Are foreign firms more technologically intensive?

UK establishment evidence from the ARD

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ABSTRACT

Using establishment level data from the ARD this paper adopts very precise measures of technology, arguably much more detailed than have hitherto been employed, to consider technological differences between establishments operating in the UK. In particular the key question addressed is whether technology differs by nationality. After numerous controls we find that typically Canadian, US and Swiss establishments have a higher probability of being more technology advanced than the average. This result also stands up in panel analysis.

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I. Introduction

The purpose of this paper is to examine some of the differences between foreign and domestically owned firms in the UK. Many explanations of the existence of multinational enterprises are based on the existence of firm-specific advantages, following the work of Dunning (1979). Numerous authors have interpreted firm-specific effects as technological advantages, and have demonstrated that such advantages are an important determinant of international production, see for example Cantwell (1989). Further work has been devoted to analysing or explaining differences in FDI flows across regions or industries in terms of productivity, capital intensity or R&D differentials, see for example Neven and Siotis (1996) or Driffield (2001a). While such work demonstrates that firm specific advantages are important in explaining FDI flows, most of these papers rely on industry level data for the host country, while seeking to explain home country decision making (i.e. the decision to invest abroad). It is also perhaps surprising that much of the work on the policy aspects associated with the desire to attract foreign capital, has focussed on linkages between foreign and domestic firms, or on simple employment creation, rather than on the level of technology employed by the inward investor. For further discussion of this, see Eltis (1996). Work examining the aggregate impact on technology of inward investment, such as Barrell and Pain (1997) demonstrates that some technology is imported with inward investment, and Driffield (2001b) shows that under certain circumstances productivity externalities are assimilated by the domestic sector. However, very little work has sought to examine the nature of technology used by domestic and foreign firms.

The remaining sections of this paper are divided as follows. Section II outlines why both theorists and policy makers expect there to be a technology gap between foreign and domestic plants, and also a discussion of why technology differentials may be smaller than otherwise imagined. Section III then presents an empirical model to consider technology differences, and section IV discusses the data used. The remaining sections are then devoted to the results and conclusions.

II. FDI and technology differences

It is well established in the theoretical literature, that technology differences are an important motivation for FDI, see for example Rowthorn (1992). It is an implicit assumption in the policy-orientated literature that foreign owned firms in a particular location have higher levels of productivity than domestic firms. In turn, several authors have sought to measure the extent to which such benefits are transferred to the host country, for a survey of this literature, see Görg and Ströbl (2001). However, in addition to ownership advantages, explanations of FDI also place emphasis on location advantages, FDI being attracted to a particular location due to the endowments of particular factors of production. Neven and Siotis (1996) present a similar argument, based on MNEs being attracted to particular locations by the prospects for 'technology sourcing'. Equally, Horstman and Markusen (1996), or Fosfuri and Motta (1999), following Graham (1978), suggest that FDI can be explained as rivalrous behaviour between oligopolists. For the purpose of this paper, it is sufficient merely to note these competing (although possibly not mutually exclusive) explanations of FDI, and the importance of treating inward investors in the UK as a heterogeneous group when analysing productivity or technology.

Davies and Lyons (1991) demonstrate that the productivity differential that foreign firms in the UK possess is in the region of 40%, although around half of this differential can be explained by the fact that foreign firms are concentrated in high-productivity industries. Oulton (2001) addresses the issue of why foreign firms may be more productive than domestic firms, and finds, that even allowing for firm size, US owned firms have higher levels of value added per head. While this of course may be due to some productivity or managerial advantage, it may also be due to the ability of such firms to exploit other firm specific advantages (such as brand names) and are thus able to charge higher prices.

The work of Oulton (2001) and Griffith (1999) suggests that there is a total factor productivity (TFP) component in the foreign productivity differential, which is hitherto unexplained. Griffith and Simpson (2001) demonstrate that foreign firms have higher levels of skill-intensity than domestic firms, and therefore that their productivity is higher. Further, 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.

The empirical literature that examines productivity impacts of FDI generally treats this differential as a result of a technological advantage which is generated within the source country firm, and then transferred across national boundaries within the firm (Barrell and Pain, 1997; and Driffield, 2001b). However, there is very little applied work that identifies sources of such technology differences. Carr *et al.* (2001) demonstrate that home country skill intensities are an important determinant of FDI, suggesting that foreign owned plants may be more skill intensive than domestic plants, while Driffield and Taylor (2000) confirm this result for the UK.

The work of Griffith (1999), Griffith and Simpson (2001) and Oulton (2001) highlight the importance of firm level characteristics in technology and productivity studies, and therefore the necessity to treat inward investors as a heterogeneous rather than homogenous group. Equally, they highlight the advantage of focusing on precise measures of technology other than unexplained elements of TFP. Rather, we employ the same data as others, but exploit information on specific aspects of technology i.e. computers and R&D. 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. We therefore focus on the use of computer equipment and employees using computers, as well as a binary indicator asking establishments whether they employ any workers for R&D purposes as our measures of technology. The empirical model presented in the following section is therefore designed to compare, not only foreign and domestic plants, but also to offer a comparison between foreign plants. 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, it is clear from the discussion above, that 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.

