MULTINATIONALS AND US PRODUCTIVITY LEADERSHIP: EVIDENCE FROM GREAT BRITAIN *†

Chiara Criscuolo‡ Ralf Martin§

September 16, 2007

Abstract

We study the productivity of US and other foreign owned plants in the UK. Using a new dataset that can identify for the first time domestic UK MNEs in such a study, we find that UK MNEs are less productive than US affiliates, but as productive as non US foreign affiliates. Exploiting dynamic variation in our data, we find evidence suggesting that this additional US advantage is due to the takeover of already highly productive UK plants rather than the sharing of superior firm specific assets. The study also features a novel approach to TFP calculation.

JEL Classification: F230, L600 **Keywords**: Multinational Firms, Productivity, Foreign Ownership, US leadership

†We thank two anonymous referees for extremely helpful comments, plus Lee Branstetter, Tony Clayton, Richard Disney, Jonathan Haskel, Wolfgang Keller, John Haltiwanger, Steve Nickell, Nick Oulton, Steve Redding, Fergal Shortall, Alessandra Tucci, John Van Reenen, Prabhat Vaze and participants at the 2004 NBER Summer Institute. This research was conducted under contract with the ONS. We gratefully acknowledge financial support from the Evidence-Based Policy Fund and from the ESRC/EPSRC Advanced Institute of Management Research, grant number RES-331-25-0030. Chiara Criscuolo thanks the ESRC, grant number PTA-026-27-0445, and the British Academy for funding. Errors and opinions are those of the authors alone.

‡Centre for Economic Performance (CEP) London School of Economics (LSE), Centre for Research into Business Activity (CeRiBA) and Advanced Institute of Management (AIM); c.criscuolo@lse.ac.uk

§Centre for Economic Performance (CEP), London School of Economics (LSE), Centre for Research into Business Activity (CeRiBA), and Advanced Institute of Management (AIM); r.martin@lse.ac.uk

1 Introduction

International comparisons show that the US is the world's most productive economy[1] and much research has gone into understanding the determinants of this productivity leadership.[2] Responsible for this success could be the *business environment* in which US firms operate and/or *technological* factors (e.g. superior technologies for designing products and production processes and better management) specific to US firms. While the latter might themselves be determined by the business environment,[3] the distinction between business environment and technological factors is interesting because of its implications for economic policy. A technological explanation for the US lead, for example, could motivate policies to source this superior technological knowledge from abroad.[4] We examine these issues by looking at a firm level dataset that automatically rules out environmental factors since all firms in the sample are located in the same environment. Using data from the UK Office of National Statistics (ONS) that comprehensively covers the whole of the UK manufacturing we compare the productivity performance of US multinationals in Britain with those of other multinational enterprises (MNE) and domestic firms. A number of existing studies have made similar comparisons for the UK.[5] These studies have found that on average US firms in Britain are significantly more productive than their domestic counterparts, which seems consistent with the explanation of US productivity leadership being based on 'technological factors'. However, care should be taken in drawing such a conclusion from this evidence, for the following reasons.

[1] see for example O'Mahony and de Boer (2002).

[2] see for example Wagner and van Ark (1996), O'Mahony and van Ark (2003) or for a very accessible discussion Lewis (2004).

[3] e.g. the quality of the educational system might determine not only the skill level of a country's workforce but also its output of new technologies and its firms' access to and adoption of these technologies; institutional differences that affect market structure likely influence entrepreneurs' incentives to develop and adopt new technologies.

[4] An example of such a policy in the UK is the subsidies offered to US and other foreign multinationals to locate in Britain.

[5] see Griffith and Simpson (2001), Oulton (2000), Harris (1999).

Firstly, by definition, all foreign owned establishments in any country, and thus all US owned establishments in Britain, must be part of a MNE. As has been suggested by Dunning (1981), Helpman (1984), Markusen (1995) and more recently by Helpman et al. (2004), MNEs can be expected to be at the upper end of the productivity distribution in any country because factors such as language barriers and ignorance of local business networks leave foreign firms at a disadvantage. If nevertheless MNE firms manage to stay in business, they must have superior firm specific assets – such as better management techniques and better production technology – which can be shared with their foreign affiliates and which give them an edge over local competitors. In fact, even in the US, foreign owned firms are found on average to be more productive than their domestic counterparts (Doms and Jensen, 1998). To account for these aspects we therefore need to compare foreign owned firms with domestic MNEs, and not to all domestic firms. Doms and Jensen (1998) did this in the case of the US and found that foreign MNEs are less productive than US MNEs in the US. This type of comparison for the UK has not been possible up to now as the available data for the UK only included indicators for foreign ownership, but not the multinational status of domestic firms.

Secondly, while Doms and Jensen (1998) results are consistent with a US technology lead this does not rule out the possibility that the US success is driven by a home advantage: US MNEs enjoy a productivity advantage only in the US, where they have a more intimate knowledge of local practices.

Finally, a major form of MNE entry into foreign markets is via takeovers of existing plants. This is likely not a random process. If US MNEs systematically take over firms that were already more productive then a US advantage in the UK could emerge even without any transfer of superior knowledge or technology from the US parent to its plant in the UK.

Our paper provides new results and progresses a number of issues. For the first time we are able to identify domestic MNEs in the productivity dataset used in earlier UK studies by combining it with data from the UK Annual Survey into Foreign Direct Investment (AFDI). This shows that UK MNEs are significantly more productive than domestic non-MNE firms. Using a wide range of different productivity measures and robustness checks we find, like Doms and Jensen, that US MNEs are on average more productive than all other MNEs. This suggests that their finding was not driven by a home market effect.

Also we have annual plant level panel data for 1996 to 2000. Using the longitudinal variation and changes in ownership of plants we examine whether this US advantage is driven by plant picking effects rather than by knowledge or technology transfer from the parent firm. The results suggest that this is indeed the case. While we find a strong effect on productivity after takeover by an MNE,[6] these effects are not any stronger for takeovers by US MNEs, we find – using two different identification strategies – that US MNEs tend to take over plants that are already more productive prior to acquisition.

Finally, our dataset allows us to examine the technology sourcing hypothesis (Branstetter, 2001; Keller, 2004). According to this hypothesis FDI might not be driven by superior firms exploiting their advantage abroad (Dunning, 1981), but rather by domestic firms trying to gain access to superior foreign technology. We can examine this by looking at the productivity performance of domestic firms that started to invest abroad during the sample period. – i.e. that became multinational in 1996-2000. Although we did not find significant evidence for such an effect, this might be due to the short panel available.

Our paper also makes a number of methodological contributions. Firstly, among the productivity measures we employ to examine the robustness of our results we use a new TFP (total factor productivity) estimator, derived from a structural production function estimation approach; i.e. the estimator is similar to those proposed by Olley and Pakes (1996) (OP) and Levinsohn and Petrin (2003) (LP) but addresses

[6] We refer to these as firm effects.

a number of shortcomings of these estimators.[7]

Secondly, we propose two new frameworks that separately identify firm and plant effects. Both exploit the facts that we have plant level data, we know which plants are under common firm ownership and we have sufficient switches of ownership of plants between different firms. Our first framework posits a double fixed effects model where the plant effect is the time invariant component of a plant's productivity as it switches between firms and the firm effect is the time invariant component as a firm owns different plants. Our second framework extends the structural productivity estimator we use for our robustness checks by explicitly including a multinomial selection model, which is simultaneously estimated with the production function equation. This framework allows flexible mapping of the relationship between pre-takeover performance and takeover. For example, we can easily examine whether an important determinant of takeover is the pre-takeover plant's short term rather than long-term performance.

The rest of the paper is organised as follows. In Section 2 we describe the dataset. Section 3 outlines the econometric framework and the details of the two-step estimation procedure used to disentangle the US productivity effect. Section 4 reports the results and Section 5 concludes.

2 The Data

2.1 Data Sources

Our sample is drawn from the Annual Respondents Database (ARD)[8], which is the UK equivalent of the US Longitudinal Respondents Database (LRD). The dataset was made available by the ONS and is based on information from the Annual Busi-

[7] STATA code to implement the estimator can be downloaded from http://193.93.28.107/pubtwik/bin/view/MP/TrueMethod.

[8] More extensive descriptions of the ARD can be found in Criscuolo, Haskel and Martin (2003), Griffith (1999) and Oulton (1997).

ness Inquiry (ABI), a mandatory annual survey of UK businesses.[9] The ARD unit of observation is defined by the ONS as an 'autonomous business unit'. We refer to this level of observation as a 'plant'.[10] It is important to note that the ARD does not comprise the complete population of UK businesses. For example, businesses located in Northern Ireland are excluded; all other businesses with more than 100 employees[11] are surveyed, with smaller businesses being sampled randomly. Each year the sampled plants account for around 90% of total UK manufacturing employment.[12] The resulting sample is an unbalanced panel of about 19,000 manufacturing plants which we observe annually for the years 1996 to 2000.

The country of ownership of a foreign firm operating in the UK – and thus the ability to identify foreign owned MNE plants in the UK – is provided in the ARD.[13] While this identifies foreign owned plants, it has not previously been possible to identify UK MNEs. To do this we use the AFDI register.

The AFDI is an annual survey of businesses which requests a detailed breakdown of the financial flows between UK firms and their overseas parents or subsidiaries; it operates at firm rather than plant level. The ONS maintains a register that provides the sampling frame for the AFDI and which holds information on the population of all UK firms that engage in or receive FDI, on the country of ownership of each foreign firm, and on which UK firms have foreign subsidiaries or branches and where these are located.[14] This register is designed to capture the universe of firms that are

[9] Annual Census of Production until 1998.

[10] Some of these business units are spread across several sites and are therefore not plants in the strictest definition. About 80% of the business units are located at a single mailing address.

[11] In some years the threshold was 250 employees, for details refer to Criscuolo, Haskel and Martin (2003).

[12] To examine whether our results are sensitive to the oversampling of larger plants we ran regressions with inverse sampling probabilities as weights. These results, available upon request from the authors, are not qualitatively different from the unweighted results reported in the Results section.

[13] The ARD data are supplemented here with information from the Dun&Bradstreet global "Who Owns Whom" database. According to Dun&Bradstreet, the nationality of a plant is determined by the country of residence of the global ultimate parent, i.e. the topmost company of a Worldwide hierarchical relationship identified bottom-to-top using any company which owns more than 50% of the control (voting stock, ownership shares) of another business entity.

[14] The working definition of FDI for this purpose is that the investment must give the investing

involved in FDI abroad and in the UK. We consequently define as 'multinational' each plant in the ARD that is owned by a firm that appears in the AFDI register.[15]

One problem with the AFDI register is that information is not always up to date. If a firm engages in or receives FDI, it will only be included in the AFDI register after the ONS learns about this from external sources, including commercial data and newspapers. Consequently, the register population has varied, somewhat spuriously, over the years with the ONS's success in identifying such firms. However, we believe that this problem does not weaken the conclusions that can be drawn from our results. If some of the plants recorded as non-multinational were actually part of a MNE, the estimated productivity gap would be a lower bound of that found using data free from measurement errors.

2.2 Descriptive Evidence

Table 1 shows the number of multinational plants that we can identify in the population and in the sample and their relevance in terms of employment and value added.

Column 1 reports the number of domestic plants with no FDI, (defined as UK non MNEs), British MNEs (UK MNE), US MNEs (US) and Non-US foreign owned plants (FOR) in the whole population. Column 2 shows the number of plants in each group for the sample surveyed by the ONS to compile the ARD. Columns 3 and 4 translate these numbers into shares. Column 3 shows that 1% of all plants in Britain are US owned, as big a percentage almost as all other foreign owned plants

firm a 'significant' level of control over the recipient firm. The ONS considers this to be the case if the investment gives the investor a share of at least 10% of the recipient firm's capital. The ONS further distinguishes between subsidiaries and branches as follows: a 'subsidiary' is a company where the parent company holds more than 50% of the equity share capital; a 'branch' is a permanent establishment as defined for UK corporation tax and double taxation relief purposes; companies where the investing company holds between 10% and 50% of the equity share capital, i.e. does not have a controlling interest, but participates in the management, are defined as 'associates'. The country of ownership is identified by the nationality of the immediate owner, Office for National Statistics (2002) p.120.

[15]Details of the procedure followed to merge the AFDI and the ARD are reported in Criscuolo and Martin (2003).

