ICT, Corporate Restructuring and Productivity

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Abstract:

We are motivated by attempts to understand the rapid growth in US productivity, particularly in ICT using sectors. We note that one of the largest changes in the US economy over the later part of the 1990s was the rapid growth in sectors that produce intermediate services, suggesting that a large number of US firms were restructuring and outsourcing services. The UK experienced some of these same changes, though to a lesser extent and with a delay. Using a nationally representative dataset at the establishment (line of business) level we find that the elasticity of output with respect to ICT is higher for firms that make greater use of outsourced services than other firms within their industry. This is consistent with the existence of complementarities between ICT and outsourced services. While we are not able to make causal inference from our results, the correlations prove interesting. We consider alternative explanations for this correlation, and find them less plausible.

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1. Introduction

Much attention has been paid to the fact that productivity growth rates in European economies have lagged behind the US, particularly since the mid-1990s. The empirical evidence points to the slower adoption of information and communication technologies (ICT) as a key factor in explaining the divergence in productivity growth, as the US experienced particularly strong productivity growth in sectors that use ICT intensively.[1] At the same time, one of the biggest recent changes to the US and UK economies has been the widespread restructuring of corporate activity, and in particular the rapid increase in business services outsourcing. This is evidenced by the rapid growth in employment in intermediate services-producing industries, which accounted for around a third of the total employment growth in the US and over 40% in the UK between 1995 and 2001.[2] These changes have been driven by a number of factors. Greater competitive pressures and rapidly changing technologies have meant that smaller and more adaptable firms are increasingly favoured by the market, so firms face incentives to scale down and specialise.[3] The rapid decline in the price of information and telecommunication technologies (ICT)[4] has meant that transactions that previously needed to be conducted face-to-face can now be conducted at arms-length,[5] thus it is now feasible to outsource services for which it was previously prohibitively expensive to do so.

[1] See, *inter alia*, Jorgenson (2001), Stiroh (2002), Oliner and Sichel (2002), van Ark et al (2002), Inklaar, O'Mahony and Timmer (2003), Van Ark and Piatkowski (2004).
[2] Authors' calculations using GGDC data on total persons engaged in employment. See also Goodman and Steadman (2002) and Abramovsky, Griffith and Sako (2004) for more detail analysis of the growth in business services.
[3] See, for instance, Milgrom and Roberts (1990), Athey and Schmutzler (1995) and Marin and Verdier (2003).
[4] See, *inter alia*, Jorgenson (2001).
[5] See, for instance, Feenstra (1998), Grossman and Helpman (2005), and Antras (2003).

ICT has increased the adaptability and compatibility of business services with the needs and technologies of the purchasers of these services. It has facilitated the ability of suppliers to customise services for individual clients needs, yet still concentrate activities in specialist firms and exploit returns to scale. For example, IBM's has moved towards providing "asset-based services, which are more repeatable, predictable and efficient than traditional labor-based services."[6] ICT also reduces the external transaction and coordination costs. Taken together, these factors mean that, by adopting ICT, firms face reduced costs and potentially increased benefits from outsourcing business services.

In this paper we explore whether ICT has played an important role in productivity growth through facilitating corporate *external* restructuring in the form of outsourcing the production of intermediate services. We use a large nationally representative cross-section of data at the line of business level for the UK. We find that the elasticity of output with respect to ICT is higher for firms that make greater use of outsourced services than other firms within their industry, which is consistent with complementarities between ICT and outsourced services. While we are not able to make causal inference from our results, the correlations prove interesting. We consider alternative explanations for this correlation, and find them less plausible.

The UK is an interesting place to investigate this question. It lags the US in productivity and ICT adoption, but has experienced faster growth in ICT capital stock than other European countries,[7] and the business services sector has substantially grown in the last decade.[8]

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[6] Tom Kucharvy, Summit Strategies, see http://www.summitstrat.com/assets/TK2oct05COL

[7] The US and the UK have higher ICT capital stock levels relative to total capital stocks than France and Germany, (author's calculations based on GGDC data).

[8] See Abramovsky, Griffith and Sako (2004).

This paper is related to several strands of the literature. There is a literature on the determinants of vertical integration and how changes in technology, in particular changes in ICT that decrease *external* coordination costs, may enable a move towards more disintegrated organization structures. The empirical literature on the determinants of outsourcing has largely focused on specific industries, and exploited variation in firm characteristics.[9] Recently, several papers have considered industry characteristics as determinants of organizational form.[10] Most of these empirical studies have focused on outsourcing of materials and have not looked explicitly at the relationship between changes in ICT adoption, outsourcing of services and productivity.

This paper also relates to the literature on ICT adoption, organizational change and productivity. This literature emphasises the role of ICT in enabling *internal* reorganisation, flexible management and decentralized structures within the firm or plant. Bresnahan, Brynjolfsson and Hitt (2002) is a key example using US firm level data.[11] Brynjolfsson and Hitt (2000, 2003) also discuss evidence of how computers contribute to business performance and economic growth, stressing the role of ICT-enabled internal reorganization of the firm. Further, they also suggest that ICT may have a role in changing the ways businesses interact with their suppliers, hence boosting productivity growth.