III. 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 Griffith and Simpson (2001) and Oulton (2001).

$$T_f^* = \alpha + \pi \mathbf{C}_f + \lambda \lg(Size)_f + \xi Skill_f + \gamma Parent_f + \psi \mathbf{AA}_f + \theta \mathbf{Z}_f + \delta \mathbf{I}_f + \varepsilon_f$$

$$= \mathbf{\Phi X}_f + \varepsilon_f \qquad (1)$$

Where f represents the establishment, T_f^* is a latent variable and T is its observed counterpart technology. T is defined as computer equipment purchases, the number of computer employees, or a binary digit to indicate whether any workers are involved in research and development at the establishment f. Where technology is constructed from computer based definitions (continuous variables) we have

$$T_f = \begin{cases} 1 \ \ if \ \ T_f^* > median \\ 0 \ \ otherwise \end{cases}, \text{ and for the R\&D measure } T_f = \begin{cases} 1 \ \ if \ \ T_f^* > 0 \\ 0 \ \ otherwise \end{cases}$$

$\mathbf{C}$ is a vector of country dummies (with the UK as the reference category), $\mathbf{Z}$ is a vector of regional dummies, and $\mathbf{I}$ is a vector of 4 digit industry dummies based upon 1980 sic codes. *Size* is measured by employment, entered as a quadratic in logarithms $g(\bullet)$; *Skill* is a dummy variable indicating whether the establishment employs a higher proportion of skilled workers (non-operatives) than the four digit average; *Parent* is a dummy variable indicating whether the establishment is the parent company and **AA** is a vector of assisted area dummy variables indicating whether the firm is located in either an intermediate or development assisted area. The probability of the technology state conditional upon the independent variables is given as:

$$\mathrm{E}\left(T_f = 1|\mathbf{X} \right) = \frac{\exp(\Phi\mathbf{X})}{1 + \exp(\Phi\mathbf{X})} \tag{2}$$

However, the ARD is a panel data set following establishments over time (although some enter and exit, so the panel is unbalanced). Consequently, it is possible to construct a panel data model for 1986 and 1988, the two years in which the computer questions were asked. The estimation is based upon a univariate probit model with random effects[1], where

$$T_{ft}^* = \Theta\mathbf{X}_{ft} + n_f + w_{ft} \qquad f=1\ldots F,\ t=1986,1988 \tag{3}$$

$$var\left[n_f + w_{ft}\right] = var\left[u_{ft}\right] = s_n^2 + s_w^2 \ \ , \ \ corr\left[u_{f1986}\, u_{f1988}\right] = r = \frac{s_n^2}{s_n^2 + s_w^2}$$

Technology is defined as above by computer based definitions (continuous variables) so

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[1] Panel estimates based upon fixed effects are not adopted since some of the independent variables are time invariant binary digits (for example, the country dummies).

$$T_{ft} = \begin{cases} 1 \;\; if \;\; T^{*}_{ft} > median \\ 0 \;\; otherwise \end{cases}$$

Equation 3 is estimated on unbalanced data with the likelihood function given as:

$$L_f = \frac{1}{\sqrt{p}} \int_{-\infty}^{+\infty} e^{-r_f^2} \left\{ \prod_{t=1986}^{Y_f} \Omega\left[q_{ft}\left(\Theta \mathbf{X}_{ft} + j r_f \right)\right] \right\} \partial r_f \qquad Y_f = 1988 \qquad (4)$$

$$q_{ft} = 2T_{ft} - 1, \; j = \sqrt{2r / 1 - r}$$

see Butler and Moffitt (1982) and Greene (1997). A panel was also created for 1986, 1988 and 1992 by defining technology from the number of computer employees (1986 and 1988) and from the R&D indicator (1992) as follows:

$$T_{ft} = \begin{cases} 1 \;\; if \;\; t = 1986 \;\; \underline{OR} \;\; t = 1988 \;\; \underline{AND} \;\; T^{*}_{ft} > median \\ 1 \;\; if \;\; t = 1992 \;\; \underline{AND} \;\; T^{*}_{ft} > 0 \\ 0 \;\; otherwise \end{cases} \qquad (5)$$

Equation 3 estimates the model with *t=1986, 1988* and *1992*, with $corr\left[u_{ft}\, \mu_{fs}\right] = r = \frac{s_n^2}{s_n^2 + s_w^2}$, $t \neq s$. The likelihood function of equation 4 is modified by allowing $Y_f = 1992$. 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 UK ones; and (ii) to provide evidence on the nationality of these establishments.

IV. Data

The data employed in this paper is the ARD from the Annual Census of Production (now known as the Annual Business Inquiry ABI). This data source has been described at length in Griffith (1999) and so only a brief discussion is given here. It covers the whole of the production sector and in latter years construction, in this paper we consider only manufacturing (sic's 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. In common with most users of these data, Haskel and Heden (1999), Girma and Wakelin (2001), Griffith and Simpson (2001) and Outlon (2001) we focus upon "selected" establishments only, that is, those required by law to fill in a return for the ONS. Only establishments employing more than ten workers are included in the analysis. The focus herein is upon incorporated or company classified establishments (see Griffith, 1999).

The three years which we focus upon are 1986, 1988 and 1992. The reason for doing this is that only in these years were establishments asked about key aspects of technology. Specifically in 1986 and 1988 the number of computer employees and the amount of computer equipment purchased[2], and in 1992 a binary digit to distinguish whether the establishment employs any workers involved in R&D. Although the computer variables are continuous, we defined them as binary digits for ease of comparison with the 1992 data and also to enable the construction of a panel. The technology variables across each year are constructed as shown in section III above.