Table 1: Importance of MNE
(Average numbers and shares 1996-2000)

	number of plants		shares		employment share		value added share	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	pop.	sample	pop.	sample	pop.	sample	weighted	unweighted
UK Non MNE	158,868	8,394	0.96	0.75	0.59	0.41	0.44	0.31
UK MNE	3,062	1,427	0.02	0.13	0.21	0.29	0.27	0.32
US	1,172	615	0.01	0.05	0.10	0.14	0.15	0.19
FOR	1,708	825	0.01	0.07	0.11	0.16	0.14	0.18

Notes: Figures reported are annual averages. Population refers to all businesses in the register, sample refers to businesses in the ARD (all large plants plus a stratified sample of smaller plants). Column 5 uses employment information from administrative data for non-surveyed plants. Columns 7 and 8 use value added at factor cost. Column 7 weights surveyed observations using employment weights calculated as described in the Appendix A to yield statistics representative of the whole population. $UK\ non\ MNE$ denotes domestic plants with no FDI; $UK\ MNE$ denotes all domestic multinationals; US all plants owned by a US multinational and FOR all plants owned by non-US foreign multinationals.
Source: Authors' calculations using matched ARD-AFDI data for the period 1996-2000.

combined. Indeed, US MNEs represent more than 40% of all foreign owned plants in Britain $((615+825)/825)$. Figures are similar for shares in employment (Column 5) and value added (Column 7), where US owned plants represent 47 and 51% of FDI, respectively. These figures are consistent with the fact that the most productive companies are also likely to have the highest market share. Also, since US MNEs are on average larger, the relative share of US MNEs in the selected sample is much higher: whereas in the total population US MNEs take a share of about 1%, in the sample the same figure rises to 5%.

Table 2 reports averages and standard deviations for relevant variables. Panel 1 shows the US owned plants' labour productivity lead: averaging over the whole manufacturing sector and not controlling for industry we find that plants owned by US firms have an advantage of 26% $((46.57-36.87)/36.87)$ over British MNEs and an advantage of 8% $((46.57-43.10)/43.10)$ over other foreign MNEs. In terms of gross output per employee (panel 2) the ranking changes: foreign non-US owned plants are the most productive and, in general, the foreign advantage becomes more dramatic. Panels 3 and 4 suggest that the figures in panel 2 can be explained in part by the fact that non-US foreign owned plants have much higher materials-to-labour and capital-to-labour ratios than all other plants. Panel 5 shows that US

Table 2: Summary Statistics in the 1996-2000 pooled sample

		UK non MNE	UK MNE	US	FOR
1	VA/Emp	27.96	36.87	46.57	43.10
		(183.47)	(39.30)	(80.79)	(51.43)
2	GO/Emp	76.55	105.35	146.23	156.39
		(207.92)	(132.22)	(232.02)	(283.73)
3	Mat/Emp	50.54	69.78	99.16	114.43
		(85.04)	(85.91)	(163.67)	(221.25)
4	K/Emp	38.23	65.43	85.54	108.92
		(92.78)	(73.07)	(125.61)	(366.37)
5	Employment	142.15	475.02	537.00	445.62
		(264.51)	(954.81)	(1394.88)	(1134.80)
6	AverageWage	17.25	21.35	24.13	23.40
		(7.89)	(10.13)	(8.53)	(8.21)
7	VA/Sales	0.43	0.40	0.38	0.33
		(0.17)	(0.15)	(0.15)	(0.15)

Notes: Figures are unweighted averages for the sample period. Standard deviations in parenthesis. Figures in panels 1 to 4 and 6 are in '000s. Figures in panel 5 are head counts. The number of observations in all panels is 38,501. $UK\ MNE$ is 1 for all domestic multinationals; US is 1 for all plants owned by a US multinational and FOR is 1 for all plants owned by non-US foreign multinationals.
Source: Authors' calculations using matched ARD-AFDI data for the period 1996-2000.

plants are on average larger and pay higher wages. This might imply that at least part of the US advantage is due to scale effects[16] and employment of higher skilled workers. Thus, the US advantage might not be based on technological or managerial superiority but simply on different input choices.

3 The Framework

3.1 A simple framework

Table 2 shows that both US and foreign MNEs have much higher capital intensity than UK owned plants. This suggests that part of the observed foreign ownership advantage could be driven by this higher capital intensity. To examine this we need to estimate Total Factor Productivity (TFP). The literature has suggested different

[16]Here we refer to scale effects at plant level. In our study we cannot control for the scale of the global operations of MNEs, e.g. we do not have information on 'global employment'.

approaches for estimating plant level TFP.

The most common approach is to assume that firms produce according to a Cobb-Douglas production technology:

$$q_{it} = \gamma \sum_{z \in Z} \alpha_z x_{zit} + a_{it} \tag{1}$$

where q_{it} is the logarithm of output produced at plant i in period t, γ is the returns to scale coefficient, Z is a set of production factors – labour (L), physical capital (K) and intermediate inputs (M), all expressed in logs – α_z are the production function parameters, and a_{it} is TFP.

With the data available we can start by examining whether TFP varies systematically between multinationally owned and domestic plants by running an OLS estimation of the following equation

$$\begin{aligned} r_{it} - p_{It} - x_{Lit} &= \gamma(\alpha_M(x_{Mit} - x_{Lit}) + \alpha_K(x_{Kit} - x_{Lit})) + (\gamma - 1)x_{Lit} \\ &+\beta_1 US_{J(i,t)} + \beta_2 FOR_{J(i,t)} + \beta_3 MNE_{J(i,t)} \\ &+\theta_{It} + \psi_R + \varepsilon_{it} \end{aligned} \tag{2}$$

i.e. we regress deflated revenue, $r_{it} - p_{It}$,[17] per worker, x_{Lit}, on inputs, ownership dummies[18] interacted dummies, θ_{It}, to control for 4-digit sectors time effects and 10 regional dummies ψ_R to control for location effects within Britain.[19]

This approach – although standard practice – raises a number of concerns. Firstly, OLS will be inconsistent if the plant's factor input choices are determined

[17] At plant level we observe nominal sales $r_{it} = q_{it} + p_{it}$ but since we do not have plant level information on prices, we deflated nominal sales using (four-digit) sector level price deflators p_{It}

[18] $US_{J(i,t)}$, for example, would be equal to 1 if plant i is owned in period t by US firm J.

[19] In our results section we further break down the other foreign and MNE categories to account for possible heterogeneity within those groups. In particular, we distinguish between 'EU-owned' multinationals and 'non-EU-owned' multinationals because EU MNEs are more likely to operate under the same regulatory environment and to make sure that the US effect does not merely reflect a 'non-EU' effect. We then want to isolate UK multinationals that are as comparable as possible to US affiliates. One way of doing this is to separate out from the UK multinationals group those UK MNEs that invest in the US.

by TFP as is likely to be the case. Secondly, since we only observe sectoral, not plant level prices, deflated revenue, which forms the LHS variable in equation 2 corresponds to output quantities Q in equation 1 only under perfect competition. Thirdly, the assumption of a Cobb-Douglas production function is very restrictive.

Our main tool to account for these issues is a modified version of the framework suggested by Olley and Pakes (1996), which is new to the literature.

3.2 A more flexible approach

To overcome the limitations outlined above using the data we have we start with an approach originally introduced by Klette and Griliches (1996) and Klette (1999) to integrate a more flexible production function into a setting of imperfect competition.

We assume that firms produce according to a homogenous o degree γ general differentiable function $f(\cdot)$:

$$Q_{it} = A_{it} \left[f\left(\mathbf{X}_{it} \right) \right]^{\gamma} \tag{3}$$

where $\mathbf{X}_{it}$ is a vector of factor inputs.

Also, using the data available, we can only observe nominal revenues – quantity times price in logs $q_{it} + p_{it}$ – deflated using (four-digit) sector level price deflators p_{It} since plant level prices are not observed; i.e.

$$r_{it} - p_{It} = q_{it} + p_{it} - p_{It} \tag{4}$$

To control for unobserved plant level prices we specify a demand function that links prices to output as follows (see also Melitz (2000)):

$$Q_{it} = \left(\frac{P_{it}}{P_{It}} \right)^{-\eta} \Lambda_{it}^{\eta-1} \Theta_{It} \tag{5}$$

where subscripts i denote firm and I industry; Λ_{it} is a firm specific demand shock,

η is industry demand elasticity and Θ_{It} is a sectoral shock to demand.[20] Taking the logs of Equation 5 and inverting gives:

$$p_{it} - p_{It} = \frac{1}{\mu}\lambda_{it} - \frac{1}{\eta}q_{it} + \frac{1}{\eta}\theta_{It} \tag{6}$$

where $\mu = \frac{1}{1-\frac{1}{\eta}}$ is the mark-up of price over marginal cost implied by profit maximizing behaviour and lower case letters denote logarithms.

Combining equations 6 and 1 with 4 gives:[21]

$$r_{it} - p_{It} = \frac{\gamma}{\mu}\sum_{z\in Z}\alpha_z x_{zit} + \omega_{it} + \frac{1}{\eta}\theta_{It} \tag{7}$$

where $\omega_{it} = \frac{1}{\mu}(a_{it} + \lambda_{it})$.

Klette showed that using the mean value theorem we can write the production function relative to the median firm as:

$$\tilde{q}_{it} = \tilde{a}_{it} + \sum_{z\in Z}\alpha_z \tilde{x}_{zit} \tag{8}$$

where small letters with a tilde denote log deviations from the median plant ($\mathcal{M}$) in a given year,[22] and α_z represent the partial derivative of the log production function evaluated at some point $\bar{\mathbf{X}}_{it}$ in the convex hull spanned by $\mathbf{X}_{it}$ and $\mathbf{X}_{\mathcal{M}t}$, so that

$$\alpha_z = \gamma f_z(\bar{\mathbf{X}}_{it})\frac{\bar{X}_{zit}}{f(\bar{\mathbf{X}}_{it})} \tag{9}$$

where $f_z(\cdot)$ represents the partial derivative of $f(\cdot)$ with respect to production factor z.

[20] This demand function can be derived by assuming monopolistic competition à la Dixit-Stiglitz (see Dixit and Stiglitz, 1977) in the product market.

[21] As stressed by Klette and Griliches (1996) – the interpretation of the estimated coefficients on the production factors is different from that in equation 1 as they are now all divided by the mark-up coefficient μ.

[22] e.g. $\tilde{q}_{it} = lnQ_{it} - lnQ_{\mathcal{M}t}$

The first order condition of profit maximization implies that

$$P_{it}\gamma\frac{Q_{it}}{f(\mathbf{X}_{it})}f_z(\mathbf{X}_{it}) = \mu W_{zit} \tag{10}$$

i.e. prices are such that the marginal value product is the mark-up μ times the marginal cost W of each factor.

As pointed out by Klette (1999), equation 10 can only be expected to hold for production factors that are easily adjustable. We assume that this is the case for intermediates and labour, but not for capital, thus:

$$\alpha_z = \mu\frac{W_z X_{zit}}{P_{it}Q_{it}} = \mu s_{zit} \tag{11}$$

where s_{zit} is the revenue share of factor z and $z \in \{L, M\}$. Further, because of the homogeneity of degree γ of the production function we get

$$\alpha_K = \gamma - \alpha_L - \alpha_M \tag{12}$$

and therefore in equation 8:

$$\tilde{q}_{it} = \tilde{a}_{it} + \mu\tilde{vi}_{it} + \gamma\tilde{k}_{it} \tag{13}$$

where

$$\tilde{vi}_{it} = \sum_{z\neq K}\bar{s}_{jt}(\tilde{x}_{zit} - \tilde{k}_{it}) \tag{14}$$

is an index of all variable factors. These results allow us to rewrite 7 as[23]

$$\tilde{r}_{it} - \tilde{vi}_{it} = \frac{\gamma}{\mu}\tilde{k}_{it} + \tilde{\omega}_{it} \tag{15}$$

[23] All aggregate expressions such as p_{It} and θ_{It} in 7 disappear because the equation is now written in terms of deviations from the median plant in the sector.

