and other indicators of ICT use. The programme for this work is described briefly below.

ICT and Total factor productivity

ONS is currently co-ordinating a project to measure the impact of ICT on firm-level performance. This has four main elements:

- building an ICT capital stock at firm level using various capital expenditure surveys
- assessing the effects of ICT investment on firm level performance

- combining this with the type of ICT use analysis outlined in the earlier sections of this article
- drawing on other sources of data on inputs, including the data available on human capital input from E-commerce and other surveys.

The objective is to analyse total factor productivity, using newly available data on firm level capital stock for the services sector, now compiled in similar detail as for manufacturing, and building into the regressions:

- ICT capital for each firm
- employees' ICT use, and measures of employee skills
- the firm's use of electronic networks for trading and for process management
- the external labour market environment and communications infrastructure available to firms.

Among the ICT variables to be tested are:

- ICT firm capital stock produced using the Perpetual Inventory Method (PIM)
- ICT use/skills, proxied by the proportion of employees using the internet
- E-commerce networks will be analysed in the form of dummies using markers from either the E-commerce Inquiry or the ABI
- In terms of infrastructure this will be analysed in terms of broadband availability and, if possible, the quality of the local labour market.

Initial results suggest positive and significant results for three of the measures, while the fourth has yet to be analysed.

ICT capital in TFP analysis shows a stable excess return for hardware of approximately 5 per cent, over and above 'normal' return on capital. This is consistent with new results for the US (Atrostic and Nguyen, 2003).

An additional, and powerful, explanatory variable examined is the percentage of firm employees using access to the internet. Although there is colinearity between this variable and ICT capital stock, the term for employee ICT use appears to be picking up some additional effects not associated with the stock of ICT capital.

As well as the descriptive data shown earlier, econometric analysis shows positive and significant results associated with the use of e-business methods. In general it appears that integration does help improve productivity and that process integration is particularly beneficial in areas such as the operation, logistics or financial systems.

Further work will assess the impact on operational measures of firm performance including inventory turnover measured through stocks: sales or stocks: purchases ratios. In addition, we will draw on the recently published studies from the OECD (The Economic Impact of ICT, 2004) which explore ICT impact measures across a number of developed economies.

Conclusions

Electronic business process management is becoming an established practice for UK firms of all sizes. Firms using e-business integration tend to apply it in a number of areas introducing automation through the enterprise. These firms, on average, tend to be more productive than firms that do not apply ICT in this way.

There is further development work required to capture the use of e-business processes across the economy. However, the data available broadly supports the hypothesis that the integration of business processes can help increase labour productivity at firm level. However it is appropriate use in specific applications that is associated with this improvement and not simply ICT use.

Our next round of work, exploring the relationship between investment in ICT and its use, may need to take account of the possibility that e-business process measures are a proxy for forms of organisational investment in firms. Studies estimate that every dollar invested in ICT requires another nine dollars in organisational change (Brynjolfsson and Yang, 1999). Understanding such effects may advance understanding of wider intangibles measures being explored in the US (Corrado, Hulten and Sichel, 2002).

Acknowledgements

The authors wish to thank Mark Pollard and Cecil Prescott for help with the survey data.

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