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Multinationals and U.S. Productivity Leadership: Evidence from Great Britain

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MULTINATIONALS AND US PRODUCTIVITY LEADERSHIP: EVIDENCE FROM GREAT BRITAIN*

Chiara Criscuolo ** and Ralf Martin***

October 2003

Abstract

US plant level studies show US multinational enterprises (MNE) are more productive than other MNEs. This could reflect US productivity leadership or could be due to the ease in which US firms operate in their home surroundings. The evidence would therefore be more compelling if US firms were leaders outside the US. We study the productivity of plants owned by US firms located in the UK. Our study differs from many studies of foreign owned plants in three ways. Firstly, using a newly available dataset we can identify not only foreign but also domestic MNEs. We find that UK MNEs are less productive than US owned plants, but as productive as non US foreign owned plants. Secondly, having a panel dataset we distinguish between different hypotheses regarding the nature of the US and MNE advantage. We find strong evidence that the US advantage lies in the ability to takeover already productive plants. Whereas we find some evidence for a shared asset effect for MNEs in general we do not find any evidence that the US advantage is driven by superior shares assets. Thirdly, this paper features a novel approach to TFP calculation.

JEL Classification: F230, L600 **Keywords:** Multinational Firms, Productivity, Foreign Ownership, US leadership, Double Fixed-Effects.

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LES MULTINATIONALES ET LE RÔLE PRÉPONDERANT DE LA PRODUCTIVITÉ AMÉRICAINE : LE CAS DE LA GRANDE-BRETAGNE*

Chiara Criscuolo et Ralf Martin*****

octobre 2003

Résumé

D'après des études américaines au niveau de l'entreprise, les multinationales américaines sont plus productives que les autres multinationales. Cette situation pourrait s'expliquer par le rôle prééminent de la productivité aux États-Unis ou par la facilité avec laquelle les entreprises américaines exercent leurs activités sur le territoire de leur pays. La démonstration serait plus convaincante si les entreprises américaines étaient en tête à l'extérieur des États-Unis. Nous étudions la productivité des établissements industriels détenus par des entreprises américaines situées au Royaume-Uni. Notre étude se démarque de beaucoup d'études consacrées aux établissements industriels à capitaux étrangers de trois manières. Premièrement, grâce à une nouvelle base de données, nous pouvons identifier non seulement les multinationales étrangères, mais également les multinationales nationales. Nous concluons que les multinationales du Royaume-Uni sont moins productives que les établissements industriels à capitaux américains, mais aussi productives que les autres établissements à capitaux étrangers non américains. Deuxièmement, à partir d'un panel de données, nous faisons une distinction entre différentes hypothèses quant à la nature de l'avantage des établissements à capitaux américains et des multinationales. Il apparaît clairement que l'avantage des multinationales américaines est lié à la capacité de prendre le contrôle d'entreprises déjà productives. Certains éléments vont dans le sens d'un effet de partage d'actifs pour les multinationales en général, mais rien ne prouve que l'avantage américain soit dû à un phénomène plus marqué de partage d'actifs. Troisièmement, cette étude présente une nouvelle approche du calcul de la PTF.

Classification **JEL :** F230, L600 **Mots clés :** Entreprises multinationales, productivité, capitaux étrangers, leadership américain.

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1 Introduction

International comparisons show that the US are the productivity leaders[1] and much research has gone into understanding the determinants of this productivity leadership. There are two broad categories of factors that could be responsible: the *business environment* and *firm or plant specific* factors. The business environment comprises the quality of a country's workforce, the efficiency of public infrastructure, market size as well geographical advantages. Firm and plant specific factors include more efficient production processes and management techniques, better marketing or more valuable patents or brands. Plant level analysis of units owned by firms based in different countries but operating in the same country can potentially distinguish between these two hypotheses. Since the business environment is the same for all plants in the sample, any observed productivity differences should be entirely due to differences in plant or firm specific factors. Then, if US leadership is to be attributed to plant or firm specific factors, we should find that US owned plants have higher productivity than others in the same business environment.