The variable factor index $\tilde{vi}_{it}$ can be directly observed from the data, since it only requires information on factor inputs and their revenue shares.[24]

Equation 15 suggests that the final element required to derive an estimate for $\tilde{\omega}_{it}$ is an estimate of $\beta_K = \frac{\gamma}{\mu}$, the ratio between the scale and the mark-up coefficients. But plant level capital stocks – like all other inputs – are presumably highly correlated with $\tilde{\omega}_{it}$,[25] we address this problem using a modified version of the Olley and Pakes (1996) (OP) approach and assume that $\tilde{\omega}_{it}$ evolves as a first order Markov Process:

$$\tilde{\omega}_{it} = E\{\tilde{\omega}_{it}|\tilde{\omega}_{it-1}\} + \tilde{\nu}_{it} \tag{16}$$

We also assume that capital is only correlated with the expected component of $\tilde{\omega}_{it}$ but not with $\tilde{\nu}_{it}$.[26] Then we can estimate equation 15 if we find a control for $E\{\tilde{\omega}_{it}|\tilde{\omega}_{it-1}\}$. In Appendix B we show that conditional on capital and assuming that mark-ups μ are constant across firms in a narrowly defined sector (4-digit) there is a monotone relationship between profits – defined as revenues minus variable costs – and $\tilde{\omega}$. Consequently we can invert the profit function and write

$$\tilde{\omega}_{it} = \phi_{\omega}\left(\tilde{k}_{it}, \tilde{\Pi}_{it}\right) \tag{17}$$

We do not know the functional form of $E\{\tilde{\omega}_{it}|\cdot\}$, but we express it as a function of observables in equation 17 so that we can rewrite 15 as

$$\tilde{r}_{it} - \tilde{vi}_{it} = \frac{\gamma}{\mu}\tilde{k}_{it} + g(\tilde{k}_{it-1}, \tilde{\Pi}_{it-1}) + \tilde{\nu}_{it} \tag{18}$$

[24]Equation 9 suggests that we should evaluate the derivatives – and thus the factor shares – at 'some point in the convex hull'. Since we do not know the exact location of this point and of course we do not know the functional form of the derivative, we follow accepted practice and approximate by averaging over the factor share at plant i and the factor share at the median plant $\mathcal{M}$ to calculate the shares in vi_{it}; i.e. $\bar{s}_{it} = \frac{s_{\mathcal{M}t}+s_{it}}{2}$. See also Baily et al. (1992) on this.

[25]see Griliches and Mairesse (1995) for a summary of the endogeneity problem and potential solutions.

[26]Olley and Pakes assume that investment in t can only be used for production in $t+1$. We take a different assumption, i.e. that investment is predetermined. Although this would be problematic in the Olley and Pakes methodology, it does not affect our estimation procedure.

where $g(\cdot) = E\{\tilde{\omega}_{it}|\phi(\cdot)\}$ is a function of unknown form. To estimate equation 18 we can either employ a semi-parametric procedure or approximate $g(\cdot)$ by a third order polynomial. For simplicity, we adopt the latter strategy. An estimator for $\tilde{\omega}_{it}$ can then be derived as

$$\hat{\tilde{\omega}}_{it} = \tilde{r}_{it} - \tilde{vi}_{it} - \widehat{\left(\frac{\gamma}{\mu}\right)}\tilde{k}_{it} \tag{19}$$

Concerning the method used to correct for endogeneity of factor inputs we would like to stress that compared to Olley and Pakes (1996) the main innovation in our approach is to use profits and not investment as a predictor for $\tilde{\omega}_{it}$. This has a number of advantages. Firstly, a major criticism of the OP framework is that investment might be a very poor predictor of the fixed component of $\tilde{\omega}_{it}$.[27] If firms are essentially in a steady state – and the capital stock in period t reflects the firm's knowledge about $\tilde{\omega}_{it}$ at $t-1$ – then the variation in investment primarily reflects adjustments to news about $\tilde{\omega}$ from period t. Our approach – similar to Levinsohn and Petrin (2000) who use material inputs rather than investment – does not suffer from this problem. Plants with high $\tilde{\omega}$ will have higher profits whether or not they are in steady state. Secondly, and unlike Levinsohn and Petrin, we can identify all relevant parameters from a moment condition on capital without having to assume separability in intermediate inputs or to rely on instrumental variable techniques. Also, we do not require any assumptions about substitutability between variable production factors.[28]

Finally, to examine whether measured TFP ($\tilde{\omega}_{it}$) systematically differs between various types of MNEs we run a regression of $\tilde{\omega}_{it}$ from equation 19 on our ownership dummies.

$$\hat{\tilde{\omega}}_{it} = \beta_1 US_{J(i,t)} + \beta_2 FOR_{J(i,t)} + \beta_3 MNE_{J(i,t)} + \tilde{\varepsilon}_{it} \tag{20}$$

How do we interpret TFP, here denoted as ω_{it} (and $\hat{\tilde{\omega}}_{it}$)? Without plant level price

[27]see Griliches and Mairesse (1995).

[28]For a more detailed discussion of our approach see Martin (2003).

information it is no longer possible to regard TFP as a shift parameter relating solely to technical efficiency.[29] Rather, $\omega_{it} = \frac{1}{\mu}(a_{it} + \lambda_{it})$ is a composite of technology shocks a_{it}, demand shocks λ_{it} and mark-up μ. How does this affect the way we interpret the MNE, US and FOR dummies in equation 20? If we assume that within 4-digit sectors μ is constant, a higher ω_{it} for US and MNE plants reflects higher product quality and/or consumer valuation λ_{it}, and/or higher technical efficiency, a_{it}. However, if μ is *not* constant within 4-digit sectors, then a higher ω_{it} might reflect greater market power, as recent papers[30] have demonstrated. This implies that revenue based measures of TFP (ω_{it}) might vary between plants for reasons other than product quality and technical efficiency. If within-sector differences in market power are positively related to the composite of technical efficiency and product quality ($a_{it} + \lambda_{it}$) then revenue based TFP provides a downward biased estimate of 'real' TFP.[31] Foster et al. (2003)[32] find a positive relationship between market power and product quality, (λ_{it}) here. If this is the case the MNE advantage estimated under the assumption of constant mark-ups within sectors is a downward biased estimate of the 'true' advantage that exists in the presence of within-sector differences in mark-up.[33]

Since we do not have firm-level prices, in order to ensure that our results are not driven by multinationals having greater market power than domestic firms we did two checks.

First, we devised a test – based on over-identifying restrictions – of the assump-

[29] Melitz (2000) stresses this point.

[30] see for example Foster, Haltiwanger and Syverson (2003), Syverson (2004) and Katayama, Lu and Tybout (2003).

[31] If in equation 7 the coefficients on factor inputs vary because of differences in market power across plants (μ_{it}) but our estimation model uses fixed coefficients $\bar{\mu}_t \in [\min\{\mu_{it}\}; \max\{\mu_{it}\}]$ and $Cov(\mu_{it}, a_{it}+\lambda_{it}) > 0$, then for plants with high $(a_{it}+\lambda_{it})$ we attribute too much output variation to production factors. More intuitively, this is the case because our regression model does not control for the fact that for plants with larger μ_{it} an increase in factors would lower prices relatively more.

[32] One of the few productivity studies to use a dataset with firm level prices.

[33] The reason for this result is that the assumption of constant mark-up leads to TFP estimates for better plants, such as MNEs, which are downward biased.

tion that μ in equation 7 is constant.[34] The hypothesis that μ is constant is rejected in a large number of sectors. We estimated our preferred specification only on plants in those sectors where we *cannot* reject the null of a constant μ. The estimates show the same productivity ranking for MNEs as found in the whole sample.

Second, we tried to identify sectors where market power might be less likely to drive the rankings. We assume that in commodity producing sectors[35] the assumption of constant mark-up within 4-digit industries is more likely to hold than in non-commodity sectors where multinationals might have more market power, for example because of stronger brands, and therefore might be able to command higher prices.

An alternative, and possibly the simplest way to handle the endogeneity problem in production function estimations is to follow a factor share approach, which involves no regression analysis at all but requires the assumptions of perfect competition and constant returns to scale to hold.[36] Following Baily et al. (1992) and adopting a similar strategy to that used to calculate the variable factor index vi_{it} in the previous subsection[37] we calculate TFP as

$$\tilde{\omega}_{it}^{BHC} = \tilde{r}_{it} - \bar{s}_{Mit}\tilde{m}_{it} - \bar{s}_{Lit}\tilde{l}_{it} + (1 - \bar{s}_{Mit} - \bar{s}_{Lit})\tilde{k}_{it} \tag{21}$$

and check the robustness of our results to using this measure of TFP as left-handside variable.

[34] The details of this test are reported in Appendix C

[35] We identify these using Rauch (1999) classification.

[36] An alternative method to estimate TFP controlling for the endogeneity of inputs would be Difference GMM (Arellano and Bond (1991)) and System GMM (Blundell and Bond (1998)). We applied these estimation methods to our sample, but encountered two problems: first the time period of our sample, 5 years, is too short, and less than 7% of the plants are observed over the whole time period; secondly, due to the fact that the ARD surveys small plants randomly, there is continuous time series information for only 12% of the plants

[37] This approach is equivalent to imposing $\frac{\gamma}{\mu} = 1$ which rules out imperfect competition and non-constant returns to scale.

3.3 Explaining the sources of the US and MNE productivity advantage

In this section we develop two different strategies to separately identify plant and firm contributions to plant productivity. As discussed in the introduction, the higher productivity of a plant owned by an MNE could be attributed to different factors.

Firstly, the parent firm might possess some superior knowledge and other transferable assets that improve the performance of its subsidiaries (*best firm* effect).[38] Examples include international distribution networks, special management techniques, patents, blueprints and reputation effects.

Secondly, MNE firms might be better at picking plants with superior performance (*plant picking* effect); for example, multinational firms might be able to take over the best plants because of deeper pockets to finance their takeover activities or higher ability to spot top performing plants.

A third reason for higher MNE plant productivity is the *going global* effect: plants owned by firms that start investing abroad might experience productivity improvements as a direct consequence of FDI because of firm-level scale economies, cheaper options to hedge against exchange rate risk, technology sourcing from abroad or other learning effects.

3.3.1 A double fixed effect approach

We first distinguish between these various effects using a double fixed effects approach. Thus we write productivity of plant i at time t, ω_{it}, as:[39]

$$\widehat{\omega}_{it} = \alpha_i + \zeta_{t,J(i,t)} + \varepsilon_{it} \tag{22}$$

[38] We can think of this effect as the 'ownership specific' factors in Dunning's explanation of FDI or the 'knowledge capital' of the firm in Markusen (1995).

[39] For simplicity at this stage we do not separate the MNE group further into US and other foreign (FOR). We reintroduce these in the empirical analysis below. Also, in the empirical implementation we use an estimate of ω_{it} the residual from equation 2 as reported in Column 5 of table 3.

i.e. productivity can be decomposed into an effect $\zeta_{t,J(i,t)}$ due to the parent firm of plant i at time t and a plant specific effect α_i.[40] The parent firm effect $\zeta_{t,J(i,t)}$ is then decomposed further in a time invariant firm specific effect $\zeta_{J(i,t)}$ and a time varying effect that captures the productivity effects from becoming a multinational, β_{MNE}; i.e.

$$\zeta_{t,J(i,t)} = \zeta_{J(i,t)} + \beta_{MNE} MNE_{J(i,t)} \tag{23}$$

so that

$$\widehat{\omega}_{it} = \beta_{MNE} MNE_{J(i,t)} + \alpha_i + \zeta_{J(i,t)} + \varepsilon_{it} \tag{24}$$

How do we identify and estimate the different determinants of the multinational advantage in this setting? The *best firm* effect implies that MNE firms - both foreign and British - have a higher firm specific fixed effect:

$$\zeta_{J(i,t) \in MNEfirms} > \zeta_{J(i,t) \notin MNEfirms} \tag{25}$$

where $MNEfirms$ is the set of firms in our sample that are multinational at some point during our sample period. Similarly, to investigate the presence of a *plant picking* effect we test that plant specific fixed effects are higher for plants that are owned by MNEs; i.e.

$$\alpha_{i \in MNEplants} > \alpha_{i \notin MNEplants} \tag{26}$$

where $MNEplants$ is the set of plants that are owned by an MNE at some point during the sample period. Finally, the *going global* effect, is represented as $\beta_{MNE} > 0$.

To separately identify these different effects we use changes in ownership status over the course of our sample period. For the identification of the *going global* effect we look at UK domestic firms that start investing abroad - i.e. become MNEs - during our sample period. For identifying the *best firm* and *plant picking* effects

[40]For simplicity of exposition we abstract from differences between types of MNEs.

we look at the performance of plants as they change ownership between MNE and non MNE firms. Figure 2 in Appendix D illustrates the identification strategy using an example. Table 7 in Appendix D presents evidence that reassures us that our data have sufficient transitions of firms between multinational states, and of plants between different types of firms.