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2 We are only aware of one other paper which makes use of these potentially interesting variables, Haskel and Heden (1999).

Tables 1 to 3 show T (defined by computer equipment, computer employees and an R&D employee indicator), *Size* and the percentage of skilled workers[3] in the raw data across countries for 1986, 1988 and 1992 respectively. Table 1 demonstrates that there is a much higher level of computer usage across North American plants, while Switzerland and Sweden are also significantly above the average. Interestingly, only 5% of Japanese plants employed computers above the average in 1986, although this rose dramatically by 1988. Turning to Table 3, and the proportion of plants employing people in R&D, Japanese and US plants are most

<<TABLES 1 TO 3 HERE>>

likely to engage in R&D, although this would appear to be uncorrelated with skill levels. Establishment size across years is also larger in the foreign owned sector, with Japan having the largest number of average employees in 1988 and 1992. Looking at the skill indicator shows that Japan isn't significantly different from the UK, with the exception of 1986. In general foreign owned establishments have a higher proportion of skilled workers in particular those from the USA, Canada and Switzerland.

V. Econometric results

The following results have been tested for groupwise heteroscedasticty in the *Size* variable and t-ratios are based upon corrected standard errors where appropriate. Each of the Tables, 4 to 10, provide a chi-squared test of whether the estimated parameters are jointly insignificant (equal to zero under the null hypothesis), and measures of fit (depending upon the model used), McFadden's R-squared and the percentage of observations predicted correctly.

[3] 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 V. 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.

The results presented in Tables 4 and 5 are based upon equations 1 and 2, using the two cross-sections of data for 1986 and 1988, and are broadly consistent. Canadian and US firms are

<<TABLES 4 AND 5 HERE>>

always ranked in the three largest impacts, indicating that North American ownership significantly increases the probability that the firm will be more computer-intensive than the average, both in terms of employees and equipment. This effect appears to have increased over the two year period. This is also true of Swiss owned establishments operating in the UK. The Japanese dummy is usually insignificant, with the exception of 1986 for computer equipment. In 1986 the impact of Japanese ownership actually decreases the probability that the firm will have higher technology than the average! This contradicts the idea that Japanese firms are highly technologically intensive and confirms the findings of Griffith and Simpson (2001), as does the unsurprising result that skill intensive plants are more likely to employ computers. These results also illustrate the heterogeneity that exists within the foreign sample (above 1,200 establishments in each year), perhaps indicating why previous studies on technological development and FDI have generated such conflicting results. Size is also associated with computer usage although at a diminishing rate. There is no evidence of a separate "parent" effect, that is to say that the foreign effects are truly related to multinationality rather than simply technology being created elsewhere within the enterprise. Finally, there is some evidence that firms in assisted areas are less likely to employ computers. This highlights a problem discussed by Morgan (1997) that such areas suffer from an underlying low level of technology, and that observed phenomena such as unemployment are a symptom of the problem rather than the cause.

A particular problem with the results of Tables 4 and 5 is that they are cross sectional. Consequently, it is possible that unobservable firm level characteristics may be driving our results. To control for this possibility we make use of the panel element within the ARD data.

By employing equations 3 and 4 applying a univariate probit model with random effects time invariant unobserved heterogeneity problems are overcome. Results are based upon an unbalanced panel and are presented in Table 6. They are consistent with cross sectional results showing that the USA, Canada and Switzerland/Sweden (depending upon the technology definition) have the largest impacts, whilst Japanese and EU dummies are insignificant.

<<TABLE 6 HERE>>

Turning to Table 7, and our second measure of technology, R&D, the results show a rather different pattern. All foreign firms (with the exception of Switzerland and Sweden) are less likely to engage in R&D than the average (although only Canada and the Other category have significant negative coefficients). Only Swiss establishments have a higher probability of being more technologically intensive. Again the likelihood of R&D increases with size, but at a decreasing rate. Skill intensities are positively associated with R&D, while the assisted area dummies are negative, but insignificant. By 1992, it is noticeable that the sample includes over 100 firms from "other" countries, as the UK had started to witness inward investment from

<<TABLE 7 HERE>>

South East Asia. It is notable that firms from such countries are significantly less likely to engage in R&D than the average firm. Typically, these firms were attracted to peripheral regions of the UK, and so are unlikely to significantly improve the technological base of the region.

Although the definitions of technology vary between 1986-88 and 1992, we sought to determine the individual country effects within a panel setting across all years. Defining the state of technology from equation 5 and employing a panel probit analysis (equations 3, 4 and 5) the results of Table 8 are wholly consistent with those found above. Notably, Japan again has an insignificant impact (with a negative sign), whilst Switzerland, USA and Canada each exhibit a higher probability of being more technologically intensive than the average.

