Are foreign firms more technologically intensive?

UK establishment evidence from the ARD

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ABSTRACT

This paper employs establishment level data from the ARD (Annual Respondents Database) to consider technological differences between establishments operating in the UK. We adopt very precise measures of technology, arguably much more detailed than have hitherto been employed to address the key question of whether use of technology differs by nationality. After numerous controls we find that typically North American establishments have a higher probability of being more technologically intensive than their UK counterparts. This result also stands up in panel analysis.

JEL Classification: F23, O20

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I. Introduction

The purpose of this paper is to examine some of the differences in the use of new technology between foreign and domestically owned firms in the UK. It is a common held assertion that foreign multinationals are more technologically intensive than the domestic sector. Indeed, this assertion is often used to explain the reported productivity differences between the sectors, see for example Davies and Lyons (1991), or Griffith and Simpson (2002). Equally, there is a large literature that seeks to determine the scale and scope of productivity spillovers resulting from inward FDI,[i] the justification for this being the assumption that the foreign owned sector is more technology intensive. An investigation of this assumption, as well as identifying specific technologies is the principal motivation for this paper.

This paper proceeds as follows: The remainder of this section discusses the motivation for the paper, along with various assumptions concerning technology differences between different types of firms in the literature. Section II presents an empirical model to consider technology differences, and section III discusses the data used. The remaining sections are then devoted to the results and conclusions.

The importance of technology in explaining FDI flows

Most explanations of FDI follow Dunning's (1979) seminal paper essentially assuming that in order to enter a foreign country successfully a firm must possess some form of firm-specific advantage over host country firms. In general, these "ownership advantages" have been interpreted as technological advantages, and as such this argument has formed the basis for comparisons between foreign and domestic firms in a given location. While firm-specific advantages as Dunning (1958) originally presents them incorporate more than a firm's technological capacity, it is these that have been the focus of subsequent extensions to the analysis of FDI. Numerous authors have attempted to demonstrate that firm specific technology is an important determinant of international production. This is an argument that goes back to Caves (1974), though more recently is expressed by Cantwell (1989), Pearce (1993) or Love (2003), who each relate FDI flows to technology.[ii] There is a large literature that seeks theoretically to link international technology transfer to FDI flows, though the number of papers that seek to test this relationship empirically is rather limited, see for example Neven and Siotis (1996), van Pottelsberghe de la Potterie and Lichtenberg (2001).

Typically, work that seeks to determine the scale and scope of productivity spillovers, from FDI treats FDI as an exogenous event and inward investors as a homogeneous group. Greater understanding of technology differences, not only between inward investors and domestic firms, but also between inward investors from different countries will inform the large spillovers literature, which is rather contradictory in its findings. For further discussion of this see Görg and Ströbl (2001). In addition, comparisons of productivity between foreign and domestic plants, such as those by Oulton (2001) and Griffith (1999), suggest that there is a total factor productivity component in the foreign productivity differential, though the determinants of this remain unexplored. Griffith and Simpson (2002) demonstrate that foreign firms have higher levels of skill-intensity than domestic firms, and therefore that their productivity is higher. Furthermore, it is increasing in age and in size. This suggests that the older (typically North American) firms in the UK have higher levels of productivity than do the newer inward investors from Europe and South East Asia.

As far as we are aware, there is no analysis for the UK which has sought to examine the nature of technology used by domestic and foreign firms, and this is one of the key aims of this paper. We will identify differences in technology intensity across different nationalities of foreign firms relative to their UK counterparts. The work of Griffith (1999), Oulton (2001) and Griffith and Simpson (2002) highlights the importance of firm level characteristics in technology and productivity studies, and therefore the necessity of treating inward investors as a heterogeneous rather than homogenous group. The aim of this paper therefore is to focus on precise measures of technology, and explain differences across firms, rather than to repeat studies that seek to measure (though largely not to explain) variations in total factor productivity. Our contribution to this literature is to employ the same data as others, but exploit information on computer usage and R&D expenditure.

The literature discussed above has essentially assumed that the productivity or technological differential between the foreign and domestic sectors of the UK is uni-directional. This however may not be the case. As is well documented, a high proportion of inward investment in the UK is attracted (possibly by subsidy) to areas of high unemployment and the commensurate availability of unskilled labour at relatively low cost. It is possible, therefore, that such operations may employ less new technology than average. It is often assumed for example that because many Japanese and South East Asian owned enterprises in the UK are in the consumer electronics sector that such establishments are technologically advanced. However, if these firms were attracted to the UK due to low labour costs, and a presence within the EU, then they may be less technologically advanced (within the UK) than the average.

Further, theoretical approaches to FDI in recent years have turned to the possibility of so called "technology sourcing" that is that FDI occurs not to exploit advantages generated in the home country, but to access technology that is generated in the host country.[iii] It is possible therefore that, in a given host region, foreign owned enterprises may not be the most technologically advanced firms in a given sample.