Our contribution in this paper is to use a nationally representative database to show that the empirical evidence is consistent with the ICT and *external* reorganisation, specifically the outsourcing of services, are complements in production.[12]

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[9] See survey in Klein (2004) and a recent example in Baker and Hubbard (2002).
[10] See, Antras (2003) and Acemoglu et al (2004).
[11] See also Caroli and Van Reenen (2001).
[12] In a previous paper, Abramovsky and Griffith (2005), we showed that firms that were more ICT intensive also purchased a greater amount of services in the market, and they were more likely to purchase offshore, when compared to less ICT intensive firms.

The remainder of the paper is structured as follows. The next section discusses our empirical approach and presents the data. Section 3 presents estimates of the correlation of ICT with productivity in the UK and their interaction with outsourcing of services. A final section concludes.

2. Empirical Approach and Data

2.1. Empirical Approach

We consider a production function of the form:

$$\tilde{y}_i = \alpha_l \tilde{l}_i + \alpha_k \tilde{k}_i + \alpha_c \tilde{c}_i + \alpha_s \tilde{s}_i + \alpha_g \tilde{g}_i + a_i, \quad (1)$$

where *i=1...N* index establishments, *y*: output, *l*: employment, *k*: total capital, *c*: information and communication technologies; *s*: purchased services, *g*: purchased goods, *a*: establishment specific productivity factor. The tilda (~) indicates that the variable is measured as the deviation from the industry mean, for example, $\tilde{y}_i = \ln Y_i - \ln Y_j$, where $\ln Y_j$ is the mean of the logged gross output across establishments in the 4-digit industry j. This controls for unobserved industry specific factors, including price deflators. All right-hand side inputs are transformed in the same way.[13]

We are interested in whether ICT and purchased services are complements. We therefore parameterize the output elasticity with respect to ICT as,

$$\alpha_c = \alpha_{c0} + \alpha_{cs} s_i . \quad (2)$$

We interpret a positive estimate of α_{cs} as evidence that ICT contributes more to productivity in establishments that outsource more services, consistent with the idea that there are complementarities between these two inputs.

[13] Girma and Gorg (2002), Gorg et al (2005) and Amiti and Wei (2006) look at international outsourcing (of services) and how it affects productivity using Ireland establishment level data and US industry level data respectively. They do not consider the interaction with ICT.

Our data spans three years, however, very few establishments are observed in more than one year (see data section). We therefore treat our data as a cross-section of establishments.[14] This means that we can not control for unobserved establishment specific productivity shocks. This is important to remember when interpreting our result. We include several observed characteristics, which we hope will help control for unobserved heterogeneity. We model the establishment specific productivity factor as composed of an establishment's age, whether the establishment is owned by a US multinational firm (*us*) or by a non-US multinational (*mne*), whether it is part of a group (*partg*), an indicator of the region the establishment is located (η_r, r indicates region), an indicator of the establishment's 4-digit industry (γ_j), year dummies (δ_t), (so that the variables in equation (3) below are also expressed as deviations from the industry and year mean), and a random shock (ε_{it}) with a general heteroskedstic structure.

$$a_i = \beta_{age} age_i + \beta_{us} us_i + \beta_{mne} mne_i + \beta_{partg} partg_i + \eta_r + \gamma_j + \delta_t + \varepsilon_i . \qquad (3)$$

We combine equations (1), (2), and (3) to derive our main empirical specification:

$$\begin{aligned} \tilde{y}_i = {} & \alpha_l \tilde{l}_i + \alpha_k \tilde{k}_i + \alpha_c \tilde{c}_i + \alpha_{cs} (\tilde{s}_i * \tilde{c}_i) + \alpha_s \tilde{s}_i + \alpha_g \tilde{g}_i + \\ & + \beta_{age} age_i + \beta_{us} us_i + \beta_{mne} mne_i + \beta_{partg} partg_i + \eta_r + \gamma_j + \delta_t + \varepsilon_i \end{aligned} \qquad (4)$$

Identification

Our main coefficient of interest is α_{cs}. We interpret a positive and significant coefficient as consistent with the idea that ICT and outsourcing of services are complements. Identification relies on establishments choosing different combinations of ICT and outsourcing of services for reasons being exogenous to productivity. This could either be because firms face different prices - for example, because of regional

[14] At the moment there are more than one observation for some establishments, we will collapse the observations such that we have one observation per establishment.

subsidies or regional variation in the role out of broad-brand coverage - or because firms respond different to the same price shocks - for example, because of heterogeneity in the adjustment cost function. While improvements in ICT are quickly available throughout the economy, firms may need some time to make other complementary changes to fully exploit the returns to ICT, due to the existence of frictions either in the firm itself or in the firms' environment. For example, the literature on ICT and *internal organization* suggests that these changes involve a move towards more flexible and flatter hierarchies within firms, which can also involve changing the skill mix of the firms' workforce through firing and hiring or even re-training the workers; and product and process innovation.[15] The outsourcing of services could also be subject to some frictions in the short run if firms need to search for the best supplier.

