The Productivity impact of E-Commerce in the UK, 2001: Evidence from microdata*

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Abstract:

This paper considers the impact of e-commerce on establishment level productivity for all sectors of the economy, using data from the UK E-commerce survey, linked with financial data from the ABI survey. E-Commerce represents the operational application of technology in the production process and may be regarded as an innovation driven change in workplace practice. Using a production function approach to measuring productivity, we find that OLS estimation fails to adequately account for the selectivity bias amongst enterprises that use e-commerce. Using a treatment effect estimator, we find that both e-buying and e-selling have significant and positive impacts on productivity.

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1. Introduction

The influence of information and communications technology (ICT) on the organisation of business processes, demand for skills and ultimately on productivity, has been the source of much research (Black and Lynch, 2001; 2004; Berman, Bound and Griliches, 1994; Chun, 2003; O'Mahony and Vecchi, 2004). Atrostic and Nguyen (2002) discuss the nature of this pervading influence and argue that computers essentially have two productivity effects; firstly a direct effect, as an input of the production process; this is the more traditionally measured impact of ICT capital. Secondly they argue that computers have a network impact through the way in which they streamline the underlying business process. Much attention has been devoted to detecting the former, a productivity impact of ICT capital (Stiroh 2002; Lichtenberg 1995, Lichtenberg and Lehr 1999), with increasing success as the subtleties of time and heterogeneity are taken into consideration (O'Mahony and Vecchi, 2004). Attention is now turning to the indirect impact that ICT is having on the demand for and combinations of inputs; for example, changes in workplace practices (Black and Lynch, 2004) and changes in the demand for skilled labour (O'Mahony et al, 2003).

ICT has had a clear impact on changing the nature of business practices through the use of networks for buying and selling, and more generally, for exchanging information both within and between organisations. E-commerce is defined here as 'transactions over the Internet or over other computer mediated networks. The goods and services are ordered over those networks, but the payment and the delivery of the goods or services may be conducted on or off line.' (E-commerce survey, ONS, 2002). The impact that these types of transactions have on business behaviour and consequently, performance are considered in greater detail below, but crucially, these differ from the direct use of computing power in the actual production process and are therefore likely to manifest in different ways, not always captured by proxies such as expenditure on ICT equipment.

The purpose in this paper is to examine the direct impact that e-commerce activity has had on productivity of enterprises in the UK, using survey data from two sources: the Annual Business Inquiry (ABI), which contains financial information on

'reporting units'[1] in both the manufacturing and service sectors, and an e-commerce survey specifically designed to elicit information about reporting units' use of the internet in their production processes. We look at the way firms use the internet, the factors that affect their choice to carry out transactions over the Internet and how the choice of operating via the Web affects sales. The findings indicate that e-buying and e-selling have an impact on productivity, when issues of selectivity are taken into account.

This paper is organised as follows: the next section reviews the changes in performance that are thought to result from increased e-commerce and recent empirical evidence. Section 3 provides an overview of e-commerce activity in the UK, considering both the production and the service sectors separately and goes on to outline the data used in the analysis in this paper, which mostly refers to 2001. Section 4 outlines the modelling approaches that have been adopted in this paper, providing a discussion of productivity (mis)measurement, particularly in relation to capturing the impact of e-commerce on productivity. Section 5 presents the results of the estimation and discusses our main empirical findings. Section 6 concludes the paper.

2. Technology and enterprise performance

It has become increasingly obvious that the application of e-commerce as a business process is changing the nature of trading, and the empirical literature is now focusing on the impact that these changes may have on productivity at the plant level as distinct from the more direct impacts (Atrostic and Nguyen, 2003). Rowlatt (2001) considers some of the implications of these changes on the way companies do business. She argues that firm level efficiency should improve because of a reduction in administrative costs, search costs and better supply chain management. Information flows should be enhanced with the application of computer networks; however, Rowlatt (*op cit*) points out that the relatively low usage of mail-order shopping in the UK suggests that most of the gains to be had are likely to occur in business to business transactions, rather than business to consumer. Whilst *purchases* are not perhaps made on-line to their perceived potential, an increasing number of

[1] Discussed in greater detail in Appendix 2.

consumers are using the internet to research their intended purchases and are thus separating the search and the purchase elements of buying in a way not previously observed (Economist, 2004). This use of e-commerce is likely to encourage further the use of branding and advertising. In terms of labour market impacts, it is evident that there is a skill bias to the demands that companies developing e-commerce trades are likely to face; increased need for computer literacy and a fall in the number of shop floor staff required.

In terms of e-commerce coverage, a recent survey of the impact of e-commerce (Economist, *op cit*) indicated that whilst in general in the US e-commerce sales represented only 1.6 per cent of the retail market in 2003, this represents $55bn of sales, excluding some expanding areas of e-commerce, such as online travel and financial services, and represents a 26 per cent growth on the previous year. Thus it can be seen that, from a retail perspective alone, e-commerce is of increasing importance.

In addition to the retail impact, the importance of e-commerce in the case of business to business transactions (B-2-B) should not be trivialised. The potential gains from B-2-B transactions were thought to be substantial prior to the dot.com collapse; however, the preference for stable suppliers appears to have outweighed the costs associated with lengthy web-based searches. The real gains now appear to stem from the use of networks in the production/supply chain.

Empirical studies

In a recent study, Atrostic and Nguyen (2004) considered the impact of e-commerce in the US using micro data predominantly for 1999. They found a positive and significant impact from e-commerce activity on plant level labour productivity, suggesting that networks increase labour productivity by around 7.5 per cent. Their study employs a gross output specification (including intermediate inputs as a third input) in order to reduce omitted variable bias. Criscuolo and Waldron (2003) have attempted to replicate Atrostic and Nguyen's findings for the UK, using the special question in the ABI survey on whether establishments either bought or sold on line. Their results were not directly comparable with Atrostic and Nguyen; however they did find that in the case of buying on line, this positively affected labour and total factor productivity. Curiously, they find that selling on-line has, if anything, a negative impact on productivity.

In earlier work, Clayton and Criscuolo (2002) highlight three main mechanisms through which e-commerce affects the business process. Firstly, they highlight the importance of e-commerce as a means of improving the effectiveness of research and development. They also point to the importance of e-commerce in improving commercial communication through access to wider markets. Finally, they emphasise the importance of e-commerce in improving the efficiency of business processes and of making the links between processes faster and more reliable. Forth and Mason (2003) attempt to capture the impact of ICT on business processes by constructing a 'connectivity' variable, which encapsulates the sorts of impacts Clayton and Criscuolo refer to in their paper.