The contrast between the long held assumptions regarding FDI and the true characteristics of inward investors in the UK highlights the importance of this issue for policy makers. This is particularly pertinent when one considers that inward investment receives a greater level of subsidy than domestic investment. While the rationale for the subsidy is employment generation, the notion of technology transfer from (superior) foreign firms to domestic ones is also stressed [see Eltis (1996)]. As a result, much of the work on the policy considerations surrounding inward investment has focused on linkages between foreign and domestic firms, or on employment creation, rather than focusing on identifying the technology that FDI introduces into the UK and such technological advantages that inward investors may possess.

The data we employ allows us to focus explicitly on specific types of technology, in particular computer equipment and employees using computers at their workplace, as well as a binary indicator asking establishments whether they employ any workers for R&D purposes.[iv] The motivation for the empirical model presented in the following section is designed to compare the employment of technology, not only between foreign and domestic plants, but also to offer an analysis of differences within the foreign owned sector.

II. An empirical model of technology intensity

In order to evaluate the technological differences between foreign and domestic firms, we construct an empirical model of technology intensity at the establishment level, similar in design to the previous work of Oulton (2001) and Griffith and Simpson (2002). Defining technology intensity $Tech$, constructed from computer based definitions (continuous variables) we estimate the following panel regression across establishments f and time t:

$$log(Tech)_{ft} = a_1 + \pi_1 \boldsymbol{C}_{ft} + \lambda_1 g(Size)_{ft} + \mu_1 h(Age)_{ft} + \beta_1 Capital_{ft}$$

$$+ \varphi_1 Skill_{ft} + \gamma_1 Parent_{ft} + \psi_1 \boldsymbol{AA}_{ft} + \theta_1 \boldsymbol{Z}_{ft} + \delta_1 \boldsymbol{I}_{ft} + \varepsilon_f + \upsilon_{ft} \qquad (1)$$

$$corr\left[\varepsilon_{ft}, \varepsilon_{fs}\right] = \rho = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \sigma_\upsilon^2},\ t \neq s$$

where $f=1 \ldots F,\ t=1986,1988$, $Tech$ is defined as either the log of computer equipment purchases divided by net capital expenditure; or as the log of computer employees intensity defined by weighting the computer measure by total employees, $\boldsymbol{C}$ is a vector of country dummies (with the UK as the reference category), $Size$ is measured by employment, entered as a quadratic $g(\bullet)$, Age is the establishments age, also entered as a quadratic $h(\bullet)$. The variable $Capital$ is a measure of the establishments capital stock[v] and $Skill$ is a dummy variable indicating whether the establishment employs a higher proportion of skilled workers (non-operatives) than the four digit average. The remaining variables are a vector of regional dummies given by $\boldsymbol{Z}$, and a vector of 4 digit industry dummies based on 1980 sic codes given by $\boldsymbol{I}$, *Parent* is a dummy variable indicating whether the establishment is the parent company and $\boldsymbol{AA}$ is a vector of assisted area dummy variables indicating whether the firm is located in either an intermediate or development assisted area.

From the error terms, ρ represents the proportion of the total variance contributed by the panel level variance component. Equation 1 is estimated by random effects,[vi] see section III for a further discussion, which allows us to establish how much of the variation in the data can be explained by unobservable intra-establishment correlations.

The data we use are taken from the ARD (Annual respondents Database) which is a panel data set following establishments over time (although some enter and exit, so the panel is unbalanced – see section III). We have specific measures of technology for 1986, 1988 and 1992. For 1986 and 1988 we have information on computer intensity defined as above. However, neither of the computer variables is reported for 1992, rather the only information given on technology is specified by a binary digit to indicate whether the plant engages in formal R&D. Consequently, in 1992 the following is estimated:

$$T1_f^* = a_2 + \pi_2 \boldsymbol{C}_f + \lambda_2 g(Size)_f + \mu_2 h(Age)_f + \beta_2 Capital_f + \varphi_2 Skill_f$$
$$+ \gamma_2 Parent_f + \psi_2 \boldsymbol{AA}_f + \theta_2 \boldsymbol{Z}_f + \delta_2 \boldsymbol{I}_f + \varepsilon_f = \Phi \boldsymbol{X}_f + \varepsilon_f \qquad (2)$$

Where f represents the establishment, $T1_f^*$ is a latent variable and $T1$ is its observed counterpart technology defined by a binary digit indicating whether any workers are involved in research and development at the establishment f:

$$T1_f = \begin{cases} 1 \ \ if \ \ T1_f^* > 0 \\ 0 \ \ otherwise \end{cases} \tag{3}$$

Equation 2 is estimated as a logit model where the probability of the technology state conditional upon the independent variables is given as:

$$E\left(T1_f = 1|\boldsymbol{X}\right) = \frac{\exp(\Phi \boldsymbol{X})}{1 + \exp(\Phi \boldsymbol{X})} \tag{4}$$

From each of the above empirical models, the key features of interest are: (i) whether foreign establishments are more likely to be technologically intensive than their UK counterparts; and (ii) to provide evidence on the nationality of these establishments.