This is an example of the generally difficult problem of identifying the parameters of a production function.[16] What we present here can only be considered as correlations.

Athley and Stern (1998) also provide a recent consideration of how certain unobserved heterogeneity can yield a positive correlation between inputs in the production function, even if the choices do not interact in determining productivity - in particular when the unobserved returns to the different choices are positive correlated. Measurement error, on the other hand, will lead to attenuation bias on the estimated coefficients. Why would these correlations be present when there is no technological complementarity between factors? Bresnahan et al (2002, p355) discuss alternative interpretations. For example, firms that decide to become more flexible are more productive, and different ways to become more flexible involve investing in ICT as well

[15] See, for example, Brynjolfsson and Hitt (2000) for a summary of this literature and Bartel, Ichniowski and Shaw (2005) for an interesting industry-specific study.
[16] See, *inter alia*, Griliches and Mairesse (1998), and for more recent considerations see Blundell and Bond (2000); Bond and Soderbom (2005); and Ackerberg et al (2006).

as outsourcing services. An alternative explanation may be that ICT is complementary to skills and firms that outsource services outsource lower-skill intensive services; hence more ICT-intensive firms become more high skill intensive and productive.

Robustness

As discussed above, other papers in the literature have emphasised the role of ICT in facilitating internal restructuring. In particular, Bloom et al (2006) show that US multinationals have a higher output's elasticity of ICT. We investigate whether after allowing for the output's elasticity of ICT to vary with the level of purchased services, it is also the case that the US multinationals have a higher output's elasticity of ICT. We do this since it could be the case that the positive correlation we find between outsourcing services, investment in ICT and productivity is driven by establishments owned by US or other multinational firms that also invest more in ICT and are more productive as proposed by Bloom et al (2006):

$$\alpha_c = \alpha_{c0} + \alpha_{cs} s_i + \alpha_{c\,us} us_i + \alpha_{c\,mne} mne_i \qquad (5)$$

We also investigate whether the positive interaction between purchases of services and ICT investment is driven by an omitted interaction between ICT and other inputs by allowing more flexibility in the production function and interacting ICT with all the other inputs.

We carry out two further robustness checks. First, we allow all coefficients in the production function to vary across manufacturing and service sectors. Second, we use a different measure of ICT - the proportion of employees with a personal computer and internet access at the industry and size-band level. This allows us to investigate whether our results are robust to some types of potential measurement error in ICT. In addition, this alternative measures is at the industry and size-band level, so it may be

less correlated with the unobservable shocks at the establishment level that affect both productivity and the choice of inputs.

2.2 Data

Our main data are from the UK Office of National Statistics (ONS) and are at the establishment (line of business) level, they come from the ABI-ARD. We use a cross section of data on establishments operating in 2001, 2002 and 2003. We use a secondary dataset for an alternative (more aggregate) measure of ICT from the UK E-commerce Survey.

ABI-ARD data

The ABI-ARD data are a nationally representative stratified sample of establishments located in the UK.[17] Response is mandatory. Information is collected on inputs and output. Large establishments are sample every year, but small establishments are randomly selected. We only observe very few establishments in consecutive years, so we treat the data as a cross section of establishments. Establishments in the sample answer either a short or a long form. All establishments report total output, employment, total capital investment and total intermediate purchases. Only those that answered the long form report a breakdown of intermediate purchases in different goods and services and of capital investment in different types of assets, from which information for those answering the short form is imputed. We include an indicator of whether the establishment answered the long or short form in our regression analysis. A list of industries we use can be found in Table A.1 in the appendix.

Gross output Y is constructed using measured revenue in current thousands of pounds at the establishment level. Labour input L uses total workers employed at the

[17] See Barnes and Martin (2002) and Griffith (1999) for a description of the data. Agriculture and the financial sector are not included.

establishment level. Total capital input K is measured by the ONS - they construct a real capital stock series using investment data reported by establishments.

We measure outsourcing of services *s* using data on the establishment's intermediate expenditure on services. A list of the intermediate purchases included in our measure *s* is provided in the appendix. Other intermediate purchases are considered to be intermediate expenditure on goods *g*. These variables potentially include establishments' intermediate purchases from other establishments belonging to the same firm. We looked at this and found that almost all purchasers of services are firms which have no vertical relationship to an intermediate service producing establishment (thus the transaction must represent outsourcing). We also use a measure of total intermediate purchases (the sum of goods and services) *m*.

ICT is the investment in purchased computer software and in computer software developed by the establishment's own staff (in thousands of pounds). Software investment is included in the investments flows used to construct capital stock. This has the drawback that it does not contain information about total ICT expenditure (it excludes telecommunications equipment and computers) and it is a flow rather than a stock. However, it has the advantage that it is measured at the establishment level. From the data that we have it is not possible to construct software capital stocks.[18,19]

Other covariates at the establishment level include whether the establishment is owned by a non-US multinational, by a US multinational or is part of a multi-establishment firm, and the establishment's age.

[18] Data on computer capital stock for a panel of establishments is held by the ONS, and used for example in Bloom et al (2006), but we do not have access to it.