3. E-commerce in the UK

The e-commerce survey is a stratified sample based on the Interdepartmental Business Register (IDBR) frame. It has been carried out on an annual basis since 2000, however the 2000 survey was refined and consequently, surveys for 2001 and 2002 are not directly comparable with it. The survey is part of an EU/OECD initiative to produce comparable data for all possible countries and so should be consistent with data collected elsewhere in Europe. The analysis in this paper concentrates on the latter two years of data, whose sample frames were 12,000 for 2001 and 2002. Williams (2001) provides the first discussion of the e-commerce survey, conducted in 2000, and as a further development to this first overview, Clayton and Criscuolo (2002) provide a detailed overview of data collected in 2000 in a number of ONS datasets, including the CIS, the ABI and the first e-commerce survey. They highlight the characteristics that are most associated with e-commerce users; these are typically large enterprises in established multiplant enterprises which tend to be located in industries such as food, drink and tobacco and insurance services, as opposed to mining and quarrying.

The purpose in this section is to describe the e-commerce data in greater detail for both services and production. In the e-commerce survey for 2001, production accounted for 2,780 enterprises, whilst the service sector accounted for 4,403 enterprises.

3.1 Data linking

In this paper data from 2001 are used. Data from 2000 is available, but not used. The 2000 survey was smaller than subsequent years and it has also been documented that these data were collected in an atypical year, which was thought to have been affected by excessive millennium-bug expenditure (Clayton and Criscuolo, 2002).

In order to carry out any form of production analysis, data from the e-commerce survey has to be matched to the Annual Business Inquiry (ABI). In the first instance, in this paper, data are matched for the year 2001, providing a one year cross-section of data. The matching procedure is based on linking the IDBR numbers and given that the ABI is a census for all large firms, the matching should capture the behaviour of the larger establishments (certainly better than the smaller establishments), thereby capturing the bulk of industry output. It was found that there were 1,536 observations for manufacturing and 1,903 observations for services, summing to 3,439 in total for 2001. Whilst this is a reduced sample (only 30 per cent), there appear to be sufficient observations to undertake some meaningful analysis in both the manufacturing and service sectors. These figures are consistent with the work of Criscuolo and Waldron (2003), who find that the match between the e-commerce survey and the ABI (production) yields a dataset of 1,600 for 2001.

It is worth briefly turning attention to the nature of the matches across the two surveys, to examine the extent to which matches are representative. Considerable attention has been devoted to exploring the validity of linked datasets. Though this literature is relatively disparate, Chesher and Nesheim (2004) have recently reviewed the statistical properties of linked datasets. They highlight three essential problems; non-response, measurement error and bad matches - the inclusion of erroneous matches or the exclusion of unmatched units. Whilst no definitive answers are given to solving these problems, Chesher and Nesheim (op cit) do well to raise awareness and it is with these issues in mind that this paper now considers the attributes of the matched data for 2001.

The matched sample exhibits many of the characteristics of the full e-commerce dataset, and a few trends may thus be described; in terms of regional location, over 30 per cent of these enterprises are located in the south east, with a broad split over the other 9 regions ranging from 3-8 per cent of enterprises. The age range is from 1 year to 22 years, since 22 years is the maximum age of any

observation in the standard variables files as these begin in 1980. In addition, over 41 per cent of enterprises are 5 years old since they enter the dataset in 1997, which is when the service sectors were first included in the BDL files. The most worrying feature to draw attention to is that there are less than 10 observations located in the smallest size band, across both production and services. This is due to the sampling structure. Apart from the size aspect, there is no obvious source of bias amongst the selected (versus the non-selected) enterprises when considering age, region, industry etc.

3.2 The matched data described

Table 1 provides a summary of responses to key questions in the e-commerce survey, 2001 from the matched sample (ABI and e-commerce)[2]. It can be seen that 99.5 and 98.6 per cent of production and service enterprises respectively use at least one PC. The result is not unsurprising given the year (2001 – quite late in internet development terms) and the relatively unspecific nature of the question; we therefore do not propose to use this question in our empirical analysis.

The average percentage of employees reported by enterprises as being without internet access is 28.5 per cent and 28.24 per cent for production and services, respectively. There is more disparity between the two sectors when one considers the percentage of employees using an internet connection, at 27.15 and 36.14, respectively. Less than one percent in both sectors had no employees using the Internet (entry not disclosed), and 4.69 and 12.72 per cent of enterprises reported 100 per cent of their employees having access, in production and services respectively. On the face of it therefore, internet access is pervasive in both sectors, although the internet appears to have a bigger role to play in terms of employee coverage in the service sector, which is in line with expectations.

When asked how long their enterprise had been using the internet, the average number of years was 3.43 and 3.32, respectively for production and services. Another question considers how the enterprises connect to the internet. Whilst this may only be indicative of intensity of use, those enterprises with Broadband are presumably more integrated into an e-commerce business plan than those who pay per minute through a land line. In the 2001 survey, we find that 26.17 per cent of production enterprise and 32.05 per cent of service enterprises connect to the internet using

broadband. These figures are not desperately different across the two sectors, certainly not in terms of their overall ranking of connection methods, but there is some suggestion that services again are more serious about the role that the internet plays in their production process.

Of the enterprises in the survey, 83.27 per cent and 84.87 per cent had a website in production and services, respectively. This figure seems very high and it shows that the two sectors are very similar in the use of this Internet devise.

Do you use the internet for placing/receiving orders?

We focus here on questions that look for B-2-B transactions using the internet, in line with previous studies. It can be seen that 35.48 and 39.73 per cent of production and service enterprises are engaged in buying over the internet, though the figure for selling over the internet is much lower; 14 and 21.44 per cent, respectively. However, when we consider the mean figure given as the percentage of all orders that are placed/received over the internet, this does not vary drastically between the two, nor is it vastly different for the production and service sectors. Placing orders over the internet accounts for on average 1.16 and 2.20 per cent of all orders, and 1.30 and 1.11 per cent of all orders received. In both sectors, between 60-65 per cent of enterprises did no buying over the internet and 78-86 per cent did no selling over the internet. It can be seen therefore that B-2-B transactions are not responsible for the bulk of transactions in either sector of the economy[3]; however, they are of interest for two reasons, it is an area of considerable expansion in some industries and is indicative of innovative behaviour.

In terms of sales to households via the internet, the mean figure was very low, less than 0.5% in both sectors, although the maximum proportion of sales received reported was 12 per cent in production and 60 per cent in services. The mean percentage of orders received from businesses was also very low – 1.10 in manufacturing and 0.66 in services. It is interesting to see that this is higher for manufacturing. The highest proportion of sales to businesses carried out over the internet was over 90 per cent in manufacturing and 100 per cent in services; these may be the result of outliers.

[2] A full list of the questions from the 2001 E-Commerce survey is given in Appendix 1.
[3] A point we discuss in greater detail in the conclusions of this paper.