<<TABLE 8 HERE>>

Robustness checks

Models of this type suffer a potential problem from sample selection bias, in particular treatment effects. For example, the typical establishment that employs high skilled labour may be technologically advanced independently of the proportion of skilled workers employed. In this case, equation 1 will overestimate the treatment effect (the effect of skill intensity) on the state of technology due to endogeneity problems. To examine this further we also estimated a model of selection in qualitative response data, see Greene (1997), using a Poisson regression and a univariate probit to control for treatment effects, Terza (1985), such that

$$T_f^* \Big| e_{1f} \sim poisson\left(?_{1f} \right)$$

$$ln\left(?_{1f} \right)\Big| e_{1f} = \Omega \mathbf{X}_{1f} + e_{1f} \qquad (6)$$

$$Skill_f^* = \Xi \mathbf{X}_{2f} + e_{2f} \qquad (7)$$

$$e_{1f}, e_{2f} \sim N\left(0,0, \mathrm{s}, 1, ?\right)$$

The latent variable T_f^* is defined as above and is observed along with $\mathbf{X}_{1f}$ when the selection variable $Skill_f = 1$, $Skill_f = \begin{cases} 1 \;\; if \;\; Skill_f^* > median \\ 0 \;\; otherwise \end{cases}$. Table 9 shows the results of estimating the above for 1986. Comparing the results corrected for treatment effects (i.e. making the skill variable endogenous) to those of Table 4, it is clear that the US and Canadian establishment impact is robust. The major difference is that the Japanese effect is no longer the largest impact or even statistically significant under the computer equipment definition of technology, and is replaced by Sweden. The results generated by this procedure in other years added little to the analysis, leaving the country effects largely unchanged, and so are omitted.

<< TABLE 9 HERE>>

Following the line of argument presented in section II, the problem of endogeneity could arise with the foreign dummy variables, in that technology generated abroad may require foreign owned plants to be more computer intensive. For instance, is the establishment likely to be more technologically advanced than the average regardless of ownership status? To control for this equation 6 is estimated based upon the following selection criteria

$$Foreign^{*}_{f} = \Pi \mathbf{X}_{3f} + \epsilon_{3f} \qquad (8)$$

$\epsilon_{1f}, \epsilon_{3f} \sim N(0,0, s,1, ?)$ again the latent variable T^{*}_{f} is defined as above, observed along with $\mathbf{X}_{1f}$ when the selection variable $Foreign_{f} = 1$, $Foreign_{f} = \begin{cases} 1 \text{ if } Foreign^{*}_{f} = 1 \\ 0 \text{ otherwise} \end{cases}$.

The results of this are shown in Table 10 for 1992, where UK establishments exhibit a significant probability of being less technologically intensive than foreign ones, supporting the positive foreign country dummies found in Table 7 (with the exception of the Other country category). The UK coefficient was also negative in 1986 and 1988 across the technology definitions (omitted for brevity) and suggests that the significant foreign country dummies of Tables 4 to 8 are not a result of treatment effects. In other words even if technology generated abroad requires foreign owned plants to be more technologically intensive (which a significant Mill's ratio in Table 10 suggests) UK owned establishments still exhibit a higher probability of having lower technology.

<<TABLE 10 HERE>>

As a final check of robustness using the 1986 and 1988 data in panel we construct the log of real computer expenditure per head $log(com)_{ft}$ as a continuous dependent variable and see if the country effects remain. Because there is a possibility of unobservable differences in firms which may be correlated with size, we employ a two step model (Hsiao, 1986; Griffith and Simpson, 2001). Initially we estimate the following using the within-group estimator

$$log(com)_{ft} = m\mathbf{X}_{ft} + ?_f + ?_{ft} \tag{9}$$

The independent variables are the same as those used in equation 1, with the exception that the foreign dummies are omitted. After estimating equation 9, we take the fixed effect plus the residual and take the time series mean, $\overline{\hat{?}_f + \hat{?}_{ft}}$, to undertake the following regression

$$\overline{\hat{?}_f + \hat{?}_{ft}} = 1\mathbf{C}_f + e_f \tag{10}$$

where $\mathbf{C}$ is a vector of country dummies. The results are shown in Table 11. The top panel shows that computer expenditure per head is increasing in size, although at a decreasing rate, and skills. Establishments which are parents generally have higher computer expenditure per head and the converse is true of those firms in intermediate assisted areas. Within-group estimates are significant at the 1 per cent level, as are regional and industry controls. In the bottom half of Table 11 we use the estimates from the top half to condition the unexplained part of computer expenditure, $\overline{\hat{?}_f + \hat{?}_{ft}}$, upon country dummies. The results suggest that Swiss firms are the most computer intensive around 86.3%[4] higher than the UK, followed by Canadian firms at 63.4% higher. Again the three largest impacts come from North America and Switzerland, as found throughout the previous analysis. Noticeably the Japanese dummy is insignificant. Replacing the foreign country dummies with a UK indicator in equation 10 yielded

[4] Calculated as $[exp(1) - 1] \times 100\%$.

the following coefficient -0.241 (*t=4.48)* suggesting that UK firms on average employ nearly 22% less computer equipment per worker than foreign firms.

VI. Conclusion

This paper has discussed some of the heterogeneity that exists with the population of inward investors in the UK. Establishments from North America i.e. USA and Canada (typically the older firms in the population[5]) are more likely to engage in technological development than Japanese firms, and not surprisingly, larger establishments are more associated with technology than smaller plants. 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 providing subsidies in order to attract inward investment to a country or region confers beneficial externalities on the host country or region. It is clear that the major rationale for local or regional Development Agencies seeking to attract foreign direct investment is the direct employment gain. It is also clear that in both the US and Europe, 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 alone. Studies on the objectives of inward investment incentives (see for example Morgan, 1997) suggest that the desire to attract inward investment has been firmly based on the assumption that certain indirect benefits from FDI will accrue to the domestic sector, in the form of technology, or technological externalities. 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.