[19] Software is harder to measure but it appears to be more important than computer investment in the second half of the 1990s in the US as evidenced in Jorgenson (2001). In the US, only in 1999 meaningful measures of pre-packaged, custom and own-account software were included in the national accounts by the BEA.

Annual E-Commerce Survey

Our second measure for ICT comes from the ONS annual E-commerce survey.[20] We construct a measure of ICT usage at the 5-digit industry and size-band level: the proportion of employees with PC with internet access. For the few cases (around 10% of the sample) where we were not able to match the E-commerce data at the 5-digit and firm-size level, we use data at the 4-digit industry and firm size level.

Sample

Table 1 shows the sample of data on which we can estimate the production function. We start with 133,736 establishments in the ABI-ARD in 2001, 2002 and 2003. We clean the data by dropping those establishments with higher intermediated purchases than turnover and drop establishments with non-positive values of our main variables[21], leaving us with 44,001 establishments. These establishments are on average larger in terms of turnover and number of employees than those in the original sample, they have higher value-added per employee and lower capital per employee.

[Table 1 here]

2.3 Descriptive statistics

Table 2 provides descriptive statistics for our sample. The median establishment employs 46 workers, which indicates that the sample contains a significant proportion of small firms. The mean establishment employs 261 workers, indicating the presence of a few very large establishments. On average, establishments' software investment as a share of gross output is around 0.5%, though the distribution is very skewed, as indicated by the percentile 75 being 0.4%. Over 10% of the establishments have a share

[20] This is a statutory postal survey of 9,000 businesses randomly sampled from the Inter-departmental Business Register (stratified by employment size). The sampling methodology ensures wide coverage of the UK economy and the estimates produced cover almost all private sectors.

[21] We also exclude 20 observations with values of software investment as a share of gross output greater than 0.5. But including those observations does not alter our main results.

of at least 1%, and the top 1% of the distribution has a share of at least 6%, the maximum is almost 50%. As a reference point, we take the figure for software capital stock as a share of value-added reported by Basu et al (2003) using aggregate data for the UK economy, which is around 2.6% in 2000. To compare it to our software revenue share we have to take into account that their measure differs in three main ways from our measure. They use software capital stock instead of investment flows; they multiply the software investment flows by three to construct the software capital stock; and their denominator is valued-added, whereas we use gross output. Taken together, our figure for the UK looks reasonable compared to Basu et al (2003).

On average, establishments purchase three times more intermediate goods than services, as a share of gross output. There are 4% of establishments that are owned by US firms, and around 8% owned by other foreign firms. This is similar to the proportions Criscuolo and Martin (2004) report use ARD data for the years 1996-2000.

[Table 2 here]

Table 3 reports descriptive statistics splitting the sample into manufacturing and services industries. As expected, the manufacturing industries purchase fewer services as a share of gross output. Services industries invest more in ICT than the manufacturing industries (the means are statistically different at the 1% confidence level).

[Table 3 here]

3. Results

We now turn to consider estimates of equation (4). All our results are estimated using Ordinary Least Square. As mentioned in section 2.1, results should be interpreted as correlations rather than causal relationships since, for example, common unobserved factors may determine the investment or use of ICT and how much services the

establishment purchase simultaneously with productivity, or there may be reverse causation from the level of productivity to ICT adoption or purchases of services.

3.1. Main results

Table 4 shows our main results. We start by presenting estimates of a baseline production function in column 1, which includes total intermediate materials purchased, capital and labour and the set of control variables specified in equation (4). The estimates of the coefficients on all inputs are positive and significant, and reasonable compared to other empirical studies.[22] In column 2 we split total intermediate materials purchased in intermediate services and intermediate goods purchased. The coefficient on labour remains the same, though the coefficient on capital goes up considerably, and the coefficient on goods purchased is considerably lower than its average revenue share (reported in Table 2). In column 3, we include ICT (measured as investment in software) in the regression, and this does not change the coefficients on the other inputs. The estimated elasticity of output with respect to ICT is 0.01. This can be compared to the average revenue share of ICT of 0.005 (Table 2), the magnitude of the estimated coefficient suggests higher than normal return.[23, 24]

The empirical literature about the returns to ICT has found in general that ICT exhibits higher than normal returns using computer stock as a measure of ICT and micro data for the US up to 1995 and the UK from 1995 onwards. For example, Bresnahan, Brynjolfsson and Hitt (2002) report an estimated IT elasticity that

[22] See, for example, Blundell and Bond (2000).
[23] Under the assumption of perfect competition in the factors and product markets, in the long run the parameters α for each input are going to be equal to their revenue shares, hence yielding "normal returns".
[24] One measurement reason why ICT may exhibit higher than normal returns is that we are measuring ICT with investment in software. This could generate an upward bias in the estimated elasticity since it may be capturing not only the contribution of software to productivity but also the contribution of closely related capital stock as telecommunication and computer capital stock.

corresponds to higher than normal returns to IT. Bloom et al (2006) report an elasticity of around 0.04 with an average revenue share of 0.01.[25]

Column 4 shows our main result. The coefficient on the interaction of the level of ICT with the level of purchases of services is positive and significant, with a magnitude of 0.004 and a standard error of 0.001. This is consistent with the existence of complementarities between ICT and purchasing of services, in a way that it is positively associated with productivity. In terms of output's elasticity with respect to ICT, this suggests that an average establishment regarding purchases of services has an ICT contribution to productivity of 0.008, but this is positively correlated with purchased services: the same figure is 0.002 for an establishment located in the 25th percentile of the distribution of purchased services and 0.014 for an establishment located in the 75th percentile of the same distribution.[26]

In the final two columns of Table 4 we allow all coefficients to vary across manufacturing and services industries. The coefficient on the interaction between ICT and purchases of services is positive and significant in both manufacturing and services sectors and its magnitude is the same as in column 3 of Table 4.