Doms and Jensen [9] is the first study of this kind for the US that also controls for the multinationality of the firms. They find that plants owned by US multinational enterprises (MNE) are the productivity leaders in the US, followed by foreign owned plants. Domestic non MNE plants come last.

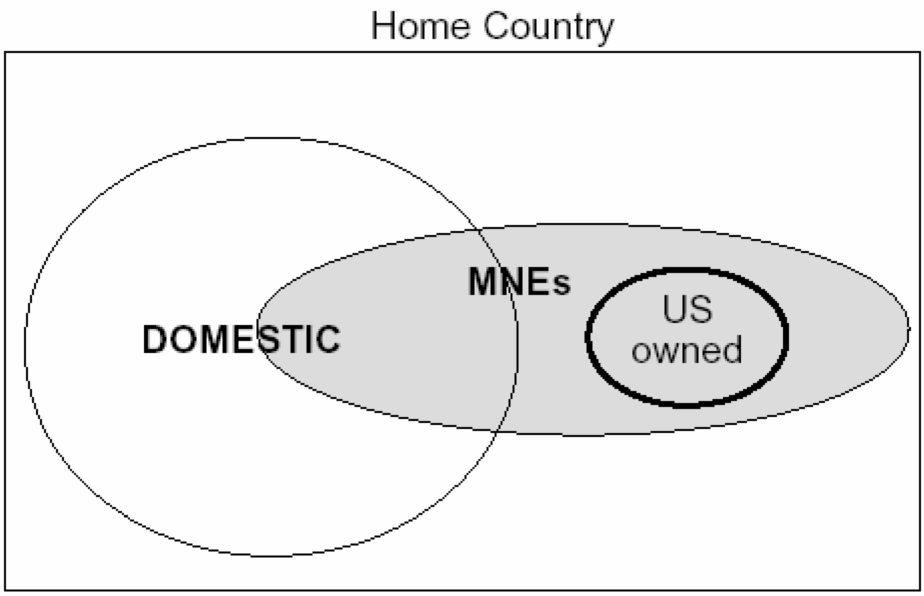
Using a newly available dataset the Annual Inquiry into Foreign Direct Investment (AFDI), which allows us for the first time to identify British MNEs, we can do a similar study for Britain. This is not only of relevance

[1] see for example O'Mahony and De Boer[25]

for Britain but allows us to qualify the findings of Doms and Jensen in one important respect: in their study they cannot rule out that the leadership of US MNE owned plants is the consequence of a home advantage rather than of transferable firm level advantages. The first innovation of our paper, therefore, is to establish the leadership of US MNEs in Britain and thereby show that the US MNE advantage found by Doms and Jensen is not a home advantage.

Figure 1 shows why in studies on foreign ownership it is crucial to control for multinationality of domestic plants. Foreign owned plants in any country

Figure 1: The populations of firms in a country



are by definition a subset of the set of multinational plants. However, only a small subset of domestic plants are owned by MNEs. If MNEs have an intrinsic productivity advantage, the superior performance of foreign owned plants might simply reflect a multinational advantage. Such an advantage might come from superior technology: as outlined in Dunning [10][2] setting up abroad is likely to be more expensive than setting up at home. Factors such as language barriers and ignorance of local business networks give foreign firms a disadvantage. If they nevertheless manage to stay in business, they must have superior technology. Thus, MNEs are by definition a self selected club of better firms. When comparing foreign owned plants to *all* domestic ones it is therefore not surprising to find superior performance of the foreign owned ones as has been established in many previous studies [3]. The second innovation of our paper is that for the first time in Britain we can establish that the foreign ownership advantage is indeed by and large a MNE advantage.