III. Data

The Annual Respondents Database (ARD) contains micro-data collected by the Office for National Statistics in the Annual Census of Production and, from 1998, is known as Annual Business Inquiry (ABI). Access is allowed only under contract and is subject to strict conditions. We focus on the years 1986, 1988 and 1992 for the reasons stated above. This data source has been described at length in Griffith (1999) and Barnes and Martin (2002) so only a brief discussion is given here. It covers the whole of the production sector though for consistency in this paper we consider only manufacturing (sic 1980 divisions 2 to 4). The most basic unit reported in the ARD is known as the “local unit” defined as a plant or office operating at a single location. An enterprise code is given which assigns local units (and establishments) to a common owner. Establishments consist of at least one local unit. Most of the data contained in the ARD relates to the establishment and this is our basic unit of observation.[vii] In common with most users of these data, Haskel and Heden (1999), Girma and Wakelin (2001), Oulton (2001) and Griffith and Simpson (2002), we focus on “selected” establishments only, that is, those required by law to fill in a return for the ONS. Only establishments employing more than twenty workers are included in the analysis. The focus herein is on incorporated or company classified establishments (see Griffith, 1999).

The ARD provides information on the nationality of ownership which allows foreign owned establishments to be distinguished from UK firms. In the data foreign affiliates are those establishments where at least 20% is owned by an overseas interest. The data also has the advantage that it reports the nationality of ownership in every year.

One of the disadvantages of using the ARD is that capital stock data is not reported, rather it has to be constructed. To do this we follow Disney *et al.* (2003) by using the perpetual inventory method at the establishment level estimated from the level of investment in plant and machinery, vehicles and buildings with starting values and depreciation rates taken from O'Mahony and Oulton (1990). To derive capital stock measures in real terms two digit industry deflators were used for buildings and plant and machinery. Vehicles were deflated by annual deflators.

Tables 1 to 3 show technology intensity (defined by computer equipment, computer employees in 1986 and 1988 both continuous variables, and an R&D employee indicator in 1992), establishment size and the percentage of skilled workers[viii] in the raw data across countries for each year. Tables 1 and 2 demonstrate that there is a much higher level of computer usage, in terms of equipment and employment intensity, across North American plants, whilst establishments which are owned by EU multinationals are also significantly above the average (the latter for computer equipment only in 1986). Interestingly, the lowest computer equipment intensity was for Japan in 1986 at around 2%. The key noticeable difference between Tables 1 and 2 is that Sweden is more intensive in terms of computer equipment than the average establishment, and more than any other foreign county in 1986, by 1988 this has changed to Switzerland. Turning to Table 3, and the proportion of plants employing people in R&D "other" countries – the catch all category, Canadian, Japanese and US plants are most likely to engage in R&D, although this would appear to be uncorrelated with skill levels.

<<TABLES 1 TO 3 HERE>>

Establishment size across years is also larger in the foreign owned sector, with the USA and Japan (excluding 1986) having the largest number of employees on average. Generally foreign owned establishments have a higher proportion of skilled workers than the UK in particular those from the USA, Switzerland and Sweden.

Over time there are changes in the sample sizes, as is evident from Tables 1 to 3. This is due predominantly to entry and exit by establishments. This is investigated in greater depth in Table 4 below as this has implications for our empirical analysis and restricts us to estimating random effects panel data models. Table 4 is split into two main columns which represent a

<<TABLE 4 HERE>>

panel of establishments over two years (1986 and 1988) and a panel of establishments over three years (1986, 1988 & 1992). Approximately 44% of establishments are there in all three years, with around 28% in the sample for one or two years. Within the foreign sample, around 65% are present for all three years, ranging from Japan with 52% to Sweden at 70%.

Part of our empirical analysis is focused on computer intensity over a two year panel (see above). The first column of Table 4 shows a much greater percentage of foreign firms there for both years than the average – 82% versus 65% respectively. As such net entry is much higher for UK establishments, across the two panel periods – this has implications for the empirical analysis in that the foreign country dummies will be largely constant across time and so we have to employ random effects methods as opposed to fixed effects in our estimation, due to lack of variation in the country dummies, as mentioned above.