Receiving and making payments via the internet are consistently used by manufacturing and services, with over 58 per cent of enterprises saying they did receive a payment via the internet. This figure is slightly higher for the making of payments, with over 68 per cent of enterprises making a payment over the internet. Interestingly, we see that figures for making and receiving payments in this fashion are slightly higher for production, rather than services.

Table 1

Summary of results from the E-commerce questionnaire,

Matched samples 2001

Q no.	Question	format	% Production (n=1536)	% services (n=1903)
q010	Did your enterprise use PCs	yes/no	99.48	98.63
q021	mean % employees without internet	%	28.5	28.24
	100% employees without internet	%	NA	NA
q022	mean % of employees using internet	%	27.15	36.14
	100% of employees using internet	%	4.69	12.72
q051	mean no of years using internet	no.	3.43	3.32
q052	mean no of months using internet	no.	1.69	1.72
q061	how do you connect?	% with broadband	26.17	32.05
q080	do you have a website?	yes/no	83.27	84.87
q090	Do you use the internet for placing orders?	yes/no	35.48	39.73
q101	mean % of orders from the internet as a % of all orders	%	1.16	2.2
	0% of orders from the internet	%	65.42	60.27
q110	Do you use the internet for receiving orders?	yes/no	14	21.44
q121	mean % of orders received from internet as a % of all orders	%	1.3	1.11
	0% of orders received from the internet	%	86	78.56
q128	mean % of orders from households	%	0.038	0.44
	max% of orders from households	%	12	60
q129	mean % of orders from businesses	%	1.1	0.66
	max% of orders from businesses	%	93.3	100
q160	use internet etc for receiving payment	yes/no	62.63	58.01
q170	use internet etc for making payment	yes/no	70.7	68
q181	link to suppliers' systems	yes/no	16.67	23.33

q182	reordering of replacement supplies	yes/no	14.26	17.71
q183	link customers' systems	yes/no	26.5	15.5
q184	invoicing and payment system	yes/no	35.74	34.42
q185	production/service operation	yes/no	22.01	19.39
q186	logistics system	yes/no	23.57	19.81
q187	marketing	yes/no	7.75	11.61

Network of systems

The survey asked a series of questions about the (electronic) links that enterprises had with other aspects of their production process. These included links to suppliers systems, reordering of replacement supplies, links to customer systems, invoice and payment systems, production/service operations, logistic and marketing. Table 1 contains details on these (q160-187), but the most popular is the invoicing and payment system. The least used is marketing links, which is particularly low in the production sector. This suggests that the internet is proving to be useful as a logistical tool, linking suppliers to customers, but not as a means of promoting the business, e.g. through advertising etc.

In addition to the initial match for 2001, it has been possible to use the IDBR link to match this one year of e-commerce data to previous years of the ABI, and thus it is possible to consider the financial performance of these plants over a short time period by constructing a panel. Table 2 below provides information on our ability to link these records in each year by broad sectors. One would expect to see a gradual decline in the proportion of enterprises identified as one goes further back over time, primarily because of closures. In this respect, there are grounds to suggest that this sample captures only winners over time, i.e. those who survive. It is worth noting that whilst it has been possible to identify a considerable proportion of matches in each year, this does not mean that the same plants are continuously captured over time. For example, it is perfectly possible amongst the sampled plants that they leave and re-enter the ABI over time. This gives an unbalanced panel dataset. However, the figures over time suggest that a similar proportion of plants are detected by sector, which suggests that broadly the same plants are being identified over time, with perhaps some marginal mismatching from one year to the next.

It is also important to note that the matching from 2001 e-commerce may be higher in years other than 2001 ABI, given nature of the sampling procedure in both

surveys, particularly for smaller plants. A case in point is 1998 where the match is higher than the matching year. This is thought to be the result of the sampling frame. Specifically, it is constructed on a three years basis, i.e. a small firm that has been sampled once, may not be approached for another 3 years.

For the second stage of the analysis, establishments are traced back to 1997, since this is when the service sector data became available. This should also provide sufficient years to consider performance over time. By way of an explanation for the relatively high match rate over time, Table 2 also provides an overview of the age profile of reporting units in 2001, by sector. It can be seen that the youngest reporting units, on average, are located in the other services sector, and are a little over 4 years old, again, a function of the start of the survey. Oldest reporting units are located in the production sector and are on average 14 years old. This is a big difference, and may in part be explained by the relative differences in average scale between the sectors. It is also manifest in the very high 'survival' rates from 2001 back to 1997.

Table 2

Number of matches - e-commerce2001 with ABI over time

Sector	2001	2000	1999	1998	1997	Mean Age
Catering	66	53	49	66	48	4.77
Construction	107	94	83	137	107	6.63
Motor trade	143	103	83	175	128	4.93
Property	39	28	23	44	29	4.61
Production	1536	1309	1354	1741	1272	14.03
Retail trade	169	160	149	170	113	4.59
Other Services	1044	711	803	894	561	4.1
Wholesale	335	235	226	449	252	5.56
SUM	**3439**	**2693**	**2770**	**3676**	**2510**	

3.3 Capital stock data

Data contained in the ABI include net capital expenditure on buildings, plant and machinery and vehicles in any year. However, these investment data as they stand do not provide a capital stock, which is necessary in order to run full total factor productivity production functions. Many studies circumvent this by considering

instead labour productivity, and indeed there are sound policy reasons why it is sensible to do so. Labour productivity is intuitively appealing and is quite often a target of government policy. However, it is generally recognised that a fully specified TFP equation is the more holistic method of capturing the true improvements in productivity, rather than simply a change in input mix which can sometimes appear as a real efficiency gain within a labour productivity specification.

In this study we use capital stock data as estimated by Martin (2002) for the production sector and extended by the ONS to the service sector. These are the data that will be employed in this study. More details are given in the appendix.

4. Modelling productivity

4.1 Production function estimation

As previously highlighted, there are two ways in which new technologies are thought to impact on the production process. Whilst ICT capital stocks are not available to estimate the direct impact of ICT on the production process, the questions covered by the e-commerce survey enable the production function to be augmented by terms which indicate the extent to which e-commerce activities have changed and are now part of the business process.

In this paper, a gross output specification of the production function is used, following Baily (1986) who shows that value added models yield biased estimates of TFP at the plant level. Output is therefore recognised as the better measure (Atrostic and Nguyen, 2004). Basu and Fernald (1997) have also shown that with imperfect competition the use of value added, even at a firm level, suffers from an omitted variable bias. We start by specifying the following log linear (Cobb-Douglas) production function:

(1) $$Ln(Q_i) = \alpha_0 + \alpha_1 Ln(L_i) + \alpha_2 Ln(K_i) + \alpha_3 Ln(M_i) + \varepsilon_i ,$$

where L, K, and M are numbers employed, capital and intermediate goods respectively.