The ICT elasticity for an establishment with average purchases of services relative to its industry mean is positive and significant for both sectors, though higher in manufacturing (0.014) than in services (0.005). This is surprising since on average, services establishments are more ICT intensive than manufacturing establishments (Table 3).

[Table 4 here]

[25] Stiroh (2004) and Brynjolfsson and Hitt (2003), among others, discuss evidence consistent with higher than normal returns for computer capital stock.
[26] The reference distribution is the distribution of the services transformed as log deviations from the year and industry mean, i.e. s_t.

3.2. Multinationals establishments

In Table 5 we allow the output elasticity of ICT to vary with the purchases of services and with the ownership status of the establishment, as indicated by equation (5). Column 1 shows a production function where only the level of ICT is included, the coefficient on US ownership is positive and significant, the productivity advantage of US-owned establishment is higher that what has been found in other studies (Bloom et al, 2006 and Criscuolo and Martin, 2003) but this could be because the reference group in our sample include a higher proportion of small establishments than in these other studies. As in these studies, US-owned multinationals are more productive than establishments owned by non US multinationals. The coefficient on the interaction between ICT and ownership is only positive and significant for the US but not for other multinationals, consistent with the evidence found by Bloom et al (2006). Column 3 shows that once we allow the output's elasticity of ICT to vary with purchases of services and ownership, our findings suggest that it varies positively with the purchases of services but US ownership is not longer associated with a higher contribution of ICT to productivity. The same holds when we split our sample in manufacturing and services industries, as shown in columns 4 and 5. It may be that the advantage of US establishments is that they are better at exploiting ICT, one reason being that they may be more able to restructure *externally*, and thus have higher purchases of services.

[Table 5 here]

3.3. Interaction of ICT with other inputs

Table 6 shows the results when we allow the output's elasticity of ICT to vary with the use of all inputs. Again, the coefficient on the interaction of ICT with purchases of services is positive and significant when looking at all firms (column 1),

but this is driven by services (column 3), since the interaction is no longer significant when looking at manufacturing. So the evidence suggests that the complementarities between outsourcing of services and ICT may be more prevalent in services than in manufacturing establishments

The fact that our main result holds up for services after allowing the output's elasticity with respect to ICT to vary with establishments' labour usage is reassuring. There is empirical evidence that ICT is complementary to skilled labour[27] and one can think that the positive correlation between ICT, outsourcing of services and productivity showed in Table 4 might be driven by the complementarily between skills and ICT. This may be the case if firms outsourcing services are outsourcing unskilled labour-intensive services, hence becoming more skill intensive and more productive. Table 6 shows that we find a negative and significant coefficient on the interaction between ICT and labour is, consistent with these inputs being substitutes. This could be driven by the unskilled labour. To explore further this explanation, data on the skill content of establishments' workforce is needed.

The implied ICT elasticity for an establishment with average purchases of services and goods and average employment, capital stock and software is the coefficient on the level of ICT; i.e. 0.008 in column 1; 0.013 in column 2; and 0.006 in column 3.

[Table 6 here]

3.4. Alternative measure of ICT

Finally, Table 7 shows our results using our alternative measure of ICT, the proportion of employees with a PC and internet access, which is a variable at the industry and size band level. Since this is an aggregate variable, we avoid transforming

[27] See, for instance, Bresnahan, Brynjolfsson and Hitt (2002) and Bartel, Ichniowski and Shaw (2005).

the variable as a log deviation from the industry-year mean since we would get rid of almost all the variation in the variable. So, instead, we include all inputs in logs and put industry and year dummies as before. Column 1 shows the results including the level of ICT and columns 2 shows the results allowing the output's elasticity of ICT to vary with the level of purchased services. Column 2 shows that the interaction between ICT and purchases of services is robust to using an alternative measure of ICT.

[Table 7 here]

4. Summary and Conclusions

In this paper we explore whether ICT has played an important role in productivity growth through facilitating corporate *external* restructuring in the form of outsourcing the production of intermediate services. We use a large nationally representative cross-section of data at the line of business level for the UK. We find that the elasticity of output with respect to ICT is higher for firms that make greater use of outsourced services than other firms within their industry, which is consistent with complementarities between ICT and outsourced services. We investigate whether these results are due to other alternative explanations by allowing more flexibility in the production function that allow the elasticity of ICT to vary with other characteristics such as ownership and other inputs. Our main result, that ICT and services outsourcing are complements, holds up.