The estimation of these effects proceeds in two steps. The first step is a productivity regression where we control for every firm-plant combination fixed effect so that in equation 24 this will cancel out both the firm and plant specific fixed components, α_i and $\zeta_{J(i,t)}$.

$$\widetilde{\widehat{\omega}_{it}} = \widetilde{MNE_{J(i,t)}}\beta + \widetilde{\varepsilon}_{it} \tag{27}$$

where a tilde represents the fixed effects within transformation.[41] If endogenous selection into the multinational group is entirely driven by the firm and plant specific fixed effects - an assumption we relax in our second approach below - then a regression of equation 27 provides a consistent estimate of the causal productivity impact of being an MNE; i.e. a positive going global effect would imply $\beta_{MNE} > 0$. With an unbiased estimate of β_{MNE} we can estimate the firm-plant combination fixed effects:

$$\widehat{\zeta_{J(i,t)} + \alpha_i} = \widehat{\omega_{it}} - \hat{\beta}_{MNE} MNE_{J(i,t)} \tag{28}$$

This provides the basis for our second stage regression where we regress the predicted fixed effects on two dummies variables MNE_J^{ever} and MNE_i^{ever}. MNE_J^{ever} is equal to one for firms that are MNEs at any point during the sample. Similarly, MNE_i^{ever} is equal to one for plants that are owned by MNEs in any year in the sample period.

[41] i.e. $\widetilde{x_{it}} = x_{it} - \frac{1}{\#_{it}[J(i,t)]} \sum_{\tau \text{ s.t.} J(i,\tau)=J(i,t)} x_{i\tau}$ where $\#_{it}[\cdot]$ is a function that returns the number of periods plant i is owned by the firm $J(i,t)$.

Formally, the second stage is

$$\widehat{\zeta_{J(i,t)} + \alpha_i} = \beta_J^{ever} MNE_{J(i,t)}^{ever} + \beta_i^{ever} MNE_i^{ever} + \upsilon_{it} \tag{29}$$

The *plant picking* effect is $\beta_i^{ever} > 0$ and the *best firm* effect $\beta_J^{ever} > 0$.

What are the potential concerns in this analysis? A strong assumption in our identification strategy is that all unobserved heterogeneity can be captured by our two fixed effects. There might be important deviations from this assumption. In particular we are concerned that takeover by a MNE is likely correlated with time varying shocks, as well as plant fixed effects. For example, the transition to foreign ownership might depend not only on a plant's fixed characteristics, but also on its time varying characteristics and idiosyncratic shocks. These might make plants more likely to be taken over because they are temporarily weak and thus an easy target for a hostile foreign takeover, or because MNEs become interested in a particular plant only after a positive productivity shock, which might reveal better future growth potential. In the next section we describe a possible estimation strategy that allows us to correct for this source of endogeneity.

3.3.2 Correcting for endogeneity of becoming a multinational

In this section we develop an econometric framework that controls for endogeneity in the probability of becoming part of an MNE[42] incorporating the effects of MNE ownership and takeover selection effects into the structural productivity estimation framework described in Section 3.2.[43] We incorporate takeover selection by explicitly integrating a choice model as a step in the estimation. The plant picking effect is then measured by the extent to which productivity prior to takeover influences the

[42]Of course, the ideal set-up to examine firm effects would be a randomized sample of plant takeovers by the different types of MNEs. Such data are not available.

[43]This implies that we control for endogeneity and plant level shocks can evolve as a general Markov Process.

occurrence of an MNE takeover.[44]

To describe our framework we start by only considering two ownership states for notational simplicity: whether a plant is owned by an MNE or not.[45] Also, we follow the control function approach described in the previous section and assume that ω can be decomposed as:

$$\omega_{it} = \tilde{\omega}_{it} + \beta_{MNE} MNE_{J(it)} \tag{30}$$

where $\tilde{\omega}$ evolves as follows: $\tilde{\omega}_{it} = g(\tilde{\omega}_{it-1}) + \nu_{it}$. If MNE ownership is correlated with ω_{it} we have to include ownership status as an additional variable together with net revenue and physical capital in the control function:

$$\omega_{it} = \phi_{\omega}(\pi_{it}, k_{it}, MNE_{J(it)}) \tag{31}$$

Secondly, if firms systematically select plants they take over this likely influences expectations about plant level ωs. Hence, in the second stage of the OP-style procedure we get

$$E_{t-1}\{\omega_{it}\} = g(\omega_{it-1}) + \beta E_{it-1}\{MNE_{J(it)}\} + \nu_{it} \tag{32}$$

or

$$E_{t-1}\{\omega_{it}\} = g(\omega_{it-1}) + \beta P_{it-1} + \nu_{it} \tag{33}$$

where in the last equation we use the fact that $E_{it-1}\{MNE_{J(it)}\} = P_{it-1}$; i.e. that the expectation at $t-1$ of being an MNEat time t is the probability of becoming an MNE in the next period.[46]

[44]For simplicity we start by looking at productivity in the year immediately prior to the takeover; we then extend the model to allow longer lags to influence the takeover choice.

[45]The framework immediately extends to the more general case of multiple ownership states, which we use in our actual implementation.

[46]If this probability is affected by ω_{it-1} then identifying the parameters of $g(\omega_{it-1})$ as opposed to those of β_{MNE} and $E_{it-1}\{MNE_{J(it)}|P_{it-1}\}$ might not be straightforward. However, since in

We then get an estimate of P_{it-1} by running a discrete choice model of becoming an MNE on a set of explanatory variables for each time t:

$$P_{it} = p(\rho_\omega \omega_{it} + \rho_k k_{it} + \rho_{MNE} MNE_{it}) \tag{34}$$

The MNE dummy captures that MNE ownership in the current period is likely to increase the probability of MNE ownership in the next period.[47] The takeover decision is also likely influenced by other factors such as the size of the capital stock – since larger plants with more valuable assets might, all else being equal, be more interesting takeover candidates – and by longer lags of ω_{it}.[48] Of course ω is not directly observable, but as before it can be controlled for by capital and net revenue.

The estimation proceeds as follows: we first run a logit[49] of the probability of becoming part of an MNE (i.e. MNE takeover) on capital, net revenue and ownership status:

$$P_{it} = p(\phi_P(\pi_{it}, k_{it}, MNE_{it})) \tag{35}$$

where $\phi_P(\cdot)$ is a general function approximated by a polynomial. We then estimate the following equation:

$$r_{it} - vi_{it} = \phi(k_{it}, MNE_{J(i,t)}, \pi_{it}, \hat{P}_{it}) + \eta_{it} \tag{36}$$

stage 2 we only need to identify the capital coefficient of the production function we introduce a combined function; i.e. $E_{t-1}\{\omega_{it}\} = \tilde{g}(\omega_{it-1}, P_{it-1}) + \nu_{it}$

[47] We report results that take into account average plant performance before takeover as well as current performance. For notational simplicity in this section we only include current performance.

[48] This could be particularly important if there are information asymmetries between plants and MNE firms and MNEs learn about plants by observing them over several periods.

[49] In our actual results we have different MNE states. Therefore we estimate a multinomial logit model. A more general approach would be to use a multinomial probit. However this would lead to computational intractabilities (Hajivassiliou and Ruud, 1993). While this can be addressed by employing a simulation based inference approach this was beyond the scope of the current paper.

where $\phi(\cdot)$ is again approximated by a polynomial to smooth out η_{it}. Note that

$$\omega_{it} = \phi(k_{it}, MNE_{J(i,t)}, \pi_{it}, \hat{P}_{it})) - \beta_k k_{it} - \beta MNE_{J(i,t)} \tag{37}$$

Using the assumption of a Markov process in ω_{it} we can obtain an estimate for β_k and β from a non-linear least squares regression of

$$\begin{aligned} r_{it} - vi_{it} &= \beta_k k_{it} + \beta MNE_{J(i,t)} \\ &\quad + g(\hat{\phi}(k_{it-1}, MNE_{J(i,t-1)}, \pi_{it-1}, \hat{P}_{it})) - \beta_k k_{it} - \beta MNE_{J(i,t)}) + \nu_{it} \end{aligned} \tag{38}$$

which from 37 immediately gives us an estimator of ω. This allows us finally to estimate equation 34:

$$P_{it} = p(\rho_\omega \hat{\omega}_{it} + \rho_k k_{it} + \rho_{MNE} MNE_{it}) \tag{39}$$

In this setting the value of β gives us an estimate of the *best firm* effect and ρ_{MNE} provides an estimate of the *plant picking* effect.[50]

4 Results

4.1 Evidence of the MNE and US productivity advantage

The labour productivity advantage of multinationals, US and non US, reported in row 1 of Table 2 might reflect the fact that MNEs tend to operate in highly productive industries and/or tend to cluster in particular regions with special geographical advantages. In fact, Figure 1 shows that MNEs are more present in medium to

[50]Since we have different types of MNEs: UK/other foreign and US, in practice we use a multinomial choice model allowing for 3 states: US MNE, other MNE (including UK), becoming UK MNE and to distinguish the going global (becoming UK MNE) from the MNE takeover effect - as in the fixed effects case – we include an 'ever MNE' as well as a current MNE dummy variable, both defined at firm level. Since the results of the double fixed effects approach show no indication of strong going global effects we do not account for them in our second approach to avoid making it too complex a framework.

high technology sectors such as chemicals and pharmaceuticals; paper; electrical and optical equipment. Thus, we start our econometric analysis by controlling for interacted 4-digit industry time fixed effects and regional dummies. The results of this exercise are reported in Column 1 of Table 3, where we regress labour productivity, measured as real value added per employee on 4-digit industry year dummy interactions, 10 regional dummies and two ownership dummies US, which equals 1 when a plant is a subsidiary of a US multinational, and FOR that takes the value 1 when a plant is owned by a foreign, non-US, corporation.

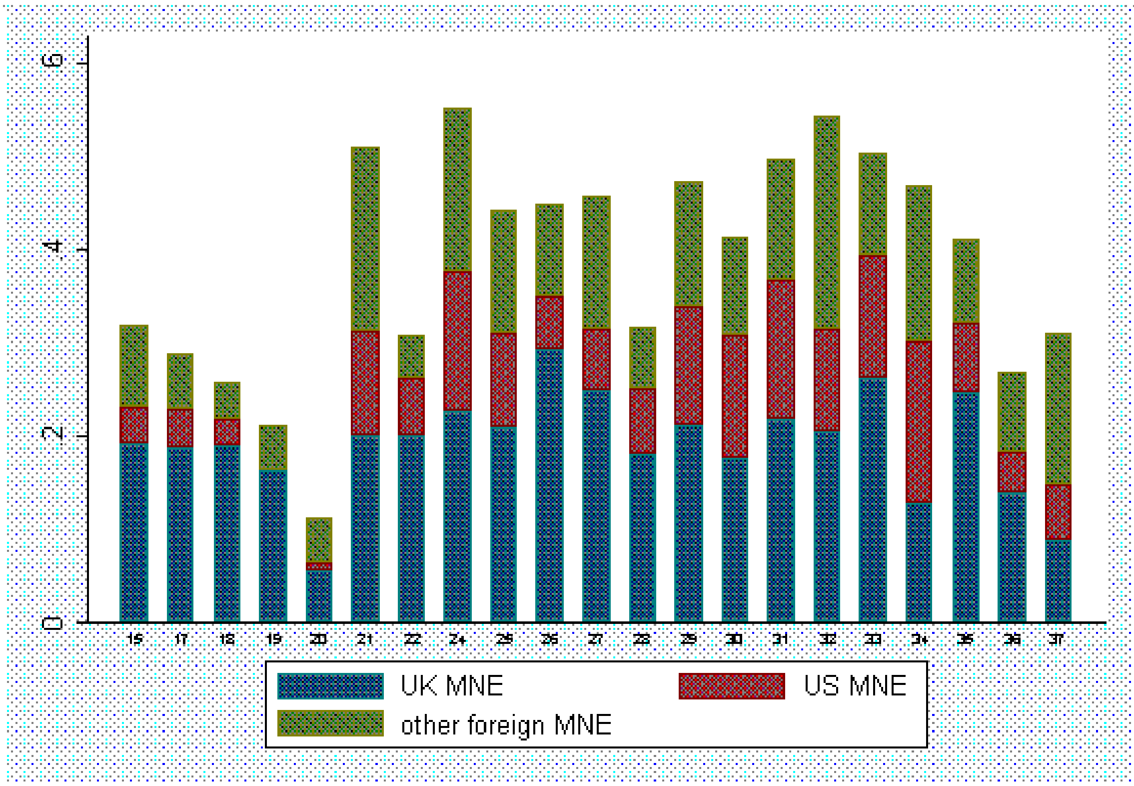
We find that US and other foreign owned plants are on average 42% and 30% respectively more productive than British domestic plants.[51] This sizeable advantage is in line with previous results for Great Britain (e.g. Oulton, 2000). But how much of this advantage is due to these plants being part of a multinational enterprise? Column 2 contains the answers to this question by including a multinational dummy MNE that is 1 whenever a plant is owned by a multinational firm. If this multinational is US owned the dummy US will be 1 as well. Consequently, in Column 2 the US coefficient measures the advantage of US MNEs over British MNEs and the FOR coefficient represents the advantage of Non-US foreign owned subsidiaries over British MNEs.[52] The coefficients' estimates reported in Column 2 show that MNEs enjoy a productivity advantage of 30%, the US has a significant additional advantage of 15%, while non-US foreign owned plants enjoy a smaller but significant 5% advantage relative to their British counterparts.