In terms of which variables to consider, we look at the impact of buying and selling goods on the Internet, following Criscuolo and Waldron (2003), by including in equation (1) the corresponding indicators (Z_{ij}) from the e-commerce survey:

(2)
$$Ln(Q_i) = \alpha_0 + \alpha_1 Ln(L_i) + \alpha_2 Ln(K_i) + \alpha_3 Ln(M_i) + + \alpha_4 Z_{ij} + \\ + \alpha_5 Multi + \alpha_6 FO + \alpha_7 age + \sum \gamma_i Ind + \sum \gamma_r reg + \varepsilon_i$$
$$j = 1,..,4,$$
$$i = 1,...,41$$
$$r = 1,..,10$$

where j=1-4 corresponds respectively to *e-buy* (Q090), *e-sell* (q110), a two linear combination of the two defined as *e-trade* and *e-trade2*. The former includes all companies that either buy or sell on the Internet while the latter only includes those companies that do both. These two indicators have been constructed in order to capture the total impact of e-buy and e-sell on productivity. All four variables have been included in equation (2) as dummies equal 1 when the relevant characteristic is present and zero otherwise.

Similarly to Atrostic and Nguyen (2004), equation (2) also includes a set of control variables to account for plant's heterogeneity: *multi*, which detects whether the reporting unit is a multi-plant organisation, *FO* indicates whether the plant is foreign owned and *age* is the age of the reporting unit. Finally, 10 regional dummy variables have been included, along with 41 2-digit industry dummies.

4.2 Correcting for endogeneity

Equation (2) can be estimated by Ordinary Least Squares (OLS). However, this technique is likely to produce inconsistent estimates as the decision of trading on the web is not orthogonal to the error term (Atrostic and Nguyen 2002, 2004). Existing research also indicates that the sign of this correlation is not known *a priori*. McGuckin et al. (1998) found that adopting advance communication technology is positively related to plant's productivity performance. On the other hand, Stolarick (1999) found that less productive plants invested more in computer equipment, compared to more productive ones, possibly in an attempt to catch up. Moreover, it is relatively well established that e-buying and e-selling are part of advanced communications technology and therefore they are not independent of the plant's performance.

Another source of correlation between e-buying and e-selling and the error term is possible sample selection issues, i.e. the coefficient estimates may be biased because the outcomes may reflect unmeasured pre-existing characteristics of the

selected firms (Barnow *et al.,* 1981). For example the decision of trading on the web may depend on the firm's ability to use the ICT technology, or on the availability of IT skills. Unfortunately ability and/or labour force skills are not observed, and as a consequence, equation 1 or 2 is affected by omitted variable bias. Therefore, to obtain consistent estimates of the parameters of equation (2) we use an instrumental variable estimator. Because of the dummy nature of the e-buy/e-sell variables we address the endogeneity issue by using a treatment effect estimator. This was initially devised to analyse the outcome of a given policy but it has found wide applications in all those cases where we have an endogenous dummy variable (Wooldridge 2002).

We instrument the firm's decision of trading on the Internet using several variables from the e-commerce survey. Specifically, we used variables that are correlated with the decision of buy/sell on the Internet but uncorrelated with establishment productivity and as such they are good candidates as instruments. These variables are: the presence in the firm of a broadband connection (*Broadband*), the percentage of employees that have Internet access (*Webusers*), the number of years the enterprise has been using the Internet (*Experience*), the presence of the firms' website (*Website*) and a measure of the intensity of use of e-commerce facilities, (*Intense*). The latter is an indicator that summarises the information of several e-commerce variables related to the use of electronic links with suppliers/customers/other parts of the organisation (q160-q187 from table 1)[4]. This score is based on a scale of 0 to 9, with 9 being the most intensive. It is hoped that by combining a number of these technologies into one measure, a more holistic impression of technology take-up is gained. This score was initially included in the production function estimation but it was never significantly different from zero and it has therefore been dropped. The intense variable, while it cannot explain firms' productivity performance, will play an important role in determining the firms' decision of trading over the Internet.

[4] The construction of an indicator that summarises several survey variables follows Forth and Mason (2003) and McGuckin et al (1998), both of whom construct a measure based on new technologies adopted. Forth and Mason (*op cit*) refer to their measure as a connectivity measure, derived from the IBS survey and based on a number of Internet-style technologies. By constructing an indicator we address the collinearity problem that is likely to arise when we try to include several variables from survey data. In our case, the correlation between the variables included in the *Intense* indicator is above 0.5 in most instances.

The instrument set also includes lagged output ($Output_{t-1}$) to evaluate the impact of past performance on the probability of trading on the web. This intends to discriminate between good and poor performance firms, i.e. whether good performance firms are more likely to trade on the Internet than poor performance firms. Our instrument equation can be specified as:

$$Z_j = \beta_{0j} + \beta_{1j} Broadband + \beta_{2j} Webusers + \beta_{3j} Experience + \beta_{4j} Website + \beta_{5j} Intense + \beta_{6j} Output_{t-1} + u_j \quad (3)$$

$$j = 1,..,4$$

Equation (3) also includes the same set of control variables included in equation (2), i.e. dummies for foreign ownership, multi-plant firms, age of firms, regions and industry. Equation (2) and Equation (3) are estimated jointly using full maximum likelihood procedure.

A priori it is difficult to predict the sign of the effect of e-buy and e-sell. Trading over the Internet allows a firm to reach a wider audience both in the selling and in the purchasing of intermediate inputs, which can have a positive impact on productivity. On the other hand, the tougher competition and the higher price transparency might negatively affect productivity. The *e-trade* variable is designed to capture the net effect, while *e-trade2* aims at evaluating the total effect of buying and selling on the Internet.