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[5] Note it is not possible to provide a satisfactory control for age using the ARD data, since establishments are not asked their start date. Although Griffith and Simpson (2001) construct such an indicator, it is truncated to an earliest date of 1973 and for our purposes wouldn't control for the large influx of North American firms to the UK in the 1950s and 60s.

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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	14.01%	13.77%	281	29.32%	*12,592*
	(34.7%)	*(34.5%)*	*(845)*	*(17.8%)*	
UK	12.22%	11.81%	261	28.23%	*11,337*
	(32.8%)	*(32.3%)*	*(779)*	*(17.3%)*	
Foreign ownership	30.12%	31.47%	457	39.19%	*1,255*
	(45.9%)	*(46.5%)*	*(1,281)*	*(19.4%)*	
By country					
USA	33.85%	35.41%	520	41.42%	*706*
	(47.4%)	*(47.9%)*	*(1,621)*	*(19.4%)*	
Canada	35.05%	36.08%	472	34.72%	*97*
	(47.9%)	*(48.3%)*	*(595)*	*(18.0%)*	
Japan	5.56%	22.22%	419	26.34%	*18*
	(23.6%)	*(42.8%)*	*(355)*	*(13.7%)*	
EU	21.37%	21.37%	351	37.67%	*234*
	(41.1%)	*(41.1%)*	*(750)*	*(20.2%)*	
Sweden	26.53%	16.33%	290	34.38%	*49*
	(44.6%)	*(37.3%)*	*(379)*	*(16.8%)*	
Switzerland	30.30%	42.42%	453	38.15%	*66*
	(46.3%)	*(49.8%)*	*(332)*	*(20.3%)*	
Other	24.71%	23.53%	318	36.19%	*85*
	(43.4%)	*(42.7%)*	*(452)*	*(17.4%)*	

Definitions: **Computer equipment** is defined as "1" from question 511 if purchases are greater than the median value for the sample, "0" otherwise. **Computer employees** is defined as "1" from question 207 if the value is than the sample median, "0" otherwise. The percentages for the technology indicators are the number of "1's" as a proportion of the country sample size. Figures in parenthesis are standard deviations from the mean.

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

	Computer equipment	**Computer employees**	**Size**	**Percentage skilled**	*Obs.*
All	13.95%	13.79%	285	30.04%	*12,784*
	(34.7%)	*(34.5%)*	*(1,022)*	*(18.9%)*	
UK	12.01%	11.79%	265	28.85%	*11,503*
	(32.5%)	*(32.3%)*	*(992)*	*(18.3%)*	
Foreign ownership	31.38%	31.69%	461	40.75%	*1,281*
	(46.4%)	*(46.5%)*	*(1,245)*	*(20.9%)*	
By country					
USA	35.09%	37.7%	531	42.78%	*664*
	(47.8%)	*(48.5%)*	*(1,621)*	*(20.5%)*	
Canada	36.59%	35.37%	433	44.89%	*82*
	(48.5%)	*(48.1%)*	*(548)*	*(26.6%)*	
Japan	38.46%	30.77%	646	29.59%	*26*
	(49.6%)	*(47.1%)*	*(582)*	*(15.5%)*	
EU	24.46%	21.89%	390	40.57%	*233*
	(43.1%)	*(41.4%)*	*(829)*	*(22.2%)*	
Sweden	23.19%	21.74%	333	33.41%	*69*
	(42.5%)	*(41.5%)*	*(427)*	*(13.9%)*	
Switzerland	35.89%	34.62%	405	40.28%	*78*
	(48.3%)	*(47.9%)*	*(423)*	*(17.9%)*	
Other	21.71%	20.16%	316	34.39%	*129*
	(41.4%)	*(40.3%)*	*(322)*	*(20.0%)*	

Definitions: **Computer equipment** is defined as “1” from question 511 if purchases are greater than the median value for the sample, “0” otherwise. **Computer employees** is defined as “1” from question 207 if the value is than the sample median, “0” otherwise. The percentages for the technology indicators are the number of “1's” as a proportion of the country sample size. Figures in parenthesis are standard deviations from the mean.

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

	R&D employees	**Size**	**Percentage skilled**	*Obs.*
All	19.51%	263	32.33%	*12,627*
	(39.6%)	*(951)*	*(20.3%)*	
UK	17.24%	235	31.03%	*11,027*
	(37.8%)	*(920)*	*(19.4%)*	
Foreign ownership	35.13%	458	41.31%	*1,600*
	(47.8%)	*(1,122)*	*(21.9%)*	
By country				
USA	40.18%	532	43.99%	*672*
	(49.1%)	*(1,479)*	*(21.4%)*	
Canada	22.01%	406	44.84%	*100*
	(41.6%)	*(388)*	*(28.3%)*	
Japan	39.51%	670	31.79%	*81*
	(49.2%)	*(1,564)*	*(19.1%)*	
EU	30.24%	386	38.73%	*463*
	45.9%)	*(654)*	*(21.1%)*	
Sweden	37.78%	256	37.62%	*90*
	(48.8%)	*(231)*	*(19.6%)*	
Switzerland	51.19%	495	46.33%	*84*
	(50.3%)	*(1,068)*	*(22.3%)*	
Other	19.09%	333	19.09%	*110*
	(39.5%)	*(442)*	*(39.5%)*	

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.