Table 2 shows that both US and foreign MNEs have much higher capital intensity than UK firms. This suggests that part of the observed foreign ownership advantage could be driven by this higher capital intensity. To examine this we need to estimate

[51] The percentage differences reported in the text are calculated from the coefficients of the dummy variables in Table 3 according to the formula diff = $(e^{\beta^{dummy}} - 1)$ e.g. for the US $0.42 = (e^{0.349} - 1)$.

[52] The performance of US MNEs relative to domestic plants can, therefore, be calculated as the sum of the coefficients on MNE and US and the advantage of other foreign-owned plants as the sum of the coefficients on MNE and FOR.

Figure 1: Share of MNE plants by 2 digit sectors



Notes: The sectors reported are at the 2-digit SIC92 level. 15 Food and beverages; 17 Textile; 18 Wearing apparel; 19 Leather; 20 Wood and wood products; 21 Pulp, paper and paper products; 22 Publishing, printing and reproduction of recorded media; 24 Chemicals and chemical products; 25 Rubber and plastic products; 26 Other non-metallic mineral products; 27 Basic metals; 28 Fabricated metals; 29 Machinery and equipment not elsewhere classified (nec); 30 Office machinery and computers; 31 Electrical machinery and apparatus nec; 32 Radio, television and communication equipment and apparatus; 33 Medical, precision and optical instruments, watches and clocks; 34 Motor vehicles, trailers and semi-trailers; 35 Other transport equipment; 36 Furniture, manufacturing nec; 37 Recycling. The figure reports shares of plants in each of the 2-digit sectors owned by UK; US and other foreign MNEs.

Table 3: Relative productivity of MNE
(estimates of Equation 2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
dep. var	$ln\frac{VA}{L}$				$ln\frac{GO}{L}$			
US	0.349	0.144	0.076	0.045	0.044		0.033	0.072
	(0.017)***	(0.019)***	(0.006)***	(0.007)***	(0.007)***		(0.012)***	(0.009)***
FOR	0.261	0.055	0.041	0.010	0.009			0.037
	(0.015)***	(0.018)***	(0.006)***	(0.007)	(0.007)			(0.009)***
MNE		0.261		0.047	0.047	0.047	0.047	0.020
		(0.011)***		(0.004)***	(0.004)***	(0.004)***	(0.004)***	(0.007)***
EU						0.008	0.008	
						(0.007)	(0.007)	
NON-EU						0.034	0.011	
						(0.007)***	(0.011)	
out US								0.036
								(0.008)***
$ln\frac{K}{L}$			0.071	0.070	0.072	0.072	0.072	0.072
			(0.003)***	(0.003)***	(0.003)***	(0.003)***	(0.003)***	(0.003)***
$ln\frac{M}{L}$			0.626	0.625	0.622	0.622	0.622	0.622
			(0.005)***	(0.005)***	(0.005)***	(0.005)***	(0.005)***	(0.005)***
lnL			-0.010	-0.014	-0.010	-0.010	-0.010	-0.011
			(0.002)***	(0.002)***	(0.002)***	(0.002)***	(0.002)***	(0.002)***
obs	38501	38501	38501	38501	38501	38501	38501	38501

Notes: Robust standard errors in parentheses are clustered by establishment, i.e. robust to heteroskedasticity and autocorrelation of unknown form. In Columns 1 and 2 the dependent variable is log real value added (at factor cost) per employee. In Columns 3 to 8 the dependent variable is the plant's real gross output per employee. Both value added and gross output are deflated by 4-digit annual output price deflators. Regressions in Columns 5 to 8 include a quadratic polynomial in age and an age censoring dummy that equals 1 if the plant has existed since 1980. All regressions (Columns 1 to 8) include region and 4-digit industry time interaction dummies. US equals 1 if a plant is owned by a US multinational, MNE is 1 for all plants that are part of MNE firms and FOR is 1 for all plants owned by non-US foreign multinationals. EU ($Non-EU$) describes plants that are owned by EU (Non-EU) MNEs; $OutUS$ is 1 for UK MNEs that have affiliates in the US. Details of the country group classifications are in the Appendix A. * is significantly different from zero at the 10% level. ** significantly different from zero at the 5% level. *** significantly different from zero at the 1%level.

TFP. We start with the simple OLS approach summarized in equation 2.

In Column 3 – besides capital and material intensity and regional and industry time effects – we only include US and non US foreign ownership dummies and find that US owned plants are significantly the most productive plants in Britain enjoying a strong and significant TFP advantage of almost 8% (with a coefficient of 7.6 as shown by row 1 of Column 3) and non US foreign owned plants follow with an advantage of 4% relative to the reference group of all British plants. This confirms previous results (Griffith (1999), Oulton (2000) and Harris (1999)). Column 4 shows that once we include a separate dummy for being part of an MNE, the advantage of non-US foreign MNEs drops to an insignificant 1%. US plants maintain a significant advantage of 4.5% relative to British MNEs, which, in turn, are 4.8% more productive than non-MNE plants. This result shows that only a part of the US productivity advantage is actually a multinational effect. Column 5 accounts for age effects by including a quadratic polynomial in age[53] to account for possible differences due to the plant life cycle, learning effects and/or the age of physical assets. The coefficient on US MNE remains virtually unchanged, while the foreign non-US advantage relative to UK MNEs is a non significant 1%. Finally, MNEs are on average 4.6% more productive than British non-MNEs.

The aggregation of all non-US foreign owned plants in one group might hide considerable heterogeneity. Therefore, in Column 6 of Table 3, we control for a possible 'EU' effect and reclassify the MNE groups in EU (excluding UK MNEs) vs. Non-EU MNEs.[54] We find that that there is no statistically significant difference between the UK and EU MNE coefficients while non-EU MNEs are significantly more productive than EU MNEs. What is driving this difference? Column 7 shows that once we separate US MNEs from non-EU MNE group, these are as before the

[53]Since our age variable is left censored in 1980, we include an age censoring dummy. We have tried alternative specifications for the age effect. We also experimented by including age categories and the logarithm of age, which leads to the same conclusions obtained under the current specification.

[54]details of the new country group classification can be found in Appendix A.

productivity leaders followed by all other MNEs. In Column 8 we report an additional robustness check for alternative definitions of multinationals. We distinguish from the group of UK MNEs those that have affiliates in the US. The rationale is that these multinationals are likely more similar to US MNEs;[55] in fact when checking the incidence of this group of UK MNEs we find that in our sample 77% of UK MNEs have an affiliate in the US. The results show that US MNEs are still the productivity leaders and that UK MNEs that have affiliates in the US are as productive as other foreign MNEs and more productive than the 23% of UK MNEs that do not have affiliates in the US.

Our results thus suggest the following. Firstly, controlling for capital intensity, material usage, scale and age effects, US MNEs are the productivity leaders, with British and non-US foreign MNEs having a comparable productivity advantage with respect to British plants that are not part of an MNE. Secondly, much of the US and all of the non-US foreign productivity advantage found in previous studies appears to be an MNE effect.

4.2 Robustness checks

Several issues arise when estimating equation 2. Most of those we discussed already in section 3.2: factor inputs might be endogenous and the production technology might be more complex than Cobb-Douglas. Further, the regressions in Table 3 impose the same production technology for the whole manufacturing sector. Finally, the assumption of perfect competition might not hold and the degree of market power might vary between the different groups of MNE and non-MNE firms within 4-digit sectors. We examine the robustness of our results to all of these concerns using a number of different TFP estimation approaches, and also restricting the estimation to different subsamples of our data. The results reported in Table 4 show that our

[55]Since both group of firms operate in the UK and the US. Ideally, one should compare MNEs that invest in the same set of third countries. However, the data do not contain information on FDI destinations other than the UK, for foreign owned MNEs.

Table 4: Robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)
	TFP	**O-P**	O-P, const. μ sectors	O-P, commodities sectors	O-P, varying capital coefficient	O-P, similar to US
MNE	0.058	0.283	0.330	0.332	0.274	0.168
	(0.004)***	(0.016)***	(0.040)***	(0.021)***	(0.027)***	(0.015)***
US	0.038	0.074	0.159	0.076	0.073	0.061
	(0.007)***	(0.034)**	(0.044)**	(0.033)**	(0.033)**	(0.022)***
FOR	-0.008	-0.015	-0.047	0.021	0.006	-0.001
	(0.006)	(0.007)*	(0.048)	(0.033)	(0.029)	(0.024)
$ln\frac{K_i}{K_{Median}}$		0.816	0.775	0.785	0.820	0.809
		(0.007)***	(0.012)***	(0.014)***	(0.007)***	(0.006)***
$ln\frac{K_i}{K_{Median}} \times MNE$					-0.004	
					(0.004)	
$ln\frac{K_i}{K_{Median}} \times US$					0.004	
					(0.006)	
$ln\frac{K_i}{K_{Median}} \times FOR$					0.008	
					(0.010)	
Observations	33848	25531	7113	6465	16936	15145

Notes: All regressions include a quadratic polynomial in age, age censoring dummy, time and region dummies, not reported in the table for brevity. Column 1: robust standard errors in parentheses are clustered by establishment, i.e. robust to heteroskedasticity and autocorrelation of unknown form. Columns 2 to 6: bootstrapped standard errors in parentheses. MNE takes the value 1 if the plant is part of an MNE group. US is 1 if the MNE group is US-owned. Similarly for the foreign other group. In Column 1 the dependent variable is log real (revenue) TFP calculated using the factor share method described in section 3.2. Columns 2 to 5 report the second stage estimates of the modified version of the OP approach described in section 4.2. Column 3 restricts the sample to plants in sectors where the test of constant mark-ups μ could not be rejected (see Appendix C). Column 4 restricts the sample to 'commodities' sectors. Column 5 allows for different capital coefficients not only within the 4-digit sector, but also across firms with different multinationality status. * is significantly different from zero at the 10% level. ** is significantly different from zero at the 5% level. *** is significantly different from zero at the 1% level.

main findings that MNEs are more productive than non MNE plants, and US MNE plants are the productivity leaders, are qualitatively robust to addressing all of these concerns. We now discuss the individual Columns in Table 4. Column 1 presents a factor share based TFP measure as discussed in section 3.2. As shown in equation 21 TFP is computed relative to the 4-digit sector median plant and factor shares are the average of the factor shares of the median plant and plant i. This implies that we impose a very flexible functional form production function, and production technology is allowed to vary between 4-digit sectors. This TFP estimator is also robust to concerns over endogeneity of production factors. The productivity ranking of different MNE types is not affected and the resulting point estimates are similar to those in Table 3. Column 2 presents the results for the structural production function estimator introduced in section 3.2. Relative to Column 1 this relaxes the assumption of perfect competition. Again the productivity ranking remains the same. A number of things are worth pointing out here. Firstly, we now get an estimate for the ratio of scale to mark-up parameter $\frac{\gamma}{\mu}$.[56] As we allow production technology and this parameter to vary at the 4-digit sectoral level the value reported in the table is actually the average across all sectors, weighted by the number of observations in each sector. The parameter estimate, 0.816, is smaller than 1,[57] which is consistent with imperfect competition. Secondly, while the productivity ranking is unchanged the point estimates for both MNE and US MNE effects are now much larger than in Column 1. This is because under imperfect competition the factor share based TFP estimator implicitly estimates $\left(\frac{\gamma}{\mu} - 1\right) k_{it}$ rather than TFP (a_{it}) or the composite shock (ω_{it}). Thus, k_{it} is positively correlated with ω and $\left(\frac{\gamma}{\mu}\right) < 1$ so that $\left(\frac{\gamma}{\mu} - 1\right) < 0$. Measured TFP of the more productive firms with larger capital stocks is too small.[58] Columns 3 and 4 primarily deal with the concern that market power might vary not only across different 4-digit sectors, but also between different firms in the same 4-digit sector. In Column 3 we restrict the sample to plants in those sectors where the Sargan test described in Appendix C cannot reject that μ is constant. In Column 4 we restrict the sample to commodity producing sectors following Rauch's goods classification.[59] The suggestion is that in those sectors price differentiation is less of an issue. Column 5 allows for separate $\frac{\gamma}{\mu}$ parameters for each group of MNE plants in each 4-digit sector.[60] Thus Column 5

[56] See equation 15.