These findings may help to explain the slower productivity growth in EU countries over recent years. A concern in European economies has been the slow uptake of ICT and how this may impact on productivity growth.[28] Many papers have shown that slower growth in EU countries is concentrated in industries which are ICT-

[28] See, for instance, van Ark et al. (2002) and Basu et al. (2003).

intensive in the US. ICT capital stock in the EU is lower than in the US. We also see that business service sectors in EU countries are smaller than in the US.[29] What we identify are correlations that are consistent with the idea that lower ICT investment has held back productivity growth in EU countries because firms have not been able to exploit its full returns due to frictions in complementary changes such as corporate restructuring (or that some other factor has inhibited corporate restructuring so that firms have not invested in ICT).

These correlations are only suggestive, and further work needs to investigate identification issues (simultaneity and unobserved heterogeneity), consider differential patterns across services versus manufacturing, and use a better measure of ICT. Furthermore, alternative explanations might be explored such as the role of skills complementarities with ICT.

[29] See C. Pissarides (2006), "What future for European jobs?", Centre Piece, Volume 11, Issue 1, Summer 2006.

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Table 1: Samples description

	N	*Turnover/revenue (£ 0,000)*	*Employment (People employed)*	*Turnover per employee (£0,000 per worker)*	*VA per employee (£0,000 per worker)*	*Capital per employee (£0,000 per worker)*
All establishments 2001-2003	133,736	*23,116*	*173*	*419*	*75*	*171*
+ w/ positive turnover	132,326	23,363	174	423	103	151
+ w/ positive employment	132,232	23,373	175	423	103	151
+ w/positive total intermediate purchases	128,061	23,930	179	399	69	155
+w/costs<turnover	113,274	22,508	176	327	142	106
+ w/positive total capital stock	94,929	26,251	204	373	160	128
+ w/positive purchases of services and goods	92,085	26,733	208	341	140	123
+w/investment in software	46,757	32,109	250	200	87	137
+w/E-commerce data	44,001	33,638	261	204	89	134
= Main sample						
Long form	12,576	101,277	784	404	188	268
Short form	31,425	6,569	52	124	49	81

Source: ONS, ARD-ABI. Descriptive statistics are for years 2001, 2002 and 2003.

Table 2: descriptive statistics for main sample

Variable		*Mean*	*Sd*	*Median*	*P25*	***P75***
Gross output	Y	33,638	296,497	3,760	785	14,271
Number of employees	L	261	2,157	46	13	142
Employment cost	L cost	5,696	45,674	904	201	3,194
	L cost /Y	0.271	0.192	0.238	0.127	0.374
Capital stock	K	24,115	293,621	1,561	290	7,859
	K/Y	0.982	40.729	0.540	0.197	0.960
Intermediate purchases	M	20,149	190,259	1,820	289	7,990
	M/Y	0.536	0.255	0.556	0.335	0.742
Services purchased	S	5,585	77,907	390	67	1,712
	S/Y	0.146	0.135	0.107	0.061	0.183
Goods purchased	G	14,564	157,938	1,032	138	5,373
	G/Y	0.390	0.260	0.382	0.155	0.598
Software investment	ICT	125	2,466	3	1	19
	ICT/Y	0.005	0.017	0.001	0.000	0.004
Proportion of employees with PC and internet access	PCINT	37	27	31	14	54
	PCINT/Y	0.111	0.494	0.006	0.001	0.035
Age	Age	9	7	6	5	8
UK single	UK single	0.666				
UK group	UK group	0.154				
UK multi	UK multi	0.062				
US	US	0.040				
Other foreign	Other foreign	0.078				

Source: ONS, ARD-ABI. Number of observations: 44,001. All nominal variables are in thousands of pounds. Descriptive statistics are for years 2001, 2002 and 2003.

Table 3: Descriptive statistics for manufacturing and services

Variable		*Manufacturing*		*Services*	
		Mean	Sd	Mean	Sd
Gross output	Y	33,366	151,089	33,146	342,175
Number of employees	L	237	475	277	2,621
Employment cost	L cost	6,014	14,774	5,552	54,767
	L cost /Y	0.280	0.137	0.268	0.210
Capital stock	K	26,857	119,684	20,497	318,247
	K/Y	0.955	0.885	1.033	49.971
Intermediate purchases	M	20,115	86,668	19,710	219,771
	M/Y	0.570	0.198	0.522	0.275
Services purchased	S	4,114	15,434	5,681	80,789
	S/Y	0.124	0.077	0.161	0.154
Goods purchased	G	16,001	76,535	14,029	186,649
	G/Y	0.447	0.180	0.362	0.285
Software investment	ICT	74	388	137	2,791
	ICT/Y	0.003	0.008	0.006	0.020
Proportion of employees with PC and internet access	PCINT	28	21	41	28
	PCINT/Y	0.033	0.391	0.141	0.530
Age	Age	15	8	6	4
UK single	UK single	0.449		0.748	
UK group	UK group	0.203		0.132	
UK multi	UK multi	0.129		0.036	
US	US	0.080		0.027	
Other foreign	Other foreign	0.138		0.058	
Observations		11,964		29,225	

Source: ONS, ARD-ABI. All nominal variables are in thousands of pounds. Descriptive statistics are for years 2001, 2002 and 2003.