IV. Econometric results – Are foreign firms more technologically intensive?

All of the following results are based on data weighted by three digit industry total employment population. We are able to do this since the ARD contains basic information on the population of manufacturing establishments in the UK, such as employment and output, although the detailed information we are interested in is restricted to the "selected" sample of firms. This is important, in that unweighted data will be significantly biased towards larger sized establishments and so any parameter estimates will not be representative of the underlying population. Furthermore, unweighted data introduces the problem of endogenous sampling, Harris (2002). As such for researchers employing the ARD it has become customary to use weighted data. The following results are based upon robust standard errors.

Baseline results

The results presented in Table 5 report the estimates of equation 1 estimated as cross sections initially, defining technology intensity by computer equipment, using the panel from the two cross-sections of data for 1986 and 1988. The first and third columns of Table 5 show that on average foreign owned firms were 14% more intensive in terms of computer equipment than UK establishments in 1986 and this had risen to 34% by 1988.[ix] Canadian firms are the most computer intensive in comparison to UK firms (the omitted category), with the difference to UK establishments growing over time. Interestingly the Japanese country dummy is negative and significant, second and fourth columns, indicating that Japanese firms will have lower technology intensity in terms of computer equipment than the average UK firm. This contradicts the idea that Japanese firms are highly technologically intensive and confirms the findings of Griffith and Simpson (2002), as does the unsurprising result that skill intensive establishment's are more likely to employ computers. Similarly there is evidence that technology intensity is associated with higher levels of capital.

<<TABLE 5 HERE>>

These results illustrate the high degree of heterogeneity across foreign firms in the UK. This is a potential explanation of why studies that seek to measure productivity differences between foreign owned and host country firms, or more frequently, productivity spillovers or technology transfer from inward FDI, generate such conflicting results. Size and age effects are also associated with computer usage usually, where significant, at a diminishing rate. Finally, there is some evidence that firms in assisted areas are less likely to employ computers, though this is largely insignificant. Firms in assisted areas by definition often receive subsidies in order to generate employment, and it is clear that these subsidies do little to attract new technology to the regions concerned.

Robustness checks – other measures of technology intensity

The results illustrated in the first four columns of Table 6 report estimates of equation 1, but using the measure of technology based on computer employees. Initially these are cross sectional estimations undertaken to examine whether the results of Table 5 are robust to alternative definitions of technology and also to determine whether foreign firm effects have increased over time, as seen above. A single cross section is also employed with technology intensity measured using the dummy variable for whether firms employ any workers for R&D purposes, estimated by a logit model in the form of equation 2, with the results shown in the final two columns.

Looking at the first and third columns, foreign firms are found to be around 82% more intensive in terms of computer employees than the average UK firm in 1986, rising to nearly 90% by 1988. Firms from the USA and Canada (in 1986) have greater technology intensity than UK firms as do firms from the EU (although only in 1986). In line with the previous results, the coefficient on Japanese ownership is negative in 1986, but insignificant. Looking at technology intensity, as defined by the existence of R&D employees i.e. a dummy indicator, in 1992, large differences are found between foreign and domestic (UK) firms in the order of 60%. This supports the evidence presented above based on technology intensity defined from continuous variables. The final column suggests the largest disparity in technology intensity, comes from North American establishments, EU countries and "other" countries.

<<TABLE 6 HERE>>

Robustness checks – panel random effects estimates

It is possible that the results considered so far are subject to unobservable variables – firm, industry, region and time specific influences that are known to the firm but observable to the econometrician. Such unobservables may be driving any observed correlation between technology intensity and foreign presence. We attempt to control for this problem through taking advantage of the panel element available in the data and estimate equation 1 across time using random effects. The results are shown in Table 7, where the panel is used for two years, 1986 and 1988, using both the computer equipment and employees definitions of technology intensity – continuous measures of technology. The first and third columns suggest a 28% and 67% difference between the intensity of foreign and UK establishments, according to the definition used, confirming the robustness of the results in cross sections (Tables 5 and 6). The second and fourth columns support the earlier results showing the role for North American establishments and EU ownership under the computer employee's specification. Again for the computer equipment definition Japanese establishments were actually less intensive than the UK average.

<<TABLE 7 HERE>>

The panel estimates reported in Table 7 are likely to be the most robust, since they control for time effects.[x] These present strong evidence that foreign firms employ different levels of technology from the domestic sector, with the results consistent across the various available measures of technology. The results in Tables 5 and 6 from cross sectional estimates suggest that these differences increased over a short time period. Furthermore, the technological advantage is robust to controls for the capital stock and establishment size.