Table 4: Logit estimates of equation 2 for 1986 with a full set of country dummies

	Computer equipment				**Computer employees**			
	Coefficient	*Marginal*	*t-ratio*		*Coefficient*	*Marginal*	*t-ratio*	
Intercept	-13.382	-0.712	*(21.39)*		-11.641	-0.503	*(15.41)*	
USA	0.270	0.014	*(2.51)*	**3**	0.458	0.019	*(4.04)*	**2**
Canada	0.624	0.033	*(2.39)*	**2**	0.729	0.031	*(2.53)*	**1=**
Japan	-1.852	-0.099	*(2.55)*	**1**	0.196	0.008	*(0.24)*	
EU	-0.023	-0.001	*(0.12)*		0.145	0.006	*(0.68)*	
Sweden	0.527	0.028	*(1.37)*		-0.067	-0.003	*(0.14)*	
Switzerland	-0.168	-0.009	*(0.54)*		0.708	0.031	*(2.31)*	**1=**
Other country	0.421	0.022	*(1.38)*		0.466	0.020	*(1.44)*	
Size	2.859	0.152	*(13.45)*		1.742	0.075	*(5.73)*	
Size squared	-0.138	-0.007	*(6.95)*		-0.005	-0.236e^{-3}	*(2.18)*	
Parent	0.057	0.003	*(0.83)*		0.012	0.528e^{-3}	*(0.17)*	
Intermediate AA	-0.217	-0.012	*(2.07)*		0.007	0.314e^{-3}	*(0.07)*	
Development AA	-0.149	-0.008	*(1.13)*		0.099	0.004	*(0.71)*	
Skills greater than mean	1.179	0.063	*(14.09)*		1.293	0.056	*(16.33)*	
Observations	12,592							
4 digit dummies	*yes***							
Regional dummies	*yes***							
Chi-squared $H_0 : \Phi = 0$	3293.192 *[p=0.000]*				4034.195 *[p=0.000]*			
Predicted outcome	85.99%				86.22%			
Log Likelihood	-3454.737				-3029.501			
McFadden's R^2	0.323				0.400			

Notes: Absolute t-ratios are shown in parenthesis, 1% significance 2.326, 5% significance 1.645, and 10% significance 1.282. ** Jointly significant at the 1% level. The largest 3 coefficients/marginals are denoted as **1, 2, 3**.

Definitions: **Computer equipment** is defined as "1" from question 511 if purchases are greater than the median value for the sample, "0" otherwise. **Computer employees** is defined as "1" from question 207 if the value is than the sample median, "0" otherwise.

Table 5: Logit estimates of equation 2 for 1988 with a full set of country dummies

	Computer equipment				Computer employees			
	Coefficient	*Marginal*	*t-ratio*		*Coefficient*	*Marginal*	*t-ratio*	
Intercept	-15.445	-0.775	*(24.28)*		-7.699	-0.387	*(9.44)*	
USA	0.353	0.018	*(3.23)*	**3**	0.549	0.028	*(4.66)*	**3**
Canada	0.903	0.045	*(3.21)*	**1**	0.591	0.029	*(1.94)*	**2**
Japan	0.061	0.003	*(0.12)*		-0.693	-0.035	*(1.27)*	
EU	0.204	0.010	*(1.07)*		0.031	0.002	*(0.15)*	
Sweden	0.236	0.012	*(0.69)*		0.150	0.008	*(0.40)*	
Switzerland	0.492	0.025	*(1.73)*	**2**	0.597	0.030	*(1.98)*	**1**
Other country	0.249	0.013	*(0.98)*		0.128	0.006	*(0.47)*	
Size	3.466	0.174	*(16.99)*		0.416	0.021	*(2.26)*	
Size squared	-0.189	-0.009	*(10.36)*		-0.109	-0.021	*(3.26)*	
Parent	-0.005	$-0.258e^{-3}$	*(0.08)*		-0.062	-0.031	*(0.85)*	
Intermediate AA	-0.242	-0.012	*(2.35)*		-0.012	$-0.582e^{-3}$	*(0.11)*	
Development AA	-0.045	-0.002	*(0.34)*		-0.038	-0.002	*(0.27)*	
Skills greater than mean	1.187	0.059	*(14.86)*		1.295	0.065	*(14.84)*	
Observations				12,784				
4 digit dummies				*yes***				
Regional dummies				*yes***				
Chi-squared $H_0 : \Phi = 0$	3326.431 *[p=0.000]*				4044.153 *[p=0.000]*			
Predicted outcome	86.05%				86.21%			
Log Likelihood	-3503.371				-3106.166			
McFadden's R^2	0.322				0.394			

Notes: Absolute t-ratios are shown in parenthesis, 1% significance 2.326, 5% significance 1.645, and 10% significance 1.282. ** Jointly significant at the 1% level. The largest 3 coefficients/marginals are denoted as **1, 2, 3**.

Definitions: **Computer equipment** is defined as "1" from question 511 if purchases are greater than the median value for the sample, "0" otherwise. **Computer employees** is defined as "1" from question 207 if the value is than the sample median, "0" otherwise.