The third innovation is that we disentangle the nature of the US and MNE advantage further. We exploit the longitudinal dimension of our data to examine two issues[4]. Firstly, is there a positive impact for domestic firms of becoming a MNE? The answer is that the effect is positive but not significant. Secondly, are the drivers of the MNE and the US advantage firm or plant specific? This distinction is important because firm specific factors would imply that MNEs have a positive impact on the performance of plants they takeover. Plant specific factors imply that the MNE effect is driven by an ability of MNEs to takeover plants which have superior productivity even before the takeover. We find some evidence for firm MNE firm effects and very strong evidence for plant effects. In particular the US advantage seems to be primarily driven by plant effects: US MNEs take over plants that are about 10 percent more productive than plants taken over by other MNEs.

[2]For a nice summary of Dunnings argument see Markusen [20]

[3]Griffith [13], Griffith and Simpson [12], Oulton[27], and Harris [15] using the ARD; Conyon et al. [6] using firm level data; Davies and Lyons [7] using industry level data for the UK. Doms and Jensen's study [9] for the US. Lipsey and Sjoholm's study [19] examines the better performance in terms of wages of foreign-owned firms in Indonesia

[4]We have done this using two alternative methods: the first one is a two-step procedure described in section 6; the second is a double fixed effects model as pioneered in the employer-employee literature and described in the appendix.

The rest of the paper is organised as follows: in sections 2 and 3 we describe our dataset. Section 4 shows that US owned plants are the productivity leaders in the UK, both in terms of labour productivity and in terms of total factor productivity (TFP), and that only part of the US ownership advantage can be explained by a multinational effect. In section 5 we show that this result is robust; using an approach on the lines of Olley and Pakes [24] and Levinsohn and Petrin [18] which controls for the endogeneity of inputs and accounts for imperfect competition. In section 6 we disentangle the US productivity effect using a two-step estimation procedure. Section 7 concludes. Appendix A contains a more detailed description of the main variables. Finally, appendix C calculates firm and plant specific effects and briefly discuss the double fixed effects technique used for this purpose and the assumptions entailed.

2 Data Sources

Our sample is drawn from the ARD[5] which is the UK equivalent of the US Longitudinal Respondents Database (LRD). It is a dataset made available by the Office for National Statistics (ONS) based on information from the mandatory annual survey of UK businesses, called Annual Business Inquiry (ABI)[6]. The ARD's unit of observation is defined by the ONS as an "autonomous business unit". We refer to this level of observation as a 'plant' and think of it as the smallest unit where profit maximization takes place[7]. It is important to note that the ARD does not consist of the complete population of all UK businesses. All businesses with more than 100 employees[8] are

[5] More extensive descriptions of the ARD can be found in Barnes and Martin [23], Griffith [13] and Oulton[26]

[6] Annual Census of Production until 1998

[7] Some of these business units are spread across several sites and are therefore not plants in the strict sense of the word. In about 80 percent of all cases a business unit is located entirely at a single mailing address.

[8] In some years the threshold was 250 employees.

sampled, but smaller businesses are sampled randomly. Only data on British plants – i.e. excluding Northern Ireland – was made available to us. Each year the sampled plants account for around 90% of total UK manufacturing employment[9]. In sum, our sample is an unbalanced panel of about 19,000 manufacturing plants which we observe annually for the years from 1996 to 2000.

The country of ownership of a foreign owned firm operating in the UK – and thus the ability to identify foreign owned MNE plants in the UK – is provided in the ARD[10]. While this identifies foreign owned plants, until now it has not been possible to identify UK MNEs. To do this we use the AFDI. 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. The AFDI is thus a survey run at the firm and not at the plant level as the ARD. The sampling frame of the AFDI is the population of all UK firms which are engaging or receiving foreign direct investment (FDI). The working definition of FDI for this purpose is that the investment must give the investing firm a 'significant' amount 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 percent[11] of the recipient firm's capital. To conduct the AFDI, the ONS maintains a register which holds information on the country of ownership of each firm and on which UK firms have foreign subsidiaries or branches[12]. This register is designed to capture the universe of firms that

[9] To examine if our results are sensitive to the oversampling of larger plants we run regressions with inverse sampling probabilities as weights. These results are available upon requests from the authors.