[57] Indeed it is significantly so. Note that the standard error is the standard error of the average derived from a bootstrap procedure, rather than the average of the standard errors for this parameter in different sectors.

[58] This implies that the standard factor share TFP estimator gives too much weight to capital. Rather than weighting capital with $1 - s_L - s_M$ it should give capital a weight of $(\frac{\gamma}{\mu} - s_L - s_M)$.

[59] Rauch (1999) classifies goods as 'homogeneous' (i.e. traded on an organized exchange);'reference priced' and 'heterogeneous'; in the sample in Column 4 we include sectors that produce goods in the first two groups.

[60] Note that in Column 5, by requiring MNE type specific $\frac{\gamma}{\mu}$ in each 4-digit sector, we have automatically to exclude all sectors with no or only very few observations in one of the MNE categories. We thus only include sectors with at least 10 observations in each MNE category.

also addresses the concern that results might be driven by MNEs being active in very different sectors of the economy. As shown by the estimates this is not the case. Also note that the average values for $\frac{\gamma}{\mu}$ for different MNE types reported in rows 4 to 7 of Column 5 suggest that there are no significant differences in this parameter across MNE groups. Again the productivity ranking remains qualitatively unchanged. In Column 6 we address the issue of within 4-digit sector plant heterogeneity by restricting the regression sample to those plants that are more similar to US MNEs according to a range of characteristics including labour and material shares, size and age.[61] This again leads to the same qualitative results. To summarize, the results shown in Table 3 seem to be robust. In the next section we shed more light on the factors that drive these differences.[62]

4.3 Explaining the US productivity leadership

Table 5 shows results from the double fixed effects approach described in section 3.3. Column 1 reports estimates from the two stages on the full sample when we control separately for US MNEs and other foreign effects, with dummies constructed as MNE_J^{ever} and MNE_i^{ever}. We also introduce a set of dummy variables equal to 1 if a plant was set up as a greenfield investment during our sample period by either a domestic or an MNE firm.[63] This controls for the possibility that any *best firm* effects – i.e. the transfer of knowledge or technology from MNE parents to their plants – could be fully realized only in plants set up as greenfields rather than in takeovers. Row 1 of Column 1 reports the coefficient β_{MNE} estimated in the first

[61] We construct this subsample by running a probit model where the left hand side variable is the probability of being US owned and as explanatory variables we include polynomials in labour share, material share, employment, capital and age. A plant is then considered to be similar to a US plant if its predicted probability exceeds the median predicted probability value in the sample.

[62] Other unreported robustness checks include weighted regressions and regressions that control for unobserved skill levels in the firm. In terms of the latter, we include in equation 2 average wages as a proxy for the average skill level of workers; in contrast to other studies (e.g. Griffith and Simpson (2001)) we cannot further distinguish between operatives' and administrative employees' average wages because this information was not reported in the ARD after 1996.

[63] The reference category for this set of dummy variables is the plants that were set up before our sample started so that we do not know who set them up.

Table 5: Sources of MNE and US advantage
(Productivity is residual of gross output regression)

	(1) all	(2) change to MNE	(3) currently domestic
MNE	0.007	0.007	0.007
	(0.007)	(0.008)	(0.007)
ever MNE firm	0.066	0.018	
	(0.013)***	(0.012)	
ever MNE plant	0.155		0.160
	(0.025)***		(0.025)***
ever US firm	-0.002	-0.023	
	(0.017)	(0.020)	
ever US plant	0.098	0.120	0.121
	(0.016)***	(0.032)***	(0.024)***
ever FOR firm	0.017	0.009	
	(0.014)	(0.019)	
ever FOR plant	0.048	0.017	0.035
	(0.015)***	(0.026)	(0.020)*
green DOM	-0.007	0.022	0.001
	(0.010)	(0.033)	(0.012)
green MNE	0.037		0.081
	(0.016)**		(0.057)
green US	0.006		-0.087
	(0.030)		(0.072)
green FOR	0.001		-0.010
	(0.024)		(0.072)
obs	38501	2501	25558

Notes: Bootstrapped standard errors in parentheses. Row 1 (**MNE**) reports first-stage estimates of the ongoing global effect. Row 2 and below: coefficients and standard errors are from the second-stage of our estimation procedure. The dependent variable is the fixed effects estimated in the first step. **ever MNE firm** equals 1 if the plant belongs at time t to a firm which is a MNE. **ever MNE plant** is 1 if the plant has ever been owned by a MNE over the course of the sample period. The same applies to the **ever US** and **ever FOR** dummies. **green** dummies take the value 1 for all plants that were established during the sample period (1996-2000), **green UK non-MNE** is 1 for plants that were owned by domestic firms when established. **green MNE** is 1 for plants owned by MNE firms when established. **green US** (**green FOR**) is 1 for plants owned by US (other foreign) firms when established. Column 1 considers the whole sample of 38,501 observations. Column 2 considers only the plants that undergo a change in status over the period they are present in the sample. Column 3 considers only observations of non-MNE plants and of MNE plants when under ownership of non-MNE firms.
* is significantly different from zero at the 10% level. ** is significantly different from zero at the 5%level. *** IS significantly different from zero at the 1% level.

step. The positive but insignificant coefficient estimate of 0.007 provides only very weak support for the *going global effect* hypothesis in our sample.[64] Row 2 and 3 show that the MNE advantage seems to be due to both a *plant picking* effect and a *best firm* effect. We find significant coefficient estimates of 0.066 and 0.155, respectively. Row 4 and 5 provide evidence that the additional US advantage is a consequence of *plant picking* rather than a *best firm* effect: plants that are at any time in the sample period US owned have an average advantage of about 10 percent over all other MNE plants. Row 7 shows a significantly positive foreign non-US

[64]The first row result holds in columns 1 to 3 because the various columns differ only with respect to the second stage regression

plant effect of 4.8 percent, which is lower than the US plant effect.

Finally, rows 8 to 11 report 'greenfield' effects. Row 9 shows that plants that are set up by MNEs enjoy a 3.7 percent advantage relative to non-greenfield domestic plants, significant at the 5 percent level; row 10 and 11 show that there is no additional advantage from being set up by a US or a foreign MNE.

What could be a potential concern with our estimates in column 1? Firstly, the estimated multinational *best firm effects* coefficients are calculated as a weighted average of all observations of plants currently owned by an MNE firm minus a weighted average of observations of all plants that are not owned by a MNE firm. Thus, the MNE firm coefficient,[65] β_J^{ever}, could be high for two reasons: if plants which are owned by multinationals throughout the sample period are very productive[66] or if plants which change their ownership over the course of our sample had a strong increase in productivity after being taken over by an MNE.[67] To get an idea of the time span that MNEs firms need to increase the productivity of the acquired plants after takeover[68] in column 2 we restrict our sample for the second stage regression to MNE plants which had a transition from domestic to MNE over the course of our sample.[69] The MNE firm dummy reduces to less than a third relative to column 1, from 0.066 to a borderline significant 0.018. This sharp drop in the magnitude and significance of the MNE firm effect suggests that improving the productivity of acquired plants might take some time. In unreported results (available from the authors) we explore this issue in more detail and found that if we restrict the analysis to plants that we can observe for at least two years after takeover, i.e. to

[65] i.e. in terms of the example in Figure 2 in Appendix D, the best firm effect is calculated as $Weighted\ Average\ \{2_{t+1}, 3_t, 3_{t+1}, 4_t, 5_t, 5_{t+1}, 6_t, 6_{t+1}\} -\ Weighted\ Average\ \{1_t, 1_{t+1}, 2_t, 4_{t+1}\}$ where (i, t) denotes a plant-year tuple.

[66] such as 3, 5 and 6 in the example in Figure 2 in Appendix D.

[67] Such as 2 in our example; also if plants such as 4 had a dramatic drop in productivity after being sold off.

[68] In our example, a particular characteristic of plants such as 5 and 6 is that they have been owned by a MNE for longer than plants such as 2. Since we have a sample period of 5 years and for plants such as 2 we must observe at least one takeover, the longest time such a plant could be owned by a MNE is 4 years.

[69] Like plant 2 in our example.

692 observations, the magnitude of the MNE firm dummy coefficient increases to 0.035, but is less precisely estimated with a bootstrapped standard error of 0.022. The next table presents this issue in more detail.

Secondly, the estimated MNE *plant picking* effects coefficients are computed as the weighted average of all observations from MNE^{ever} plants minus a weighted average of all observations from non MNE^{ever} plants.[70] This *plant picking* effect estimate might be upward biased since the estimation includes observations from periods in which some of the 'cherry-picked' plants were owned by an MNE^{ever} firm.[71] Therefore to check the robustness of the *plant picking* effects estimates in Column 3 we restrict the second stage regression sample to observations in the years where all plants (including those that are at some point in time owned by an MNE^{ever} firm) are owned by non-MNE firms.[72] Similar to Column 1 Column 3 shows strong MNE and US plant picking effects suggesting that MNEs, and especially US MNEs, choose the better plants. In contrast to Column 1, we cannot find an additional plant picking effect for plants that are taken over by non-US foreign firms.

Finally, a strong assumption in our identification strategy is that all unobserved heterogeneity affecting MNEs' selection of plants can be controlled for by non-time varying fixed effects. However, it is possible that MNEs are more likely to take over plants following a temporary negative shock - which makes these plants more vulnerable to hostile takeovers but is un-related to their long-term productivity potential (scenario 1), or following a positive productivity shock, e.g. an innovation that would be indicative of better future growth potential for these plants (scenario 2).

Either of these cases can be accounted for using the extension to our structural

[70] Note that a similar argument holds for US and other foreign *plant picking* effects. In terms of our example, the plant picking effect is calculated as $WeightedAverage\{2_t, 2_{t+1}, 3_t, 3_{t+1}, 5_t, 5_{t+1}, 6_t, 6_{t+1}\} - WeightedAverage\{1_t, 1_{t+1}, 4_t, 4_{t+1}\}$.

[71] In terms of the example these are $(2, t+1)$ and $(4, t)$.

[72] i.e. we identify the plant effect from $WeightedAverage\{(2, t)\} - WeightedAverage\{(1, t), (1, t+1), (4, t+1)\}$.

productivity estimation framework introduced in section 3.3.2. Before discussing the results it is worth noting that only scenario 2 could undermine the conclusion that the estimated US advantage over other MNEs is due to plant picking rather than firm effects. This is because in scenario 1 the double fixed effects set-up would lead to an overestimation of any firm effects. Scenario 2 on the other hand would lead to an underestimation of firm effects in the double fixed effects case and could therefore explain why we fail to find any additional US firms effects.

In Table 6 we report the results from the structural model extension from section 3.3.2. We make a number of simplifying assumptions based on the results so far; but it should be noted that our framework does not depend on these assumptions. For instance, we no longer let the capital coefficient – $\frac{\gamma}{\mu}$ vary across sectors.

Column 1 simply replicates the OP style regression from Table 4 with constant $\frac{\gamma}{\mu}$. Our results of large MNE and larger US MNE effects remain. Secondly, since in the double fixed effects case where we did not find much evidence of a going global effect, we no longer allow for this in this setting. This reduces the dimensionality of the selection model that we are adding to the structural framework. Column 2 of Table 6 shows the results from allowing a selection model where only ω_{it-1} enters the equation determining takeover in period t. We find: firstly, that any additional US effect vanishes while a general MNE effect persists; secondly, rows 5 to 7 show that for all three types of MNEs the coefficients on ω_{it-1} from the selection equations[73] are positive and significant. Thus, MNEs select firms that were more productive in the period before takeover. Moreover, note that the selection coefficient is higher, and significantly so, as the t value in row 12 reveals – for US firms. Column 3 includes both ω_{it-1} and the average of ω before takeover $\bar{\omega}_{it-1}$. In this set-up the coefficient on ω_{it-1} captures the importance solely of short term effects.[74] None of the short-term coefficients is significant. The long-term average coefficients are similar in size

[73]Compare with equation 34.