V. Conclusion

This paper has discussed some of the heterogeneity that exists with the population of inward investors in the UK, from the perspective of technological intensity. All of the results are robust to the inclusion of four digit industry dummies, regional controls and allowing for the time dimension. Establishments from North America i.e. USA and Canada (typically the older firms in the population[xi]) are more likely to engage in technological development than Japanese firms, and not surprisingly, larger establishments are more associated with technology than smaller plants.[xii] These results, however, have some bearing on policies associated with inward investment in the UK. One of the basic tenets of regional policy in both the developing and developed world over the past 20 years, is that in addition to generating employment, subsidising inward investment confers beneficial externalities on the host country or region, associated with the new technology that is presumed to accompany inward FDI. It is widely accepted that purely in employment terms, the "cost per job" of the investment incentives offered cannot be justified on the basis of the number of jobs directly associated with the investment. However, there is only limited evidence that attracting inward investment will stimulate technological development, and that this is less likely to occur with firms from outside North America. In turn therefore, any initiatives designed to generate technology spillovers from inward FDI must be seen in this light.

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Table 1 Sample statistics: Technology intensity, size and skills across countries 1986

	Computer equipment	**Computer employees**	**Size**	**Percentage skilled**	*Obs.*
All	9.98%	1.26%	293	55.91%	*12,320*
	(21.43%)	*(5.25%)*	*(925)*	*(49.65%)*	
UK	9.60%	1.21%	272	54.65%	*11,069*
	(21.07%)	*(5.13%)*	*(841)*	*(49.79%)*	
Foreign ownership	13.30%	1.77%	480	67.15%	*1,251*
	(24.16%)	*(6.20%)*	*(1,456)*	*(46.99%)*	
By country					
USA	13.76%	2.03%	548	67.15%	*703*
	(24.22%)	*(7.06%)*	*(1,835)*	*(45.72%)*	
Canada	17.88%	1.72%	489	60.82%	*97*
	(29.59%)	*(4.19%)*	*(650)*	*(49.07%)*	
Japan	2.15%	0.62%	361	61.11%	*18*
	(5.79%)	*(0.71%)*	*(395)*	*(50.16%)*	
EU	11.34%	1.14%	363	61.28%	*266*
	(22.82%)	*(1.92%)*	*(849)*	*(48.80%)*	
Sweden	18.46%	1.26%	299	71.43%	*49*
	(29.93%)	*(2.33%)*	*(411)*	*(45.64%)*	
Switzerland	10.25%	2.98%	458	62.12%	*66*
	(20.04%)	*(12.24%)*	*(364)*	*(48.88%)*	
Other	11.33%	0.92%	395	67.31%	*52*
	(19.15%)	*(1.55%)*	*(721)*	*(47.37%)*	

Definitions: **Computer equipment** is defined from question 511 as a percentage of net capital expenditure in the establishment. **Computer employees** is defined from question 207 as a percentage of overall employment in the establishment. Figures in parenthesis are standard deviations from the mean. Note summary statistics are generated using the unweighted data.

Table 2 Sample statistics: Technology intensity, size and skills across countries 1988

	Computer equipment	**Computer employees**	**Size**	**Percentage skilled**	*Obs.*
All	10.95%	1.42%	432	51.94%	*12,585*
	(22.57%)	*(6.08%)*	*(1,726)*	*(49.96%)*	
UK	10.64%	1.37%	429	50.75%	*11,305*
	(22.38%)	*(6.00%)*	*(1,965)*	*(49.96%)*	
Foreign ownership	13.71%	1.88%	462	62.53%	*1,273*
	(24.01%)	*(6.73%)*	*(1,268)*	*(48.42%)*	
By country					
USA	14.07%	2.01%	537	63.73%	*659*
	(23.36%)	*(5.73%)*	*(1,663)*	*(48.11%)*	
Canada	12.43%	3.34%	453	59.26%	*81*
	(19.91%)	*(13.84%)*	*(530)*	*(49.44%)*	
Japan	2.77%	1.26%	515	53.85%	*26*
	(4.17%)	*(1.65%)*	*(566)*	*(50.84%)*	
EU	13.07%	1.92%	361	64.55%	*268*
	(24.61%)	*(8.46%)*	*(749)*	*(47.92%)*	
Sweden	10.60%	0.85%	332	65.22%	*69*
	(18.78%)	*(0.96%)*	*(405)*	*(47.98%)*	
Switzerland	14.14%	1.04%	399	67.95%	*78*
	(26.76%)	*(1.27%)*	*(357)*	*(46.97%)*	
Other	12.50%	1.10%	351	44.71%	*92*
	(22.99%)	*(3.31%)*	*(396)*	*(50.14%)*	

Definitions: **Computer equipment** is defined from question 511 as a percentage of net capital expenditure in the establishment. **Computer employees** is defined from question 207 as a percentage of overall employment in the establishment. Figures in parenthesis are standard deviations from the mean. Note summary statistics are generated using unweighted data.