[10] The ARD data is supplemented here with information from Dun&Bradstreet global "Who own's 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. is the top-most company of a world-wide 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.

[11] 20 percent before 1997

[12] The ONS distinguishes between subsidiaries and branches as follows: a 'subsidiary' is

are involved in foreign direct investment abroad and in the UK. We consequently define as 'multinational' each plant in the ARD that is owned by a firm which appears in the AFDI register.

A problem with the AFDI register is that information is not always up-to-date. If a firm engages or receives FDI, it will only be included in the AFDI register after the ONS learns from various sources, including commercial data and newspapers, that this happened. Consequently, the register population has varied spuriously over the years with the ONS' success in identifying such firms. However, we believe that this problem does not affect the conclusions that can be drawn from our results. If some of the plants which we record as non-multinational are actually multinational plants and we still find that multinationals are more productive than non-multinational plants then this means that this result would be even stronger if we measured the status of all plants correctly.

3 Descriptive Statistics

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 GB Non MNEs), British MNEs (GB MNE), US MNEs and non US foreign owned plants (Non US MNEs) in the whole population. Column 2 shows the number of plants for each group in the sample of plants surveyed by the ONS to compile the ARD. Columns 3 and 4 translate these numbers into shares. Column 3 shows that 1 percent of all plants in Britain are US owned, almost as much as all other foreign owned plants combined.

mainly 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 using the nationality of the immediate owner, ONS [11] p.120.

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

	number of plants		shares		emp share		va share	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	pop.	sample	pop.	sample	pop.	sample	wghtd	unwghtd
GB Non MNEs	158,868	8,394	0.96	0.75	0.59	0.41	0.44	0.31
GB MNEs	3,062	1,427	0.02	0.13	0.21	0.29	0.27	0.32
US MNEs	1,172	615	0.01	0.05	0.10	0.14	0.15	0.19
Non US MNES	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 sample of smaller plants). Column 5 uses employment information from administrative data for non-surveyed plants. Column 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.

Source: Authors' calculations using matched ARD-AFDI data over the 1996-2000 period.

Indeed, US MNEs represent more than 40 percent of foreign owned plants in Britain. Similar figures hold for the share in employment (column 5) and value added (column 7), where US owned plants represent 47 and 51 percent 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 percent, in the sample the same figure rises to 5 percent.

Table 2 reports averages and standard deviations for relevant variables. Panel 1 shows the US owned plants' labour productivity lead: averaging over the whole production sector and not controlling for industry we find that plants owned by US firms have an advantage of 26 percent over British MNEs and an advantage of 8 percent 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 partly explained by the fact that non US foreign owned plants have much higher

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

		GB non MNE	GB MNE	US	Foreign other
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 over the sample period. Standard deviations in parenthesis. Figures in panels 1 to 4 and 6 are in thousands of pounds. The number of observations is 38,501.

Source: Authors' calculations using matched ARD-AFDI data over the 1996-2000 period.

materials-to-labour and capital-to-labour ratios than all other plants. Panel 5 shows that US plants are on average larger and pay higher wages. This might imply that at least part of the US advantage is the consequence of scale effects[13] and employment of higher skilled workers. Thus, the US advantage might not be due to technological or managerial superiority but simply to different input choices.

Finally, note that the results in table 2 could be misleading because of compositional effects (e.g. MNEs are concentrated in certain industries). It is therefore crucial to control for all these factors jointly which we do in the next section.