5 Empirical analysis

5.1 Some general trends in the data

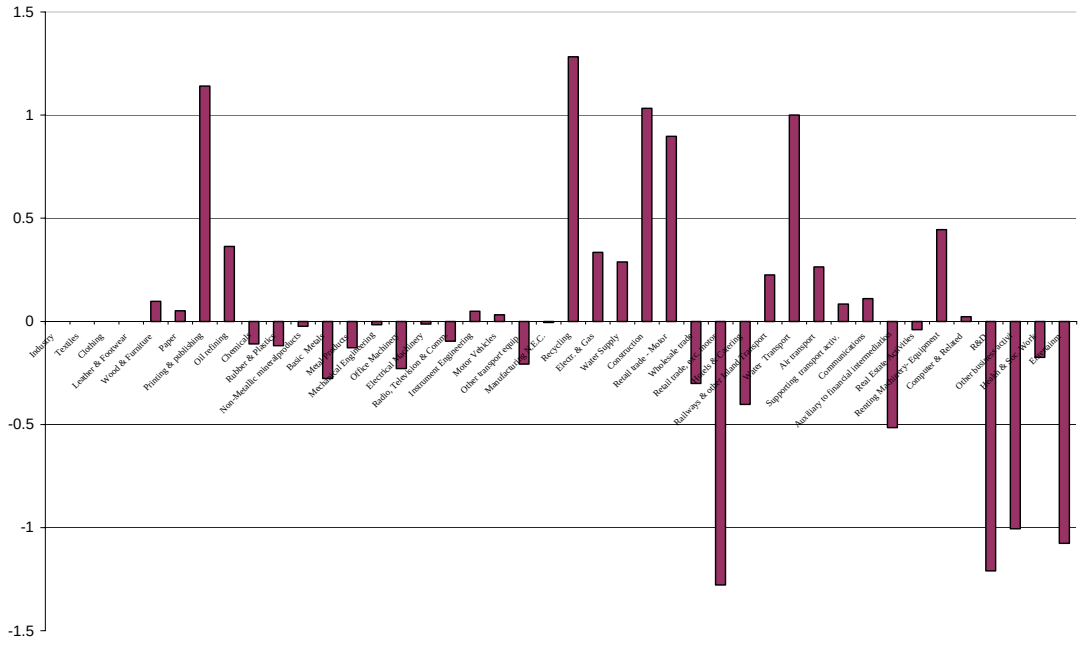
Before showing the results from the estimation of the production function we briefly look at the general productivity trends in the data. Figure 1 presents the average rate of growth of productivity in the industries included in our sample. The figure shows a high degree of heterogeneity across the economy, with a large number of industries being characterised by a negative productivity or very low rate of productivity growth.

The best performing industries, with a productivity growth less than or equal to 1%, are Oil Refining, Electricity and Gas, Air Transport and the motor vehicles and motorcycles section of Retail Trade. This is consistent with previous research showing that productivity growth in the EU is mainly confined to non-ICT intensive sectors (Inklaar et al 2003).

Within manufacturing, only Oil refining and Chemicals display some noticeable productivity growth, while the other industries are characterised by rates very close to zero or negative. This supports existing evidence on the slowdown of productivity growth in the UK and in Europe after 1995 (Rincon and Vecchi 2004, Basu et al. 2003, Daveri 2002).

FIGURE 1

LABOUR PRODUCTIVITY GROWTH BY INDUSTRY



The retail sector, excluding the sale of motor vehicles, is characterised by a negative labour productivity growth. This is in sharp contrast with the high productivity performance of the retail sector in the USA in recent years (7.9% between 1995 and 2002 - McGuckin et al. 2004). In fact, Wholesale, Retail trade and Financial Services, three of the main ICT using industries, account for much of the overall US-EU gap in productivity growth since 1995 (O'Mahony and Van Ark 2003, Van Ark et al. 2002, 2003).

Table 3 compares labour productivity growth between firms that trade and firms that do not trade on the Internet. The table shows that companies that have used the e-commerce technology have outperformed companies that have opted for more traditional means of trade.

Table 3
Rate of growth of labour productivity
in E-trade and non E-trade firms

	Total	E-buy	E-sell	E-trade2	NO E-trade
1998	-0.001	0.132	0.151	0.155	-0.097
1999	-0.002	0.141	0.171	0.217	-0.111
2000	-0.006	0.099	0.117	0.127	-0.095
2001	0.001	0.146	0.228	0.239	-0.128

The productivity gains have been particularly high in the last year and firms that have chosen to buy and sell on the Internet have experienced the highest productivity growth. Given that we could only use e-commerce data for 2002 and we do not know when firms have started to trade on the Internet it is difficult to discern a cause and effect relationship. Nevertheless the table shows that good performance firms are the ones that have traded on the Internet and they are likely to have invested more in advance communication technology. Other studies have also shown a positive relationship between output and IT spending (Brynjolfsson and Hitt 1993, 1996a, 1996b and Stolarick 1999a).

On the other hand, Strassmann (1990) finds that best-performing firms show the lowest levels of spending on information technology. The fact that 'moderately lower spending levels are related to higher productivity' is possible since the most productive firms, spending less on IT, can achieve the same level of benefit as the less productive firms. Stolarick (1999b) argues that although lower productivity plants are spending more on IT to compensate for their productivity shortcomings, other factors such us management skill affects the level of benefit that a firm can get from its IT spending.

5.2 Ordinary Least Squares Results

In the first instance, we estimate a cross sectional model for 2001 following equation (2), using OLS. This was estimated for the full data set and for production and services separately. In all cases, the control variables discussed in the previous section are included but are not reported in the results contained in Table 4 below.

The results presented in Table 4 reveal that the coefficients on labour, capital and intermediates are relatively similar in production and service sectors and they

suggest the presence of constant or slightly decreasing returns to scale. The capital and labour coefficients are quite small compared to prior knowledge of factor shares but this is likely caused by the inclusion of intermediate materials. Also, capital coefficient estimates might be affected by the measurement errors, discussed in the appendix.

Using a simple OLS model, our results suggest that e-buy has a negative impact on productivity while e-sell has a positive effect. This is contrary to Criscuolo and Waldron (2003) who find a positive impact of e-buy and a negative impact of e-sell on both labour and total factor productivity. However, our coefficient estimates are not significantly different from zero at the 5% significance level. When using the variable e-trade we find that the effect is negative while e-trade2, which summarises the information for those companies that buy and sell on the Internet, the effect turns positive for Services but it is negative for production firms. Again the coefficients are not statistically significant.

The coefficient estimates for the control variables (not shown) imply that being part of a multi plant organisation and being foreign owned does not have very high levels of significance, nor do they particularly reflect *a priori* assumptions with their signs. The age of the reporting unit has an average impact of 0.2%, significant at the 10% level, on the productivity of companies operating in the production sector, while it is not statistically significant for those firms operating in the service sector. The coefficients on the industry dummies show a high degree of heterogeneity across the economy and they largely reflect the trends depicted in Figure 1 above, showing positive and significant coefficients, for example, in Utilities, Construction, Motor Retail Trade and Wholesale Trade.

Table 4

Cross section results for production, services and all sectors.