Table 4

	(1)	(2)	(3)	(4)	(5)	(6)
Sector	All	All	All	All	Manufacturing	Services
Dependant variable: ln (Gross output) $_i$						
ln $(L)_i$	0.353	0.366	0.364	0.360	0.326	0.364
Labour	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.010)**	(0.006)**
ln $(K)_i$	0.148	0.211	0.203	0.205	0.176	0.215
Capital	(0.005)**	(0.005)**	(0.006)**	(0.006)**	(0.010)**	(0.008)**
ln $(M)_I$	0.468					
Material	(0.006)**					
ln $(S)_i$		0.161	0.161	0.162	0.143	0.155
Services		(0.005)**	(0.005)**	(0.005)**	(0.011)**	(0.005)**
ln $(G)_i$		0.237	0.238	0.240	0.329	0.226
Goods		(0.005)**	(0.005)**	(0.005)**	(0.013)**	(0.006)**
ln $(ICT)_i$			0.010	0.008	0.014	0.005
ICT			(0.002)**	(0.002)**	(0.002)**	(0.003)*
ln $(ICT)_i$ *ln $(Services)_i$				0.004	0.006	0.004
				(0.001)**	(0.001)**	(0.001)**
Observations	44,001	44,001	44,001	44,001	11,964	29,225
R-squared	0.94	0.93	0.93	0.93	0.95	0.93

Source: Authors' calculations using the ABI-ARD for years 2001-2003.

Note: Robust standard errors are in parentheses; * significant at 5%; ** significant at 1%. Variables are transformed as log deviations from the mean at 4-digit industry level. All regressions include region dummies; year dummies; 4-digit industry dummies; establishment's age, whether it is part of a group, owner by a multinational US firm or other multinational firm; whether it answered the long form questionnaire.

Table 5

	(1)	(2)	(3)	(4)	(5)
Sector	All	All	All	Manufacturing	Services
Dependant variable: ln(Gross output)$_i$					
ln (L)$_i$	0.364	0.364	0.361	0.326	0.364
Labour	(0.005)**	(0.005)**	(0.005)**	(0.010)**	(0.006)**
ln (K)$_i$	0.203	0.203	0.204	0.176	0.215
Capital	(0.006)**	(0.006)**	(0.006)**	(0.010)**	(0.008)**
ln (S)$_i$	0.161	0.162	0.162	0.143	0.155
Services	(0.005)**	(0.005)**	(0.005)**	(0.011)**	(0.005)**
ln (G)$_i$	0.238	0.239	0.241	0.329	0.227
Goods	(0.005)**	(0.005)**	(0.005)**	(0.013)**	(0.006)**
ln (ICT)$_i$	0.010	0.009	0.009	0.014	0.008
ICT	(0.002)**	(0.002)**	(0.002)**	(0.003)**	(0.003)**
ln (ICT)$_i$ *ln (Services)$_i$			0.005	0.006	0.005
			(0.001)**	(0.001)**	(0.001)**
US$_i$	0.175	0.154	0.159	0.101	0.207
	(0.013)**	(0.014)**	(0.014)**	(0.014)**	(0.028)**
US$_i$*ln(ICT) $_i$		0.017	0.005	0.005	-0.000
		(0.006)**	(0.006)	(0.007)	(0.009)
MNE$_i$	0.122	0.118	0.125	0.046	0.218
	(0.008)**	(0.009)**	(0.009)**	(0.009)**	(0.017)**
MNE$_i$*ln(ICT) $_i$		0.003	-0.009	0.001	-0.024
		(0.003)	(0.004)*	(0.004)	(0.006)**
Observations	44,001	44,001	44,001	11,964	29,225
R-squared	0.93	0.93	0.93	0.95	0.93

Source: Authors' calculations using the ABI-ARD for years 2001-2003.

Note: Robust standard errors are in parentheses; * significant at 5%; ** significant at 1%. Variables are transformed as log deviations from the mean at 4-digit industry level. All regressions include region dummies; year dummies; 4-digit industry dummies; establishment's age, whether it is part of a group, owner by a multinational US firm or other multinational firm; whether it answered the long form questionnaire.

Table 6

	(1)	(2)	(3)
Sector	All	Manufacturing	Services
Dependant variable: ln (Gross output) $_i$			
ln $(L)_i$	0.360	0.316	0.367
Labour	(0.005)**	(0.010)**	(0.006)**
ln $(K)_i$	0.196	0.177	0.202
Capital	(0.006)**	(0.009)**	(0.007)**
ln $(S)_i$	0.159	0.152	0.152
Services	(0.005)**	(0.011)**	(0.005)**
ln $(G)_i$	0.255	0.326	0.244
Goods	(0.005)**	(0.013)**	(0.006)**
ln $(ICT)_i$	0.008	0.013	0.006
ICT	(0.002)**	(0.002)**	(0.003)*
ln $(ICT)_i$ *ln $(Services)_i$	0.026	0.006	0.028
	(0.002)**	(0.005)	(0.002)**
ln $(ICT)_I$ *ln $(Labour)_i$	-0.034	-0.026	-0.036
	(0.002)**	(0.004)**	(0.003)**
ln $(ICT)_i$ *ln $(Capital)_i$	0.015	0.016	0.016
	(0.002)**	(0.005)**	(0.003)**
ln $(ICT)_i$ *ln $(Goods)_i$	-0.012	0.005	-0.015
	(0.002)**	(0.006)	(0.003)**
Observations	44,001	11,964	29,225
R-squared	0.93	0.95	0.93

Source: Authors' calculations using the ABI-ARD for years 2001-2003.