4 Foreign or Multinational Effect?

As with most other studies on plant level microdata we do have plant level input and output data but no plant level price data. If we cannot assume perfect competition which would imply equal prices across plants in a sector, typical TFP estimates capture not only technological differences between plants but also demand side differences arising from factors such as product differentiation and branding. We follow Klette and Griliches [16] in making this explicit by specifying a demand function. What we observe at the plant level is revenue $R_{it} = Q_{it}P_{it}$ deflated with a sectoral price index P_{It}. Writing all variables in logs we get the identity:

$$r_{it} - p_{It} = q_{it} + p_{it} - p_{It} \tag{1}$$

Assuming Cobb Douglas technology[14], we have, in log terms:

$$q_{it} = a_{it} + \gamma \sum_{z \in Z} \alpha_z x_z \tag{2}$$

[13]Here we refer to scale effects at the plant level. In our study we cannot control for the scale of the global operations of MNEs, which might also the performance of plants located in Britain. We do not have information on 'global employment'.

[14]We examine the sensitivity of our results to this assumption by adopting a more flexible production function in section 5

Table 3: Relative productivity of MNE
(estimates of Equation 7)

	(1)	(2)	(3)	(4)	(5)	(6)
dep. var		value added			gross output	
foreign US	0.329	0.137	0.130	0.070	0.045	0.045
	(0.017)***	(0.021)***	(0.020)***	(0.007)***	(0.008)***	(0.008)***
foreign other	0.238	0.045	0.047	0.038	0.013	0.011
	(0.015)***	(0.019)**	(0.019)**	(0.006)***	(0.007)*	(0.007)
mult		0.246	0.149		0.034	0.046
		(0.014)***	(0.014)***		(0.005)***	(0.005)***
$ln\frac{K}{L}$				0.061	0.058	0.068
				(0.003)***	(0.003)***	(0.003)***
$ln\frac{M}{L}$				0.619	0.619	0.614
				(0.005)***	(0.005)***	(0.005)***
lnL			0.075			-0.009
			(0.004)***			(0.002)***
age			0.012			0.002
			(0.003)***			(0.001)*
$age^2/10$			-0.005			-0.002
			(0.001)***			(0.001)***
age_{cens}			-0.023			0.013
			(0.017)			(0.007)*
obs	38501	38501	38501	38501	38501	38501

Notes: Robust standard errors in parentheses, estimated allowing correlation between unobservables for plants in the same firm. In columns 1-3 the dependent variable is log real value added (at factor cost) per employee. In columns 4-6 dependent variable is plant's real gross output per employee. Both value added and gross output are deflated by 4-digit annual output price deflators. Age_{cens} equals one if the plant exists since 1980. All regressions include time, region and 4-digit industry dummies. * significantly different from zero at the 10 percent level. ** significantly different from zero at the 5 percent level. *** significantly different from zero at the 1 percent level.

Table 4: Robustness checks

	(1)	(2)	(3)	(4)	(5)
	$ln\frac{go}{L}$	translog	O-P	TFP	obs
MNE	0.047	0.038	0.148	0.054	11938
	(0.005)***	(0.005)***	(0.017)***	(0.004)***	
USA	0.044	0.018	0.066	0.033	2607
	(0.008)***	(0.006)***	(0.023)***	(0.006)***	
EUnorth	0.017	-0.011	-0.031	-0.002	801
	(0.011)	(0.009)	(0.049)	(0.009)	
EUsouth	0.006	-0.042	-0.036	-0.016	83
	(0.027)	(0.020)**	(0.528)	(0.024)	
France	0.014	-0.017	-0.004	0.005	452
	(0.012)	(0.009)*	(0.049)	(0.011)	
Germany	-0.018	-0.041	0.018	-0.024	530
	(0.010)*	(0.009)***	(0.054)	(0.009)**	
Japan	-0.019	-0.064	-0.011	-0.033	364
	(0.015)	(0.013)***	(0.074)	(0.013)***	
Netherlands	0.025	-0.014	-0.042	-0.021	388
	(0.016)	(0.013)	(0.042)	(0.012)*	
Tax	-0.104	-0.088	-0.194	-0.069	75
	(0.026)***	(0.022)***	(0.067)***	(0.022)***	
other	-0.028	-0.051	-0.093	-0.050	137
	(0.025)	(0.021)**	(0.052)*	(0.021)**	
otherEurope	0.060	0.028	-0.032	0.013	341
	(0.028)**	(0.025)	(0.093)	(0.020)	
otherOECD	0.057	-0.001	-0.018	0.019	235
	(0.019)***	(0.016)	(0.078)	(0.016)	
obs	38501	38501	37928	38253	.