[74]The previous Column ω_{it-1} in the absence of any other control, captured a combination of short and long run effects.

Table 6: Sources of MNE and US advantage
(Results from the extension to the structural productivity estimation framework)

	(1) OLS	(2) OP extended 1	(3) OP extended 2	(4) OP extended 3	(5) OP extended 4
MNE	0.084	0.072	0.069	0.024	0.029
	(0.004)***	(0.010)***	(0.012)***	(0.014)*	(0.016)*
US	0.027	0.004	-0.005	-0.014	0.01
	(0.007)***	-0.015	(0.019)	(0.026)	(0.032)
FOR	-0.000	0.009	0.010	0.041	0.048
	(0.006)	-0.013	(0.017)	(0.023)*	(0.023)**
long run MNE				0.048	0.046
				(0.011)***	(0.019)**
long run US				0.011	-0.006
				(0.019)	(0.041)
long run FOR				-0.035	-0.044
				(0.017)**	(0.022)**
$ln\frac{K_i}{K_{Median}}$ [(a)]	0.948	0.955	0.952	0.951	0.954
	(0.001)***	(0.004)***	(0.007)***	(0.005)***	(0.007)***
$\rho_{UK,\omega}$ [(b)]		0.321	0.034	0.034	0.276
		(0.026)***	(0.163)	(0.113)	(0.052)***
$\rho_{US,\omega}$		0.412	-0.047	-0.047	0.385
		(0.031)***	(0.283)	(0.227)	(0.073)***
$\rho_{FOR,\omega}$		0.3	0.016	0.016	0.306
		(0.035)***	(0.233)	(0.207)	(0.097)***
$\rho_{UK,\bar{\omega}}$			0.300	0.300	
			(0.166)*	(0.114)***	
$\rho_{US,\bar{\omega}}$			0.485	0.485	
			(0.287)*	(0.231)**	
$\rho_{other,\bar{\omega}}$			0.297	0.297	
			(0.229)	(0.220)	
$\rho_{UK,\Delta\omega}$					-0.019
					0.147
$\rho_{US,\Delta\omega}$					-0.157
					(0.156)
$\rho_{other,\Delta\omega}$					-0.085
					(0.180)
	34736	34736	34736	34736	34736
t value for $\rho_{UK,\omega} - \rho_{US,\omega}$		2.293			1.243
t value for $\rho_{UK,\bar{\omega}} - \rho_{US,\bar{\omega}}$			0.583	1.016	

Notes: (a) For simplicity we do not allow the capital coefficient to vary in this specification. (b) The coefficient on ω in the selection equation is for becoming a part of UK MNE in the subsequent period. Compare with equation 34. This is also the basis for the interpretation of the interpretation of the subsequent regression coefficients. In Column 3 we consider the effect of ω in the previous period, as well as the influence of the average value of ω in all previous periods. Column 4 includes dummies to identify long run MNE firm effects. Column 5 considers TFP growth in the selection equation.

to the coefficients on ω_{it-1} from Column 2. The values there were driven by longer rather than short run effects. The long-run coefficients for UK and US MNEs are still significant while the coefficient for other foreign MNEs is not.[75] In Column 4 we also include a dummy that takes effect the first year after the plant comes under MNE ownership; therefore a positive and significant coefficient indicates additional long-run advantages from being part of an MNE. No additional long-run advantage

[75]This is likely due to problems of collinearity and the fact that we are increasingly extending how much can be separately identified from our data.

derives from being part of a US multinational. Finally, in Column 5 we include both level of ω_{it-1} and its lagged growth rate; this latter should capture whether changes in productivity rather than levels are driving the decision of MNE firms to take over particular plants. The growth term is never significant. In all of these cases, the key conclusion that there are no additional US firm effects once selection is controlled for, holds.

5 Conclusions

This study looks at the reasons behind aggregate US productivity leadership by examining the performance of US MNEs in the UK relative to the performances of UK MNEs and other foreign MNEs. This allows us to identify to what extent US productivity leadership is driven by firm specific technological factors rather than factors that are specific to the business environment in the US.

Compared to earlier studies, we are able to identify UK MNEs in such an analysis. Thus, we are able to control for the potential bias that arises because in any country MNEs are a self-selected group of top firms.

Our analysis confirms and qualifies an earlier study by Doms and Jensen (Doms and Jensen, 1998) using US data, which ranks US MNEs highest followed by other MNEs, with domestic firms ranked lowest. However, in their case it cannot be ruled out that the leadership of US multinationals is simply the consequence of a home advantage. Our results suggest that this ranking is not driven by a home market advantage for US firms.

In fact, we find that US owned plants have a significant productivity advantage in the UK, relative to both British MNE and other foreign owned plants, which show similar productivity levels and are both more productive than plants that do not invest abroad. This result is robust to imperfect competition, non-constant returns to scale and differences in flexible production technologies across 4-digit sectors and different types of firms.

Using the dynamic variation in our data we address the concern that US productivity leadership might be driven by the selection in the takeover process of superior plants, rather than by technology and knowledge transfers from MNE parent companies to their subsidiaries. We find evidence for both US MNE firm effects and plant selection effects. However, firm effects are as strong for US MNEs as for other MNE firms, but the takeovers by US MNEs tend to target plants at the top of the productivity spectrum. We conclude therefore that the US productivity lead found in the level regressions is driven mainly by these stronger picking effects.

There could be some concern in relation to the short time period of our sample in that if firm effects take some time to materialise they would not be detected in our study. Although we cannot exclude the possibility that if we had a longer panel we might find stronger firm effects, the fact that we actually find strong MNE firm effects occurring soon after an MNE takeover (except that they are not any stronger for US firms) gives us some confidence that a longer time span would not change the qualitative ranking.

Our results have a number of implications.

Firstly, they suggest that aggregate US productivity leadership might be driven by factors other than technology, i.e. that other factors are driving the aggregate gap. An interesting hypothesis is that well functioning competitive markets in the US[76] are more efficient at allocating larger market shares to more productive plants. Because aggregate productivity is the sum of each firm's productivity weighted by its market share, this better selection mechanism results in higher aggregate productivity.[77]

Secondly, in terms of UK economic policy where there is a widely held view

[76]This is the conclusion of Lewis (2004) on the basis of an impressive number of case studies.

[77]To answer this question thoroughly we would need comparable UK and US micro data. Although beyond the scope of this paper efforts are under way to make progress in this area, see for example Bartelsman et al. (2003).

that incentives for foreign MNEs to locate in Britain are a potential instrument to increase aggregate productivity performance, our results suggest that attracting specifically US FDI is unlikely to provide a quick fix for productivity problems.

Thirdly, while we cannot find any evidence that US MNEs are better at transferring knowledge and technology to their subsidiaries, we did find evidence that they are better at choosing the best plants to take over. Why should US firms be better than all other MNEs at selecting the best plants? There are several possible reasons. One hypothesis is that managers of US MNEs pursue more aggressive takeover strategies and have specific skills that make them more successful in this activity. A second explanation is related to the particular time period considered. Indeed, in the second half of the 1990s, the US Stock market experienced a boom accompanied by spectacular equity price increases. During that period, the S&P500, the Dow Jones Industrial and the NASDAQ Composite indices more than doubled. US MNEs, overvalued in the US stock market, and thus with access to low cost capital, might have found it more profitable to use this capital to target firms abroad (e.g. in the UK) not affected by the same stock market bubble, rather than in the home country.[78] From our data it is not possible to thoroughly investigate these hypotheses, but this is an area of research that deserves further exploration.

References

Arellano, M. and Bond, S. R. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, 58:277–297.

Baily, M. N., Hulten, C., and Campbell, D. (1992). Productivity dynamics in manufacturing plants. *Brookings Papers: Microeconomics*, pages 187–267.

[78] This is the 'cheap capital' view of FDI (Baker et al., 2004)

Baker, M., Foley, C. F., and Wurgler, J. (2004). The stock market and investment: Evidence from FDI flows. *NBER Working Paper*, 10559.

Bartelsman, E., Scarpetta, S., and Schivardi, F. (2003). Comparative analysis of firm demographics and survival: micro-level evidence for the OECD countries. *OECD Economics department working paper*, (348).

Blundell, R. and Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87:115–143.

Branstetter, L. (2001). Are knowledge spillovers international or intranational in scope? microeconometric evidence from the United States and Japan. *Journal of International Economics*, 53:53–79.

Criscuolo, C., Haskel, J., and Martin, R. (2003). Building the evidence base for productivity policy using business data linking. *Economic Trends*, 600:39–51.

Criscuolo, C. and Martin, R. (2003). Using the Annual Inquiry into Foreign Direct Investment to create a multinational identifier in the ARD. Ceriba data guide.

Dixit, A. K. and Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. *American Economic Review*, 67:297–308.

Doms, M. E. and Jensen, J. B. (1998). Comparing wages, skills and productivity between domestically and foreign-owned manufacturing establishments in the United States. In Robert E. Baldwin, R. E. L. and Richardson, J. D., editors, *Geography and Ownership as bases for economic accounting*, pages 235–258. University of Chicago.

Dunning, J. H. (1981). *International Production and the Multinational Enterprise*. George Allen and Unwin.

Foster, L., Haltiwanger, J. C., and Syverson, C. (2003). Reallocation, firm turnover, and efficiency: Selection on productivity or profitability? working paper.

Griffith, R. (1999). Using the ARD establishment level data to look at foreign ownership and productivity in the UK. *Economic Journal*, 109:F416–F442.

Griffith, R. and Simpson, H. (2001). Characteristics of foreign owned firms in British manufacturing. *IFS Working Paper*.

Griliches, Z. and Mairesse, J. (1995). Production functions: The search for identification. *NBER Working Paper*, (5067).

Hajivassiliou, V. and Ruud, P. A. (1993). Classical estimation methods for LDV models using simulation. Econometrics 9311002, EconWPA. available at http://ideas.repec.org/p/wpa/wuwpem/9311002.html.

Harris, R. (1999). Efficiency in UK manufacturing 1974-1994. mimeo.

Helpman, E. (1984). A simple theory of international trade with multinational corporations. *Journal of Political Economy*, 92:451–477.

Helpman, E., Melitz, M. J., and Yeaple, S. R. (2004). Export versus FDI with heterogenous firms. *American Economic Review*, 94(1):300–316.

Katayama, H., Lu, S., and Tybout, J. (2003). Why plant-level productivity studies are often misleading, and an alternative approach to interference. *NBER Working Paper*, (9617).

Keller, W. (2004). International technology diffusion. *Journal of Economic Literature*, 42:752–782.

Klette, T. J. (1999). Market power, scale economies and productivity: estimates from a panel of establishment data. *Journal of Industrial Economics*, XLVII(4):451–476.

Klette, T. J. and Griliches, Z. (1996). The inconsistency of common scale estimators when output prices are unobserved and endogenous. *Journal of Applied Econometrics*, 11:343–361.

Levinsohn, J. and Petrin, A. (2000). Estimating production functions using inputs to control for unobservables. *NBER Working Paper*, (7819).

Levinsohn, J. and Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, 70(2):317–342.

Lewis, W. (2004). *The power of productivity*. The University of Chicago Press.

Markusen, J. R. (1995). The boundaries of multinational enterprises and the theory of international trade. *Journal of Economic Perspectives*, 9(2):169–186.

Martin, R. (2002). Building the capital stock. CeRiBA mimeo.

Martin, R. (2003). Computing the true spread. CEP Discussion Paper 0692.

Melitz, M. J. (2000). Estimating firm-level productivity in differentiated product industries. working paper.

Office for National Statistics (2002). *Foreign Direct Investment 2000 - Business Monitor MA4*. HMSO, London.

Olley, S. and Pakes, A. (1996). The dynamics of productivity in the telecomunications equipment industry. *Econometrica*, 64:1263–97.

O'Mahony, M. and de Boer, W. (2002). Britain's relative productivity performance: updates to 1999. Final report to DTI/HM Treasury/ONS, NIESR.

O'Mahony, M. and van Ark, B. (2003). *EU productivity and competitiveness: An industry perspective*. Office for Official Publications of the European Communities.

Oulton, N. (1997). The ABI Respondents Database: A new resource for industrial economics research. *Economic Trends*, 528:46–57.