Table 6: Panel probit estimates for 1986 & 1988 with a full set of country dummies

	Computer equipment				**Computer employees**			
	Coefficient	*Marginal*	*t-ratio*		*Coefficient*	*Marginal*	*t-ratio*	
Intercept	-7.039	-0.859	*(26.91)*		-4.374	-0.505	*(17.61)*	
USA	0.222	0.027	*(5.04)*	**2**	0.281	0.032	*(5.42)*	**3**
Canada	0.368	0.045	*(3.01)*	**1**	0.376	0.043	*(2.70)*	**1**
Japan	-0.032	-0.004	*(0.16)*		-0.029	-0.003	*(0.11)*	
EU	0.069	0.008	*(0.88)*		0.052	0.006	*(0.56)*	
Sweden	0.203	0.025	*(2.34)*	**3**	0.008	$0.894e^{-3}$	*(0.04)*	
Switzerland	0.134	0.016	*(1.04)*		0.347	0.040	*(2.59)*	**2**
Other country	0.160	0.019	*(1.61)*		0.092	0.011	*(0.78)*	
Size	1.352	0.165	*(18.03)*		0.173	0.020	*(2.40)*	
Size squared	-0.056	-0.007	*(9.01)*		-0.064	-0.007	*(9.26)*	
Parent	-0.008	-0.001	*(0.31)*		-0.025	-0.003	*(0.82)*	
Intermediate AA	-0.108	-0.013	*(2.65)*		-0.008	$-0.901e^{-3}$	*(0.17)*	
Development AA	-0.029	-0.004	*(0.57)*		0.013	0.001	*(0.22)*	
Skills greater than mean	0.718	0.088	*(21.72)*		0.739	0.085	*(19.40)*	
Rho r		0.044 *(1.31)*				0.103 *(2.71)*		
Observations				25,376				
Industry dummies				*yes***				
Regional dummies				*yes***				
Chi-squared $H_0 : \Theta = 0$		2.74 *[p=0.187]*				7.55 *[p=0.006]*		
Predicted outcome		86.01%				86.22%		
Log Likelihood		-7156.859				-6382.094		

Notes: Absolute t-ratios are shown in parenthesis, 1% significance 2.326, 5% significance 1.645, and 10% significance 1.282. ** Jointly significant at the 1% level. The largest 3 coefficients/marginals are denoted as **1, 2, 3**.

Definitions: **Computer equipment** is defined as "1" from question 511 if purchases are greater than the median value for the sample, "0" otherwise. **Computer employees** is defined as "1" from question 207 if the value is than the sample median, "0" otherwise.

Table 7: Logit estimates of equation 2 for 1992 with a full set of country dummies

	R&D employees			
	Coefficient	*Marginal*	*t-ratio*	
Intercept	-19.681	-1.479	*(35.54)*	
USA	-0.043	-0.003	*(0.42)*	
Canada	-0.702	-0.053	*(2.43)*	**1**
Japan	-0.190	-0.014	*(0.68)*	
EU	-0.152	-0.011	*(1.18)*	
Sweden	0.365	0.027	*(1.40)*	
Switzerland	0.439	0.033	*(2.62)*	**3**
Other country	-0.595	-0.045	*(2.15)*	**2**
Size	5.499	0.413	*(30.04)*	
Size squared	-0.382	-0.029	*(23.88)*	
Parent	-0.041	-0.003	*(0.67)*	
Intermediate AA	-0.108	-0.008	*(1.25)*	
Development AA	-0.134	-0.010	*(1.19)*	
Skills greater than mean	0.493	0.037	*(7.88)*	
Observations		12,627		
4 digit dummies		*yes***		
Regional dummies		*yes***		
Chi-squared $H_0 : \Phi = 0$		3930.281 *[p=0.000]*		
Predicted outcome		80.49%		
Log Likelihood		-4265.967		
McFadden's R^2		0.315		

Notes: Absolute t-ratios are shown in parenthesis, 1% significance 2.326, 5% significance 1.645, and 10% significance 1.282. ** Jointly significant at the 1% level. The largest 3 coefficients/marginals are denoted as **1, 2, 3**.
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.

Table 8: Panel probit estimates for 1986, 1988 & 1992 with a full set of country dummies

	Technology employees			
	Coefficient	*Marginal*	*t-ratio*	
Intercept	-2.206	-0.408	*(15.43)*	
USA	0.289	0.053	*(7.22)*	**2**
Canada	0.268	0.049	*(2.56)*	**3**
Japan	-0.108	-0.019	*(0.74)*	
EU	0.168	0.031	*(3.09)*	
Sweden	0.147	0.027	*(1.16)*	
Switzerland	0.379	0.070	*(3.52)*	**1**
Other country	0.064	0.012	*(0.65)*	
Size	0.209	0.039	*(4.38)*	
Size squared	-0.068	-0.012	*(15.58)*	
Parent	-0.033	-0.006	*(1.40)*	
Intermediate AA	0.177	$0.326e^{-4}$	*(0.01)*	
Development AA	0.069	0.013	*(1.78)*	
Skills greater than mean	0.177	0.098	*(24.19)*	
Rho r		0.177 *(4.67)*		
Observations		38,003		
Industry dummies		*yes***		
Regional dummies		*yes***		
Chi-squared $H_0 : \Theta = 0$		18.799 *[p=0.000]*		
Predicted outcome		84.32%		
Log Likelihood		-13531.03		

Notes: Absolute t-ratios are shown in parenthesis, 1% significance 2.326, 5% significance 1.645, and 10% significance 1.282. ** Jointly significant at the 1% level. The largest 3 coefficients/marginals are denoted as **1, 2, 3**.