Notes: Columns 1, 2 and 4: robust standard errors in parentheses, estimated allowing correlation between unobservables for plants in the same firm. Column 3: bootstrapped standard errors in parentheses. MNEs takes value 1 if plant is part of an MNE group. USA is one if the MNE group is US-owned. Similarly for the other country groups. Details on the country group classifications are in the appendix A. In columns 1 and 2 the dependent variable is log real gross output per employee. Column 1 estimates a Cobb-Douglas production function. Unreported regressors include log capital per employee, log materials per employee, log employment, and 4-digit industry dummies. Column 2 estimates a translog production function. Unreported regressors include quadratic polynomials, interaction terms of the (log of) inputs, and 4-digit industry dummies. Column 3 reports the second stage estimates using the method along the lines of Olley and Pakes described in section 5. In Column 4 the dependent variable is log real TFP calculated using a factor share method as outlined in the appendix A. All regressions include a quadratic polynomial in age, age dummy, time and region dummies. * significantly different from zero at the 10 percent level. ** significantly different from zero at the 5 percent level. *** significantly different from zero at the 1 percent level. Column 5 row 1 reports the number of observations for all MNEs in the sample, row 2 reports the number of observations for US MNEs, row 3 to 13 report the number of observations from MNEs in each country group reported in column 1.

Our set of production factors Z includes labour, materials and capital. γ represents returns to scale. a_{it} captures firm specific variations in technology. we further assume that demand of plant i at time t is given by:

$$Q_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} \Lambda_{it}^{\eta-1}\Theta_{It} \quad (3)$$

where Λ_{it} is a demand shock specific to the firm and Θ_{It} is a sectoral shock to demand[15]. Taking logs of 3 and inverting gives:

$$p_{it} - p_{It} = \frac{1}{\mu}\lambda_{it} - \frac{1}{\eta}q_{it} + \frac{1}{\eta}\theta_{It} \quad (4)$$

where $\mu = \frac{1}{1-\frac{1}{\eta}}$ is the markup of price over marginal cost implied by profit maximizing behavior and lower case letters denote logarithms. Combining equations 4 and 2 with 1 we get:

$$r_{it} - p_{It} = \frac{\gamma}{\mu}\sum_{z\in Z}\alpha_z x_z + \omega_{it} + \frac{1}{\eta}\theta_{It} \quad (5)$$

where $\omega_{it} = \frac{1}{\mu}(a_{it} + \lambda_{it})$ is what one obtains when estimating TFP in a production function framework using deflated revenues as output: not technological TFP a_{it}, but a combination of technology shocks a_{it} and demand shocks λ_{it}. In our current context this is exactly what we are interested in. We want to capture if US firms are superior because of both, more efficient technology and production of inherently more valuable goods[16].

[15] This demand function can be derived by assuming monopolistic competition à la Dixit-Stiglitz [8] in the product market

[16] To make the point clearer consider the example of two plants producing fizzy drinks. President's Cola is US owned whereas Queen's Cola is the British competitor. Suppose the two plants employ exactly the same production technology so that the number of cola cans produced per input – i.e. a_{it} – is equal across the two plants. Queen's Cola can charge a higher price because their branding resonates with the patriotic feelings of Britons. If we only measured genuine TFP we would not capture this. Crucially the differential in the λ component suggests that - ceteris paribus - shifting production factors from President's to Queen's Cola or allowing President Cola to sell using Queen's Cola branding, will be welfare improving.