Note: Robust standard errors are in parentheses; * significant at 5%; ** significant at 1%. Variables are transformed as log deviations from the mean at 4-digit industry level. All regressions include region dummies; year dummies; 4-digit industry dummies; establishment's age, whether it is part of a group, owner by a multinational US firm or other multinational firm; whether it answered the long form questionnaire.

Table 7

	(1)	(2)	(3)	(4)
Sector	All	All	Manufacturing	Services
Dependant variable: ln (Gross output) $_i$				
ln $(L)_i$	0.366	0.366	0.331	0.370
Labour	(0.005)**	(0.005)**	(0.010)**	(0.006)**
ln $(K)_i$	0.212	0.211	0.181	0.219
Capital	(0.005)**	(0.005)**	(0.010)**	(0.007)**
ln $(S)_i$	0.161	0.144	0.126	0.135
Services	(0.005)**	(0.006)**	(0.012)**	(0.007)**
ln $(G)_i$	0.236	0.237	0.325	0.223
Goods	(0.005)**	(0.005)**	(0.013)**	(0.006)**
ln(PCINT)	0.013	-0.015	-0.023	-0.012
PC per employee	(0.003)**	(0.008)	(0.019)	(0.010)
ln(PCINT) *ln(Services) $_i$		0.005	0.006	0.006
		(0.001)**	(0.003)*	(0.002)**
Observations	44,001	44,001	11,964	29,225
R-squared	0.95	0.95	0.96	0.94

Source: Authors' calculations using the ABI-ARD for years 2001-2003.

Note: Robust standard errors are in parentheses; * significant at 5%; ** significant at 1%. All regressions include region dummies; year dummies; 4-digit industry dummies; establishment's age, whether it is part of a group, owner by a multinational US firm or other multinational firm; whether it answered the long form questionnaire. The variable PCINT is at the employment 5-size band and 5-digit industry level.

Appendix

Table A.1.Industries included in the analysis

sic code	Description	Sample size
Manufacturing		
15	Food Products and Beverages	1,177
17	Textiles	407
18	Wearing Apparel; Dressing and Dyeing of Fur	173
19	Tanning and Dressing of Leather	68
20	Wood And Products of Wood	228
21	Pulp, Paperand Paper Products	589
22	Publishing, Printing and Reproduction of Recorded Media	1,097
23	Coke, Refined Petroleum Products and Nuclear Fuel	34
24	Chemicals and Chemical Products	879
25	Rubber and Plastic Products	931
26	Other Non-metallic Mineral Products	458
27	Basic Metals	414
28	Fabricated Metal Products, Except Machinery and Equipment	1,162
29	Machinery and Equipment Not Elsewhere Classified	1,168
30	Office Machinery and Computers	138
31	Electrical Machinery and Apparatus Not Elsewhere Classified	543
32	Radio, Television and Communication Equipment	383
33	Medical, Precision and Optical Instruments	522
34	Motor Vehicles, Trailers and Semi-trailers	499
35	Other Transport Equipment	285
36	Furniture; Manufacturing Not Elsewhere Classified	733
37	Recycling	76
	Total	11,964
Services		
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles;	2,605
51	Wholesale	6,436
52	Retail	4,011
55	Hotels and Restaurants	2,759
60	Land Transport; Transport Via Pipelines	1,390
61	Water Transport	76
62	Air Transport	85
63	Supporting And Auxiliary Transport Activities; Activities Of Travel Agencies	1,114
64	Post and Telecommunications	387
71	Renting of Machinery and Equipment Without Operator and of Personal and Household Goods	515
72	Computer and Related Activities	1,610
73	Research and Development	181
74	Other Business Activities	8,056
	Total	29,225
Other		
40	Electricity, Gas, Steam and Hot Water Supply	75
41	Collection, Purification and Distribution of Water	26
45	Construction	2,711
	Total	2,812

Services purchased include (the code in parenthesis refers to the question in the ABI questionnaire):

- payment for hiring, leasing or renting plant, machinery and vehicles (wq405);
- commercial insurance premiums (wq406);
- purchases of road transport services (wq407);
- purchases of telecommunications services (wq408);
- purchases of computer and related services (wq409) – excludes hardware and software included in investment flows;
- purchases of advertising and marketing services (wq410);
- other services purchased (wq411);
- purchases of services for resale without processing (wq433);
- payment to employment agencies for agency staff (wq430)