	All Sectors		Production		Services	
Buying on the WEB						
Constant	1.441*	(.099)	1.444*	(.131)	1.459*	(.241)
Emp	0.252*	(.016)	0.210*	(.024)	0.266*	(.020)
K (2001)	0.124*	(.022)	0.092*	(.031)	0.156*	(.031)
Inter	0.636*	(.024)	0.688*	(.039)	0.598*	(.032)
e-buy	-0.014	(.017)	-0.010	(.019)	-0.018	(.028)
Selling on the WEB						
Constant	1.445*	(.099)	1.445*	(.132)	1.451*	(.237)
Emp	0.252*	(.017)	0.209*	(.024)	0.266*	(.021)
K (2001)	0.123*	(.022)	0.092*	(.031)	0.155*	(.031)
Inter	0.635*	(.024)	0.688*	(.039)	0.598*	(.032)
e-sell	0.012	(.019)	0.007	(.019)	0.006	(.030)
Using the WEB for selling or buying						
Constant	1.439*	(.099)	1.444*	(.131)	1.452*	(.240)
Emp	0.253*	(.016)	0.210*	(.024)	0.266*	(.021)
K (2001)	0.124*	(.022)	0.092*	(.031)	0.156*	(.031)
Inter	0.636*	(.024)	0.688*	(.039)	0.599*	(.032)
e-trade	-0.008	(.018)	-0.006	(.019)	-0.015	(.029)
Using the WEB for selling and buying						
Constant	1.442*	(.099)	1.444*	(.132)	1.450*	(.239)
Emp	0.253*	(.017)	0.210*	(.024)	0.266*	(.021)
K (2001)	0.124*	(.022)	0.092*	(.031)	0.155*	(.031)
Inter	0.636*	(.023)	0.688*	(.039)	0.598*	(.032)
e-trade2	0.004	(.027)	-0.001	(.024)	0.001	(.041)
Observations	2435		1188		1247	

*= significant at the 5% level, ** at the 10% level. All specifications include the following control variables: age of the reporting unit, dummies for Multiplant, Foreign Ownership, Industry and Region.

Overall, our OLS results show that buying and selling on the Internet has no effect on productivity. This conclusion diverge from the evidence of the large use that companies make of the Internet and the large amount of goods and services that are traded daily on the Web[5]. The most likely explanation of our results is the endogeneity of the decision to trade on the Web. If the error term of the model that

explains this decision is correlated with the error term in the production function then the estimates in table 4 are biased. To correct for this bias we need to instrument the decision of trading on the Internet. This is the focus of the next section.

5.3 Selection bias and its impact on the effect of e-buy and e-sell on productivity

The decision trading on the Internet is instrumented using the specification discussed in section 4.1, equation (3). This is a probit equation whose predicted values are used in the production function (equation (2)) to capture the effect of trading on the Internet, after controlling for the selectivity bias. The estimates of the production function based on the treatment effect model are presented in table 5. The model is estimated for all sector as well as for production and services to analyse the relative importance of e-commerce on productivity by major economic sector, as previously considered.

Recall that, without the treatment, the impact of buying and selling on the web was found not to be significantly different from zero, as shown in table 4. The inclusion of the treatment effect changes the results dramatically. All 4 indicators of trading on the Internet have a strong and positive impact on productivity, when we consider all sectors.

Some differences emerge when we look at the Service and Production sector separately. E-buy is not significant in Services, while it has a strong impact on Production sector companies. The results also indicate that the productivity effect of buying on the Web is higher than selling on the web (respectively 0.302 and 0.224 for the whole sample, 0.342 and 0.242 for production).

The impact of productivity is even higher when the e-buy and e-sell are considered jointly, using the variable e-trade. Combining the two variables aims at correcting for another potential misspecification in the results based on a single side of the trade, i.e. if both selling and buying positively affect productivity, each equation is omitting an important variable and therefore the coefficient estimates on e-buying and e-selling can be affected by an omitted variable bias. Table 5 shows that our combined variable is positive and significant and its effect is higher than the average impact of e-buy and e-sell in all specification. This contrasts with the

[5] Internet sales in 2000 in the UK were estimated as being worth nearly £60billion, representing 2 percent of total sales, while sales via all electronic networks totalled £160 billion, or 5.8 per cent of sales (Rowlatt 2001).

findings of Criscuolo and Clayton (2003) who found opposing signs to buying and selling over the Internet. However, their results were based on a different specification and on questions from the ABI only, rather than the e-commerce survey.

Finally, we consider those companies that buy and sell on the Internet (e-trade2) to investigate the possibility of extra productivity gains when the Internet is used for both sides of the transaction within the same firm. Contrary to our expectations, given the previous positive results on both e-buy and e-sell and the labour productivity trends in Table 3, the impact on productivity is smaller and not even significantly different from zero in the service sector. It is possible that the reduced size of the sample (302 firms compared to 1242 firms doing e-buy and 554 firms doing e-sell) affects our results.

The results of the likelihood ratio test are also reported in table 5. This tests the null that the errors in the two equations (the production function and the treatment equation) are uncorrelated. Rejection of the null implies that there selectivity bias is important and it largely affects the OLS results without treatment. Failure to reject the null hypothesis, on the other hand, makes the treatment effect estimator equivalent to the simple OLS. The null is rejected at the 5% significance level most cases. It is worth noting that the estimated coefficients on employment, capital and intermediate materials are only marginally affected by the treatment, suggesting stability in their measurement.

Table 5 shows that trading on the Internet has a positive effect on productivity when using instrumental variables. However, while in OLS we simply include 0-1 dummies for those firms that trade on the Internet and we can directly derive the impact of the decision on productivity, in the treatment effect estimator trading on the web is a continuous variable and its interpretation is less straightforward. A better understanding of the impact of trading on the Internet on productivity can be achieved by comparing the productivity impacts of trading on the Internet on firms at two points in the predicted probability of doing e-trade (Atrostic and Nguyen 2004). We present this comparison in table 6, using the total sample of firms that either buy or sell on the Internet (e-trade).

Table 5

The impact of trading on the Internet on firms' productivity performance
Treatment effect estimator