Oulton, N. (2000). Why do foreign-owned firms in the UK have higher labour productivity? Bank of England.

Rauch, J. (1999). Network vs markets in international trade. *Journal of International Economics*, 48(1):7–35.

Syverson, C. (2004). Market structure and productivity: A concrete example. *Journal of Political Economy*, 112(6):1181–1222.

Wagner, K. and van Ark, B. E. (1996). *International Productivity Differences, Measurement and Explanations.* North-Holland.

A Variables Definitions

- Capital stock: capital stock was calculated using a perpetual inventory method (PIM). For a more detailed description of the method adopted we refer to Martin (2002).

- Deflators: to deflate output measures (gross output and value added) we use producer price indices (PPI) at the 4-digit SIC92 industry level. To deflate intermediates, we use material price deflators at the 2-digit SIC92 industry level. The base year is 1995. Capital stock is deflated using investment deflators with base year 1995; for years pre-1995 these are implicitly derived from nominal and real sectoral ONS historical investment series. From 1995 onwards we use the publicly available MM17 series.

- Foreign plants are plants owned by foreign owned enterprise groups.

- Country groups:

EU includes plants owned by Austria, Belgium, Denmark, Finland, Luxembourg, Sweden, the Republic of Ireland, Italy, Spain and the Canary Islands, Portugal, and Greece.

non-EU includes plants owned by British Virgin Islands, Channel Islands, Isle of Man, Liechtenstein, Antigua and Barbuda, Cyprus, US Virgin Islands, Norway, Switzerland, Australia, Canada, Czech Republic, Iceland, Mexico, Poland, South Korea and Turkey and plants owned by the rest of the world and plants that are foreign owned, but whose nationality is unknown.

- Weights are calculated using the employment register information on the basis of 4 digit sector, region and employment cells. For each cell i the weight is calculated as $\frac{\text{Number of plants in register in cell i}}{\text{Number of selected plants cell i}}$.

B The monotone relationship between profits and shocks

Start by noting that given our assumption of a homogenous production function (equation 3) we can write the cost minimization problem as:

$$\breve{C}(\breve{K}_{it}, \mathbf{w}_{Vit}) = \min_{\breve{\mathbf{X}}_{Vit}} \sum_{z \neq K} w_{zit} \breve{X}_{zit} \text{ s.t. } 1 = f\left(\breve{K}_{it}, \breve{\mathbf{X}}_{Vit}\right) \tag{40}$$

where w_{zit} represents the cost of factor z and $\breve{K}_{it} = \frac{K_{it}}{\breve{Q}_{it}}$ with $\breve{Q}_{it} = \left(\frac{Q_{it}}{A_{it}}\right)^{\frac{1}{\gamma}}$. $\breve{\mathbf{X}}_{Vit}$ collects the same transformation for all variable production factors in a vector. Total costs become in terms of Equation 40

$$C_{it} = \breve{C}_{it} \breve{Q}_{it} \tag{41}$$

Next consider the profit function.

$$\Pi_{it}(K_{it}, \lambda_{it}, a_{it}, \mathbf{w}_{it}) = R_{it} - C_{it}$$

Given the demand function 5 and the cost function 41 we can write it as

$$\Pi_{it}(K_{it}, \lambda_{it}, a_{it}, \mathbf{w}_{it}) = \left(\frac{\Lambda_{it} R_t}{P_t}\right)^{\frac{1}{\eta}} P_t Q^{1-\frac{1}{\eta}} - \breve{C}_{it}\breve{Q}_{it} \tag{42}$$

Note that the firm's profit maximization first order condition is

$$\left(1 - \frac{1}{\eta}\right) \frac{R_{it}}{Q_{it}} = \frac{1}{\gamma} z(\breve{Q}_{it}, \breve{K}_{it}) \frac{\breve{Q}_{it}}{Q_{it}} \tag{43}$$

where

$$z(\breve{Q}_{it}, \breve{K}_{it}) = \frac{\partial \breve{C}_{it}}{\partial \breve{Q}_{it}} \breve{Q}_{it} + \breve{C}_{it} \tag{44}$$

Finally, note that the derivatives of profits with respect to λ_{it} and a_{it} are

$$\frac{\partial \Pi_{it}}{\partial \lambda_{it}} = \mu^{-1} R_{it}$$

and

$$\frac{\partial \Pi_{it}}{\partial a_{it}} = z(\breve{Q}_{it}, \breve{K}_{it}) \frac{1}{\gamma} \left(\frac{Q_{it}}{A_i t}\right)^{\frac{1}{\gamma}} = \mu^{-1} R_{it} \tag{45}$$

where applying the envelope theorem the last equality follows from the first order condition 43. and

$$\mu = \left(1 - \frac{1}{\eta}\right)^{-1}$$

As a consequence of all these results we get for the total differential of profits

$$d\Pi_{it} = R_{it} \frac{1}{\mu} \left(d\lambda_{it} + da_{it}\right) = R_{it} d\omega_{it} \tag{46}$$

which establishes that there is a positive relationship between profits and the composite shock index ω_{it}.

C Testing if μ is constant

In this section, we describe a simple test based on over-identifying restrictions of the hypothesis that μ is constant within each 4-digit sector. As expected, the null hypothesis is rejected in the majority of sectors. Column 3 of Table 3 shows estimates of equation 20 for a restricted sample of plants in those sectors where the null hypothesis of constant μ cannot be rejected to check the robustness of our results. Our test works as follows. To allow for a more general market structure we let the coefficient of capital in equation 18 depend on the demand shock of the firm, λ_{it}.[79]

$$r_{it} - vi_{it} = \beta_{it}^{K} k_{it} + g(k_{it-1}, \Pi_{it-1}) + \nu_{it} \tag{47}$$

where $\beta_{it}^{K} = \frac{\gamma}{\mu_{it}}$ and $\mu_{it} = \mu(\lambda_{it-1})$. Note that we assume that markups depend only on lagged values of λ_{it}. We require this assumption for our test. One can motivate it by a certain sluggishness in price setting. To understand our next steps suppose that we had a way of observing λ_{it-1} but are ignorant about the shape of the markup function $\mu(\cdot)$. To estimate 47 we can approximate β_{it}^{K} by yet another polynomial expansion in λ. Thus in the regression we would get interactions between k_{it} and the polynomials terms as extra explanatory variables; e.g. $k_{it} \times \lambda_{it-1}^{2}$. If we assume that markups and thus β^{K}'s are constant across firms on the other hand, we can use zero moment conditions between these interaction terms and the residuals as *additional* moment conditions – e.g. $E\{\nu_{it} \times k_{it} \times \lambda_{it-1}^{2}\} = 0$ – to identify the reduced set of parameters of the constant markup model. The problem with this strategy is that λ is not observed. Notice however that[80] a necessary implication of these additional

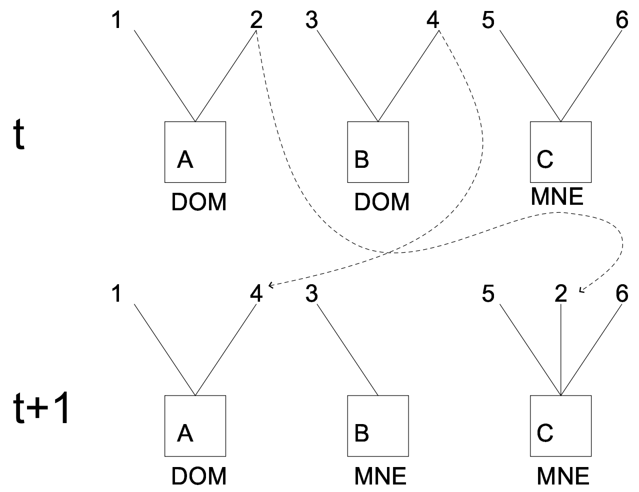
[79] For simplicity we make the formal argument in terms of log levels and not deviations from log values of the median plant as in section 3.2. A similar argument can be made in both cases.

[80] Unless demand shocks λ and technical TFP shocks a_{it} are perfectly negatively correlated that is

moment conditions is that the interaction terms are not correlated with $\omega =$ either; e.g $E\{\nu_{it} \times k_{it} \times \omega_{it-1}^2\} = 0$ Thus to examine if these additional moment restrictions are valid we need estimates of ν_{it} and ω_{it-1}. We described above how we can derive those.

D Identification of double fixed effects

Figure 2: An example



Suppose our sample consists of 6 plants[81] which are owned by 3 different firms (A, B and C). We observe them for two periods, t and $t+1$. In period t firms A and B are domestic, while firm C is an MNE. In period 2 firm B starts investing abroad and thus becomes an MNE whereas A remains domestic.[82] Moreover, we have the following takeover events: plant 2 is acquired by C and plant 4 is sold off to firm A by firm B before it starts investing abroad.[83] How can we differentiate between the MNE effects discussed in the paper with the variation in this example? Consider first the *plant picking* effect. The plant in the example that was taken over by an

[81]numbered 1 to 6 in figure 2

[82]In terms of our earlier dummies we would thus have $MNE_A^{ever} = 0$, $MNE_B^{ever} = 1$ (both, in year t and t+1) and $MNE_C^{ever} = 1$

[83]Consequently $MNE_1^{ever} = 0$ and $MNE_4^{ever} = 0$ whereas for all other plants $MNE_i^{ever} = 1$ $\forall i = 2, 3, 5, 6$.

MNE is plant 2. If we found that in year t plant 2 had a higher productivity than plant 1 this would be evidence of a *plant picking* effect. To examine the existence of *best firm* effects we can compare the productivity of plant 2 in year $t+1$ relative to year t. If its productivity increases after it is taken over by firm C this would be evidence of a *best firm* effect.[84] Finally, for the going global effect we need to look at firm B and examine whether the productivity of its plant 3 increases from t to $t+1$.

In our sample, how many changes between multinational Status for firms and between different types of firms for plants, do we observe? Table 7 reports the occurrence of all these changes in our dataset. The upper panel reports the number of status changes for each possible transition between UK non-MNE, UK MNEs, US MNEs and non-US Foreign MNEs (FOR). For example the cell in row 1, Column 2 reports that in our sample there are 589 transitions from UK non-MNEs to UK MNEs. The lower panel reports only the number of status changes that also involve an ownership change. Therefore, the cell in row 5 Column 2 reports that 255 of the 589 British plants that became multinational did so by means of an ownership change, i.e. a takeover. This implies that the remaining 334 plants became part of a British MNE because the firm they belonged to started investing abroad. This is the variation we use to identify β_{MNE}. In total, the upper panel shows that we have 1,118 changes between non-MNE and MNE status.[85] The lower panel shows that 784 of these changes involved a change in ownership, i.e. a takeover. Overall, panel 1 of Table 7 shows that about 10% of all the transition events we observe in the data involve a change in multinational status.[86] From panel 2 we can derive that about 40% of all ownership changes in our sample involve changes between multinational

[84]Equally, we could see whether the productivity of plant 4 decreases once it is taken over by A in period $t+1$.

[85]We obtain this figure by summing the off diagonal elements of row 1 and Column 1 in the upper panel.

[86]This is computed as the share of all off diagonal elements to the sum of all cells in table 7.

status.[87] Thus, while the majority of plants do not change status, in the data there is still some non-negligible number of status changes.

Table 7: Status changes in the data
(Transitions in ownership and MNE status in sample 1996-2000)

	(1) UK non MNE	(2) UK MNE	(3) US	(4) FOR
	Status changes			
UK Non MNE	11164	589	225	304
UK MNE	251	3170	101	46
US	155	62	1290	48
FOR	138	42	26	1857
	Status changes with ownership change			
UK Non MNE	1511	255	225	304
UK MNE	164	51	101	46
US	155	62	131	48
FOR	138	42	26	246

Notes: $UKnonMNE$ denotes domestic plants with no FDI; $UKMNE$ is 1 for all domestic multinationals; US is 1 for all plants owned by a US multinational and FOR is 1 for all plants owned by non-US foreign multinationals. Panel one of the table reports the number of plants that change their MNE status; panel two reports the subset of these that also experienced an ownership change. For example Row 1 Column 2 reports that there are 589 transitions from UK non-MNE to UK MNE. Row 5 Column 2 reports that in 255 cases these transitions also involved a takeover. The number of observations in the sample is 38,501. The period considered is 1996-2000. Source: Authors' calculation using the ARD AFDI matched data.

[87] Again, computed as the share of all off diagonal elements, but this time of panel 2