Table 3 Sample statistics: Technology intensity, size and skills across countries 1992

	R&D employees	**Size**	**Percentage skilled**	*Obs.*
All	54.63%	272	50.40%	*11,537*
	(49.79%)	*(1,102)*	*(50.0%)*	
UK	50.90%	240	49.01%	*10,133*
	(49.99%)	*(1,050)*	*(49.99%)*	
Foreign ownership	81.70%	505	60.47%	*1,404*
	(38.68%)	*(1,402)*	*(48.91%)*	
By country				
USA	83.67%	589	61.73%	*588*
	(36.99%)	*(1,872)*	*(48.64%)*	
Canada	85.90%	451	75.64%	*78*
	(35.03%)	*(515)*	*(43.20%)*	
Japan	84.62%	729	50.00%	*78*
	(36.31%)	*(1,854)*	*(50.32%)*	
EU	79.23%	415	59.82%	*443*
	(40.61%)	*(762)*	*(49.08%)*	
Sweden	77.11%	316	50.60%	*83*
	(42.27%)	*(325)*	*(50.30%)*	
Switzerland	74.29%	522	61.43%	*70*
	(44.02%)	*(1,335)*	*(49.03%)*	
Other	85.94%	382	59.38%	*64*
	(35.04%)	*(455)*	*(49.50%)*	

Definitions: **R&D employees** is defined as "1" from question 211 if the establishment responds to employing workers for R&D purposes, and "0" otherwise. The percentage of R&D employees are calculated as the number of "1's" as a proportion of the country sample size. Figures in parenthesis are standard deviations from the mean. Note summary statistics are generated using unweighted data.

Table 4 Sample statistics: Percentage of the same establishments present across time

	Panel 1986 & 1988		Panel 1986, 1988 & 1992		
	1 year	*2 years*	*1 year*	*2 years*	*3 years*
All	34.71%	65.29%	27.63%	28.26%	44.11%
UK	36.58%	63.42%	29.13%	29.23%	41.64%
Foreign Ownership	18.07%	81.93%	15.20%	20.21%	64.59%
By country					
USA	16.45%	83.55%	12.97%	18.36%	68.67%
Canada	12.92%	87.08%	13.67%	20.70%	65.63%
Japan	25.00%	75.00%	27.05%	21.31%	51.64%
EU	25.28%	74.72%	19.04%	21.39%	59.57%
Sweden	16.95%	83.05%	14.93%	15.42%	69.65%
Switzerland	11.81%	88.19%	11.21%	25.23%	63.55%
Other	23.75%	76.25%	18.73%	22.95%	58.31%

Table 5 Technology intensity given by computer equipment in cross sections

	Computer equipment *1986*		Computer equipment *1986*		Computer equipment *1988*		Computer equipment *1988*	
	Coef.	*t-ratio*	*Coef.*	*t-ratio*	*Coef.*	*t-ratio*	*Coef.*	*t-ratio*
Intercept	-4.126	*(11.19)*	-4.132	*(11.19)*	-3.500	*(9.73)*	-3.494	*(9.72)*
Foreign	0.132	*(2.16)*			0.291	*(2.46)*		
USA			0.142	*(0.96)*			0.153	*(0.95)*
Canada			1.025	*(2.74)*			1.241	*(3.05)*
Japan			-1.750	*(1.82)*			-1.419	*(1.85)*
EU			0.122	*(0.23)*			-0.614	*(1.35)*
Sweden			0.350	*(0.71)*			0.305	*(0.67)*
Switzerland			-0.997	*(2.06)*			0.216	*(0.51)*
Other			0.023	*(0.05)*			0.878	*(2.24)*
Age	0.404	*(3.12)*	0.403	*(3.12)*	0.308	*(3.61)*	0.309	*(3.61)*
Age squared	0.008	*(0.18)*	0.009	*(0.19)*	0.035	*(1.26)*	0.035	*(1.27)*
Size	0.415	*(3.91)*	0.415	*(3.92)*	0.178	*(2.11)*	0.176	*(2.08)*
Size Squared	0.006	*(0.32)*	0.005	*(0.29)*	-0.035	*(2.42)*	-0.035	*(2.45)*
Capital	0.682	*(29.03)*	0.685	*(29.14)*	0.658	*(27.69)*	0.661	*(27.82)*
Skills	0.920	*(14.66)*	0.918	*(14.64)*	0.928	*(14.17)*	0.929	*(14.19)*
Parent	0.419	*(5.34)*	0.416	*(5.31)*	0.303	*(3.88)*	0.299	*(3.82)*
Intermediate AA	0.028	*(0.29)*	0.025	*(0.25)*	-0.193	*(1.97)*	-0.186	*(1.90)*
Development AA	-0.048	*(0.38)*	-0.043	*(0.34)*	-0.143	*(1.09)*	-0.128	*(0.98)*
Observations			12,318				12,582	
Industry					*yes***			
Region					*yes***			
Adjusted R^2	0.273		0.274		0.219		0.220	