	All Sectors	Production	Services
Buying on the Web			
Constant	1.580* (.087)	1.541* (.099)	2.090* (.454)
Emp	0.260* (.012)	0.214* (.016)	0.277* (.017)
K (2001)	0.111* (.013)	0.077* (.014)	0.141* (.021)
Inter	0.622* (.013)	0.684* (.015)	0.588* (.020)
e-buy	0.302* (.070)	0.342* (.032)	0.206 (.132)
L. ratio test	5.920* (.015)	34.43* (.000)	2.640 (.104)
Selling on the WEB			
Constant	1.626* (.084)	1.534* (.089)	2.440* (.464)
Emp	0.257* (.012)	0.221* (.016)	0.264* (.017)
K (2001)	0.116* (.013)	0.087* (.015)	0.140* (.021)
Inter	0.622* (.013)	0.680* (.015)	0.582* (.020)
e-sell	0.224* (.057)	0.242* (.048)	0.331* (.084)
L. ratio test	12.04* (.001)	11.120* (.000)	11.87* (.000)
Using the WEB for buying or selling			
Constant	1.693* (.090)	1.545* (.099)	2.167* (.478)
Emp	0.254* (.012)	0.217* (.016)	0.268* (.017)
K (2001)	0.108* (.013)	0.076* (.014)	0.134* (.021)
Inter	0.615* (.013)	0.680* (.015)	0.572* (.020)
e-trade	0.364* (.045)	0.346* (.032)	0.399* (.081)
L. ratio test	27.32* (.000)	37.07* (.000)	17.66* (.000)
Using the WEB for buying and selling			
Constant	1.534* (.077)	1.507* (.087)	2.228* (.440)
Emp	0.262* (.011)	0.224* (.016)	0.274* (.017)
K (2001)	0.118* (.013)	0.090* (.015)	0.145* (.021)
Inter	0.627* (.013)	0.680* (.015)	0.593* (.020)
e-trade2	0.064 (.063)	0.178* (.060)	0.046 (.105)
L. ratio test	0.880 (.348)	5.400* (.020)	0.120 (.724)
Observations	1983	979	1004

Note: a'*' indicates rejection of the null hypothesis at 5% significance level, a '‡' indicates rejection at 10% significance level. All specifications include the following control variables: age of the reporting unit, dummies for Multiplant, Foreign Ownership, Industry and Region.

The results in table 6 show that in the total sample, for example, firms in the 99th percentile of the probability distribution (more likely to trade on the Internet)

have over a 29% increase in productivity compared to firms on the 1st percentile (less likely to trade on the Internet). The productivity gain is stronger in the Service than in the Production sector where the difference between the 1st and the 99th percentile is 35.91% and 24.79% respectively.

Table 6

The impact of e-trade on firms' productivity

Based on the treatment effect estimator

Percentiles (%) of Pr (E-Trade)	Percent increase in labour productivity.
Total	
1% (0.0798) vs. 99% (0.8914)	29.54%
5% (0.1639) vs 99% (0.8914)	26.48%
1% (0.0798) vs 10% (0.2200)	5.10%
10%(0.2200) vs 90% (0.7416)	18.98%
25%(0.3317) vs 75% (0.6147)	10.30%
Production	
1% (0.1048) vs. 99% (0.8215)	24.79%
5% (0.1661) vs 99% (0.8215)	22.67%
1% (0.1048) vs 10% (0.2166)	3.86%
10%(0.2166) vs 90% (0.6599)	15.33%
25%(0.3053) vs 75% (0.5410)	8.15%
Services	
1% (0.0780) vs. 99% (0.9781)	35.91%
5% (0.2011) vs 99% (0.9781)	31%
1% (0.0780) vs 10% (0.3069)	9.13%
10%(0.3069) vs 90% (0.9009)	23.7%
25%(0.4762) vs 75% (0.8135)	13.45%

Table 7 presents the determinants of the probability of buying/selling on the Internet, which constitutes our instrument/treatment equation. The coefficient on lagged output is always positive and significant showing that firms that performed well in the year 2000 are more likely to trade on the web in 2001, confirming the general productivity trends in table 3. Past performance appears to particularly affect the probability of production firms of selling on the Web, while it is not statistically different from zero in the determination of the probability to buy on the Web in the service sector. Also past performance does not affect the decision of Service sector firms to buy and sell over the Internet.

The results also show that having a website has a very strong influence on the firm's decision of trading on the web, particularly in the e-selling part of the trade. This is understandable as a website is likely to be something of a prerequisite to

trading on the internet. In addition, websites now have become one of the major marketing tools for companies to advertise their products and services.

Table 7

Analysis of the determinants of the probability of trading on the Internet

		e-buy	*e-sell*	*e-trade*	*e-trade2*
Total	Constant	-2.031* (.371)	-3.891* (.414)	-2.935* (.329)	-2.872* (.505)
	Output-1	0.075* (.035)	0.140* (.034)	0.161* (.029)	-0.001 (.039)
	Website	0.261* (.097)	0.561* (.152)	0.348* (.092)	0.486* (.199)
	Experience	0.066* (.017)	0.002 (.019)	0.044* (.015)	0.054* (.022)
	Intense	0.059* (.015)	0.123* (.018)	0.076* (.014)	0.142* (.020)
	Webusers	0.313* (.009)	0.326* (.120)	0.293* (.097)	0.387* (.140)
	Broadband	0.097 (.101)	0.090 (.137)	0.080 (.094)	0.120 (.184)
Production	Constant	-2.205* (.448)	-3.341* (.617)	-2.101* (.442)	-4.092* (.792)
	Output-1	0.106* (.038)	0.138* (.054)	0.118* (.038)	0.106* (.066)
	Website	0.272* (.109)	0.629* (.214)	0.333* (.106)	0.704* (.323)
	Experience	0.049* (.020)	0.016 (.029)	0.039* (.019)	0.073* (.034)
	Intense	0.064* (.018)	0.131* (.026)	0.078* (.018)	0.169* (.032)
	Webusers	0.015 (.137)	0.374‡ (.210)	0.075 (.139)	0.396 (.250)
	Broadband	0.134* (.135)	-.464* (.188)	0.013 (.125)	-0.319 (.276)
Services	Constant	-1.095 (.595)	-3.610* (.601)	-2.415* (.545)	-1.725*(.690)
	Output-1	0.034 (.054)	0.181* (.042)	0.198* (.042)	-0.028 (.050)
	Website	0.366* (.165)	0.487* (.214)	0.433* (.155)	0.368 (.262)
	Experience	0.087* (.024)	-0.007 (.024)	0.051* (.022)	0.035 (.029)
	Intense	0.055* (.021)	0.108* (.023)	0.075* (.020)	0.123* (.026)
	Webusers	0.417* (.133)	0.257‡ (.145)	0.374* (.128)	0.349* (.173)
	Broadband	0.081 (.147)	0.517* (.204)	0.134 (.132)	0.528* (.256)

Note: a'*' indicates rejection of the null hypothesis at 5% significance level, a '‡' indicates rejection at 10% significance level. All specifications include the following control variables: age of the reporting unit, dummies for Multiplant, Foreign Ownership, Industry and Region.

Experience appears to play a relevant, albeit small, role in the buying online while it is not significant in selling. The *Intense* variable, which captures a composite of e-commerce activity (use of electronic links with suppliers/customers/other parts of the organisation etc, q160-q187) also appears to be quite strong and positive in its impact. This is significant in all specifications and it particularly affects the probability of buying and selling on the Internet.