Definitions: **Technology employees** is defined as "1" from question 207 (number of computer employees) if the value is than the sample median, "0" otherwise for 1986 and 1988, plus "1" from question 211 if the establishment responds to employing workers for R&D purposes in 1992, and "0"otherwise.

Table 9: Estimates of equation 6 based upon selection from 7 for 1986 – controls for skill endogeneity

	Computer equipment					**Computer employees**				
	Probit selection (treatment=skill)		*Poisson*			*Probit selection (treatment=skill)*		*Poisson*		
	Marginal	*t-ratio*	*Coefficient*	*t-ratio*		*Marginal*	*t-ratio*	Coefficient	*t-ratio*	
Intercept	0.238	*(4.92)*	-1.416	*(8.13)*		0.238	*(4.92)*	-1.633	*(9.12)*	
USA			0.567	*(7.76)*	**2**			0.697	*(9.65)*	**3**
Canada			0.764	*(4.31)*	**1**			0.870	*(4.97)*	**2**
Japan			-1.038	*(1.03)*				0.640	*(1.26)*	
EU			0.254	*(1.74)*				0.355	*(2.44)*	
Sweden			0.566	*(2.02)*	**3**			0.209	*(0.59)*	
Switzerland			0.478	*(2.11)*				0.889	*(4.61)*	**1**
Other country			0.415	*(1.88)*				0.469	*(2.07)*	
Size	0.078	*(7.91)*				0.078	*(7.91)*			
Size squared	-0.002	*(5.37)*				-0.002	*(5.37)*			
Parent			0.801	*(16.39)*				0.935	*(19.04)*	
Intermediate AA			-0.125	*(1.52)*				-0.007	*(0.09)*	
Development AA			-0.105	*(1.02)*				0.066	*(0.66)*	
Mills ratio			0.438	*(12.87)*				0.423	*(12.39)*	
Observations					12,592					
Industry, Region	*yes***		*yes***			*yes***		*yes***		
Chi-squared $H_0 : \Omega = 0$			1234.151 *[p=0.000]*					1221.033 *[p=0.000]*		
Predicted outcome			90.04%					90.32%		
Log Likelihood	-7307.179		-4614.027			-7307.179		-4561.365		

Notes: Absolute t-ratios are shown in parenthesis, 1% significance 2.326, 5% significance 1.645, and 10% significance 1.282. ** Jointly significant at the 1% level. The largest 3 coefficients/marginals are denoted as **1, 2, 3**.

Table 10: Estimates of equation 6 based upon selection from 8 for 1992 – controls for foreign endogeneity

	R&D employees			
	Probit selection (treatment=foreign)		*Poisson*	
	Marginal	*t-ratio*	*Coefficient*	*t-ratio*
Intercept	-0.840	*(20.20)*	3.822	*(18.83)*
Skills greater than mean	0.047	*(8.66)*		
UK			-7.279	*(32.48)*
Size	0.209	*(14.09)*		
Size squared	-0.143	*(10.38)*		
Parent			0.141	*(3.21)*
Intermediate AA			-0.093	*(1.44)*
Development AA			-0.147	*(1.77)*
Mills ratio			-4.331	*(30.83)*
Observations	12,627			
Industry, Region	*yes***		*yes***	
Chi-squared $H_0 : \Omega = 0$			2128.906 *[p=0.000]*	
Predicted outcome			87.34%	
Log Likelihood	-4082.083		-5424.215	

Notes: Absolute t-ratios are shown in parenthesis, 1% significance 2.326, 5% significance 1.645, and 10% significance 1.282. ** Jointly significant at the 1% level.

Table 11: Estimates of equations 9 & 10, differences in computer expenditure per head

	Coefficient		*t-ratio*
<u>Equation 9</u>			
Dependent variable: $log(com)_{ft}$			
Skills greater than mean	1.862		*(29.51)*
Size	2.398		*(7.54)*
Size squared	-0.175		*(5.25)*
Parent	0.122		*(1.65)*
Intermediate AA	-0.151		*(1.63)*
Development AA	0.037		*(0.31)*
Regional controls		*yes***	
Year dummy		*yes***	
Industry controls		*yes***	
Within-group		*yes*** *[p=0.181]*	
Observations		25,376	
<u>Equation 10</u>			
Dependent variable: $\overline{\hat{?}_f + \hat{?}_{ft}}$			
USA	0.207	**3**	*(2.82)*
Canada	0.491	**2**	*(2.42)*
Japan	0.091		*(0.21)*
EU	0.188		*(1.62)*
Sweden	0.311		*(1.38)*
Switzerland	0.622	**1**	*(3.65)*
Other country	-0.171		*(0.82)*
Chi-squared $H_0 : 1 = 0$		19.87**	
F [7,25368]		8.45**	

Notes: Absolute t-ratios are shown in parenthesis, 1% significance 2.326, 5% significance 1.645, and 10% significance 1.282. ** Jointly (individually for the year dummy) significant at the 1% level. The largest 3 coefficients are shown as **1, 2, 3**.
Definitions: $log(com)_{ft}$ is the log of real computer expenditure (1986 prices) defined from question 511 weighted by establishment employment.