Table 6 Alternative measures of technology intensity in cross sections

	Computer employees 1986		Computer employees 1986		Computer employees 1988		Computer employees 1988		R&D employees 1992		R&D employees 1992	
	Coef.	*t-ratio*	*Coef.*	*t-ratio*	*Coef.*	*t-ratio*	*Coef.*	*t-ratio*	*Coef.*	*t-ratio*	*Coef.*	*t-ratio*
Intercept	-15.773	*(32.36)*	-15.770	*(32.38)*	-15.807	*(33.07)*	-15.847	*(3313)*	-12.082	*(12.62)*	-12.119	*(12.63)*
Foreign	0.597	*(4.13)*			0.637	*(4.51)*			0.472	*(3.47)*		
USA			0.731	*(3.96)*			0.987	*(5.33)*			0.414	*(2.21)*
Canada			1.299	*(2.98)*			0.804	*(1.56)*			0.512	*(0.59)*
Japan			-0.279	*(0.23)*			0.196	*(0.20)*			-0.185	*(0.44)*
EU			1.169	*(1.68)*			0.833	*(1.44)*			0.770	*(3.06)*
Sweden			0.707	*(1.14)*			0.402	*(0.78)*			0.301	*(0.68)*
Switzerland			0.212	*(0.37)*			-0.779	*(1.44)*			-0.527	*(0.80)*
Other			-0.757	*(1.19)*			-0.245	*(0.48)*			0.786	*(1.78)*
Age	0.619	*(3.48)*	0.619	*(3.47)*	0.157	*(1.38)*	0.152	*(1.34)*	2.279	*(14.15)*	2.283	*(14.12)*
Age squared	0.259	*(4.05)*	0.258	*(4.03)*	0.089	*(2.39)*	0.089	*(2.37)*	-0.716	*(9.57)*	-0.717	*(9.54)*
Size	0.578	*(4.35)*	0.578	*(4.35)*	0.712	*(5.39)*	0.713	*(5.41)*	4.954	*(7.07)*	4.978	*(7.11)*
Size Squared	-0.044	*(2.05)*	-0.043	*(2.02)*	-0.033	*(1.28)*	-0.032	*(1.25)*	-0.314	*(1.88)*	-0.308	*(1.85)*
Capital	0.245	*(7.39)*	0.245	*(7.37)*	0.182	*(5.60)*	0.183	*(5.64)*	0.096	*(3.11)*	0.097	*(3.15)*
Skills	1.431	*(16.93)*	1.429	*(16.91)*	1.507	*(17.92)*	1.503	*(17.87)*	0.153	*(1.89)*	0.154	*(1.91)*
Parent	0.017	*(0.16)*	0.019	*(0.18)*	-0.076	*(0.76)*	-0.080	*(0.80)*	0.343	*(3.49)*	0.347	*(3.52)*
Intermediate AA	0.377	*(2.92)*	0.378	*(2.93)*	-0.058	*(0.47)*	-0.069	*(0.55)*	-0.193	*(1.51)*	-0.196	*(1.53)*
Development AA	0.468	*(2.77)*	0.474	*(2.80)*	0.176	*(1.04)*	0.157	*(0.93)*	-0.189	*(1.17)*	-0.193	*(1.19)*
Observations	12,320				12,585				11,537			
Industry	*yes***											
Region	*yes***											
Adjusted R^2	0.156		0.157		0.157		0.158		–		–	
Pseudo R^2	–		–		–		–		0.728		0.730	
Log likelihood	–		–		–		–		-2156.11 *p=[0.000]*		-2153.09 *p=[0.000]*	