The percentage of employees using the web is, after having a web site, the strongest determinant of trading on the Internet, while the presence of a Broadband connection is significant for production firms buying on the web and for service firms selling on the web. Quite surprisingly, having a broadband connection negatively affects the decision of production firms of selling on the Internet. In general, having a broadband connection appears to be quite sensitive to changes in the specification,

particularly to the inclusion of the *intense* indicator, which is intended to capture the effect of the intensity of use of network technology; this suggests that the two variables might be looking at a similar phenomenon, basically, how intense the use of IT technology is within the firm. However, in some cases (e-selling in the service sector, for example) the two variables are both positive and significant which suggests that both are warranted in the specification.

6. Conclusions

In measuring the productivity impact of ICT, attention is turning to the e-commerce aspect of production. This has been regarded as the more indirect impact, and as such, has been hard to capture within a production function framework. The availability of survey data that specifically analyses the use of ICT equipment in trading goods has given researchers recent insight; however the data are limited in their applicability, in part because of problems of selectivity when modelling. This paper has attempted to highlight a possible solution to this selectivity problem which is likely to result in coefficient biases. We find that whilst the OLS regressions suggest very little impact from e-buying or selling, when selectivity biases are taken into account both have a large and positive impact on enterprise level productivity.

The paper has also focused on the difference between the production and service sectors. Among companies operating in the production sector we find that both e-buying and e-selling have a positive effect on productivity, while in companies operating within the service sector selling on the Internet is comparatively more important in improving productivity performance. This shows that for these companies the Internet has been an excellent device for expanding their business but that more can be done to enhance the productivity impact of buying on the Internet.

The present work only covers one cross section of data. However, we believe that e-commerce is having a substantial effect on the growth of productivity, and as such, a more appropriate way to capture its full impact is to consider growth rather than levels. Therefore further research will be needed to extend our analysis in this direction.

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Appendix 1: Questions from the E-Commerce 2001 survey

SECTION A

- Did your business have personal computers, workstations or terminals?
- Did your business have internet access?
- For how long has your business had internet access?
- How did your business primarily connect to the internet?
- What type of broadband connection was your business primarily using?
- What was the single most important barrier preventing your business from using a broadband connection?
- Does your business plan to start using the internet during 2003?
- Did your business have a website, whether own or third party?
- Did your business have the following technologies?
    - External email, intranet, extranet, EDI, automated telephone entry, mobile technology wide or local area network?

SECTION B

- What percentage of your employees had personal computers, workstations or terminals for their work?
- Please breakdown the percentage recorded into those that had internet access and those that did not.

SECTION C

- What was the cost of the purchases your business made for goods, materials and services?
- Were any of your business's orders placed over the internet?
- Of the total value of your business's orders, what percentage were placed over the internet?
- Of the total value of the orders placed by your business, please give a percentage breakdown into internet orders for physical products, internet orders for digitised products, internet orders for services.
- Did your business place any orders over information and communication technologies other than the internet? (email, EDI, etc.)

SECTION D

- What was the total turnover of your business?
- Were any of your business's orders received over the internet?
- Of the total value of orders received by your business, what percentage were received over the internet?
- Of the total value of orders received, please give a percentage breakdown into internet orders for physical products, internet orders for digitised products, internet orders for services
- Of the total value of orders received, please give a percentage breakdown into internet orders from households, internet orders from businesses
- Did your business receive any orders over information and communications technologies other than the internet?
- Of the total value of the orders received by your business, what percentage were made over information and communications technologies other than the internet?
- Of the total value of the orders received by your business, please give a percentage breakdown into other information and communications technology orders from households, and other information and communications technology from businesses

SECTION E

- Did your business make payments over any ICTs?
- Did your business received payments over any ICTs?

SECTION F

- Did your electronic ordering systems link automatically to electronic systems either within or outside of your business?
- Did your business's electronic ordering, sales or purchasing systems link automatically within your business to: your production or service operating systems, your logistics or delivery systems, your invoicing or payment systems. Your marketing or customer relationship management systems, you other internal operating systems, your suppliers' ordering or business systems, your customers' ordering or business systems, other links to external businesses' systems?

SECTION G (new to 2002)

- Did your business use the internet for interaction with public authorities?
- Why did your business use the internet to interact with public authorities?

Appendix 2: Data Issues

Establishment data versus plant level data

Note that the nature of the data collection and storage system means that enterprises are actually reporting units, which may contain more than one plant, but need not be a whole firm. In the vast majority of cases, enterprises (or reporting units) are in fact single plant firms, however the multiplant units represent the large firms and therefore account for the lions' share of output. The problem with using reporting unit level data is that this is essentially an accounting unit, determined by the firm on the basis of administrative convenience. A counter argument to this is that the nature of firms is such that frequently the administrative organisation of a firm will be base on production process and therefore like-plants are frequently grouped together. An alternative approach to the analysis of ABI data is to use plant level analysis, based on the population of plants contained in non-selected data files. Whilst financial data are not strictly available at this level, data may be created by 'spreading back' financial data pro rata, on the basis of employment (See Harris 2002; Robinson, 2004 for detailed discussion). This paper uses reporting units because that is the way ONS have chosen to store the data; it is however recognised that there may be problems with interpretation of results as a consequence of this level of analysis and care should be exercised.

Capital stock data

Capital stock data, particularly at the plant/firm/reporting unit level are difficult to obtain; however Martin (2002) has estimated capital stocks for production and the ONS has extended this framework to include service sectors also. These are the data that will be employed in this study. Full details of the way in which capital stocks have been estimated are given in Martin (op cit) but to provide a brief outline, the following assumption have been made in their calculations. Martin's approach follows the Perpetual Inventory Method (PIM) of calculation, following a geometric depreciation rate to investment. Where values are missing over time, straight-line

interpolation has been used. Starting values have been derived from investment stock aggregates from ONS's historical series dating back to 1948, at the 2-digit level.

There are a number of concerns with this approach. Firstly, the initial starting values have had to be allocated to the 4 digit level, and there are potentially problems with this matching over time. In addition, there are problems associated with the reporting units which may or may not increase the number of plants they report on in any one year (in practice though, this is not thought to be a large problem). Secondly, the geometric depreciation rate is assumed, so all assets are assumed to have a similar length of life. Also, no account has been taken of plant closures over time, which may also lead to distortion over time. Finally, the authors have note that there are some negative values within the capital stocks series. Whilst for this analysis these have been assumed equal to zero, this is indicative of a problem with the calculation method – probably the initial allocation of stocks.

Thus, whilst there are limitations to the approach used by Martin (2002), these are the data that are provided by the ONS as capital stock estimates for ABI data, and these are therefore adopted in this paper. Alternative calculation methods have been applied to ARD data, the production part of the ABI (Harris and Drinkwater, 2000); however these are only for plant and machinery, and are therefore not holistic enough to be used in the service sector as well, given the importance of other capital in services. In addition, these data are not readily available from the ONS.