Table 7 Panel estimates of technology intensity: Random effects estimation

	Computer equipment 1986&88		Computer equipment 1986&88		Computer employees 1986&88		Computer employees 1986&88	
	Coef.	*t-ratio*	*Coef.*	*t-ratio*	*Coef.*	*t-ratio*	*Coef.*	*t-ratio*
Intercept	-3.576	*(13.38)*	-3.578	*(13.39)*	-15.881	*(43.42)*	-15.894	*(43.47)*
Foreign	0.245	*(3.09)*			0.512	*(4.72)*		
USA			0.176	*(2.67)*			0.762	*(5.25)*
Canada			1.193	*(4.42)*			0.812	*(2.25)*
Japan			-1.547	*(2.71)*			-0.309	*(0.41)*
EU			-0.388	*(1.17)*			0.937	*(2.13)*
Sweden			0.358	*(1.09)*			0.493	*(1.11)*
Switzerland			-0.222	*(0.73)*			-0.357	*(0.85)*
Other			0.592	*(2.01)*			-0.505	*(1.31)*
Age	0.326	*(4.71)*	0.325	*(4.69)*	0.166	*(1.82)*	0.165	*(1.80)*
Age squared	-0.052	*(2.28)*	-0.053	*(2.31)*	0.105	*(3.53)*	0.105	*(3.53)*
Size	0.198	*(2.96)*	0.196	*(2.93)*	0.616	*(7.04)*	0.617	*(7.06)*
Size Squared	-0.033	*(2.92)*	-0.033	*(2.91)*	-0.031	*(2.15)*	-0.031	*(2.11)*
Capital	0.683	*(36.90)*	0.686	*(37.05)*	0.233	*(9.50)*	0.234	*(9.52)*
Skills	0.803	*(17.86)*	0.805	*(17.89)*	1.205	*(20.97)*	1.203	*(20.95)*
Parent	0.369	*(6.71)*	0.365	*(6.63)*	-0.034	*(0.46)*	-0.035	*(0.47)*
Intermediate AA	-0.086	*(1.18)*	-0.085	*(1.17)*	0.156	*(1.55)*	0.151	*(1.50)*
Development AA	-0.103	*(1.09)*	-0.093	*(0.99)*	0.324	*(2.47)*	0.317	*(2.41)*
Observations	24,900				24,905			
Industry	*yes***							
Region	*yes***							
ρ	0.150 *p=[0.000]*		0.150 *p=[0.000]*		0.443 *p=[0.000]*		0.442 *p=[0.000]*	
Adjusted R^2	0.240		0.241		0.151		0.152	

ENDNOTES

[i] For a review of the literature on spillovers from inward investment, see Görg and Strobl (2001) or Görg and Greenaway (2002).

[ii] Notice that this theoretical explanation of FDI offers no theoretical basis for why UK multinationals may have advantages over other domestic UK firms, who may for example choose to service foreign markets through different mechanisms, exporting or licensing for example.

[iii] For theoretical approaches to technology sourcing see Siotis (1999) or Fosfuri and Motta (1999), while for an applied study see Driffield and Love (2003).

[iv] Haskel and Heden (1999), taking advantage of the same indicators of technology, show that increased use of computers within the workplace reduces the demand for manual workers, and that within-establishment upgrading is the most important source of increased skill intensity within the economy. If foreign firms employ more technology then this has implications for wage inequality since technological advantages may be transferred to domestic producers in the form of technology spillovers which complement skilled labour and so could exacerbate wage inequality – indeed Taylor and Driffield (2004) find evidence of this for the UK.

[v] Note that the capital stock data is not available in the ARD and has to be constructed. This is explained in the data section.

[vi] Note that although we have an unbalanced panel of establishments, because the technology variable based upon equation 1 uses only two years of data, estimation by fixed effects would rely upon changes in establishment ownership over time otherwise the country of ownership dummies would be absorbed by the fixed effect. Consequently our estimation is based upon random effects, which is arguably the appropriate specification, given that we are drawing *N* establishments from a large population [see Baltagi (2002)].

[vii] Note we use the terms establishment and firm interchangeably throughout the remaining text. It should be realised though that there are three levels of aggregation available in the data: firms the most aggregated; establishments (which is the unit of observation we adopt); and plants.

[viii] Although the ARD contains information on the number of employees at the establishment, we construct a binary indicator of skill. The reason for doing this is that employment is used to control for establishment size in a quadratic and so would be highly correlated with a skill share variable. We experimented with including a continuous skill variable and this did not change the results of section IV. Consequently, a skill dummy is constructed for each year indicating whether the establishment employs a higher proportion of skilled workers (defined as total employment less operatives divided by total employment) than the four digit average.

[ix] Calculated as follows $\left[exp(\pi)-1\right]\times 100\%$, where the π represent foreign firm effects.

[x] Throughout Table 7 the hypothesis that ρ is equal to zero is rejected, as shown by the probability (*p*) values. This suggests that although we only have a very short panel, that the panel level variance component i.e. unobservable intra-establishment effects, are important and that the panel estimator would be different to a pooled estimator, as such there are efficiency gains to employing a random effects framework.

[xi] Note it is not possible to provide a satisfactory control for age using the ARD data, since establishments are not asked their start date. Rather our measure of age, like that used by Griffith and Simpson (2001), is truncated to an earliest date of 1973. Arguably this doesn't control sufficiently for the large influx of North American firms to the UK in the 1950s and 60s.

[xii] One could argue that by definition all foreign firms are multinationals but only a subset of the UK owned establishments are part of a multinational. Thus in a sense we are not comparing like with like by taking a simple comparison of foreign firms (all MNEs) to all UK firms (only some MNEs). Recent evidence for the UK indeed suggests that being able to distinguish whether UK firms are in fact multinationals is important, Criscuolo and Martin (2002). Generally, the authors find that UK multinationals are more productive than other domestic firms and are not worse than non US multinationals. However, there does appear to be a genuine specific advantage to US firms over and above being multinational enterprises.