We test if US firms have superior ω by explaining the variation in ω by a multinational, US and other foreign ownership dummies; i.e.:

$$\omega_{it} = \beta_1 USA_{J(i,t)} + \beta_2 FOR_{J(i,t)} + \beta_3 MNE_{J(i,t)} + \varepsilon_{it} \quad (6)$$

where the subscript $J(i,t)$ indicates that plant i is owned by firm J at time t and ε_{it} is the error component. The MNE dummy takes the value of one each time a plant i is owned in period t by a multinational firm. If this multinational is US owned the dummy USA will be also one. Consequently, β_1 represents the advantage of US MNEs over British MNEs [17]. Thus, we estimate the following equation:

$$\begin{aligned} r_{it} - p_t - x_{Lit} &= \tfrac{\gamma}{\mu} \textstyle\sum_{z \in Z} \alpha_z (x_{zit} - x_{Lit}) + \tfrac{\gamma}{\mu} x_{Lit} \\ &\quad + \beta_1 USA_{J(i,t)} + \beta_2 FOR_{J(i,t)} + \beta_3 MNE_{J(i,t)} \\ &\quad + \tfrac{1}{\eta} \theta_I + \varepsilon_{it} \end{aligned} \quad (7)$$

where we have normalised gross output, capital and material inputs by labour. Least squares estimates of 7 are subject to a number of criticisms including endogeneity of factor demands, inflexibility of functional form and absence of fixed effects. We address these issues below using a novel framework in the spirit of Olley and Pakes[18] [24]. The qualitative conclusions are robust to the adoption of alternative frameworks, however. Consider first the OLS results in table 4. Column 1 to 3 contain regressions of value added per employee on various controls. Columns 4 to 6 report estimates of various versions of equation 7 with deflated revenues per employee as dependent variable.

In column 1 – besides industry controls – we only include US and non US foreign ownership dummies and find that US owned plants enjoy a strong and significant labour productivity advantage of 39 percent and non US foreign owned plants an advantage of 27 percent[19] relative to the reference group

[17] The performance of US MNEs relative to domestic plants can, therefore, be calculated as $\beta_1 + \beta_3$

[18] For a nice explanation of Olley and Pakes method, see Pavcnik[28].

[19] The percentage differences are calculated from the coefficients of the dummy variables in Table 4 according to the formula diff = $(e^{\beta} - 1)$

of all British plants. US owned plants are significantly the most productive plants in the Britain. Column 2 shows that once we include a separate dummy for being part of an MNE, US plants have a significant advantage of 14.7 percent relative to British MNEs. The non US foreign advantage drops to 4.7 percent and is significant only at the 5 percent level. Column 2 also shows that plants that are part of a British MNEs are 28 percent more productive than non MNE plants. This result shows that only part of the US productivity advantage is actually a multinational effect. Column 3 extends the results of the previous column: it accounts for scale and age effects by including employment and a quadratic polynomial in age[20]. The coefficients of US and Non US MNEs remain virtually unchanged, however the MNE coefficient decreases by 40 percent but is still a strongly significant 16 percent. Column 4 looks at TFP by estimating equation 7, initially with capital and material controls and foreign ownership dummies only. Both US and other foreign plants have a significant TFP advantage over British plants. However, once we control for multinationality of plants in column 5, the advantage of other foreign MNEs disappears whereas the US plants show a significant advantage of 4.5 percent. Column 6 controls for age and scale effects and confirms that MNEs are on average 4.6 percent more productive than British non MNEs, US MNEs are still the productivity leaders with an additional advantage of 4.5 percent, while the foreign non US advantage is a non significant 1 percent.

Our results so far 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, for foreign non-US owned plants, the labour productiv-

[20]Since our age variable is left censored in 1980, we include an age censoring dummy. We have tried alternative specifications for the age effect, including age categories and the logarithm of age; the estimates do not change significantly from the ones obtained under the current specification.

ity advantage estimated in previous studies[21] appears to be largely an MNE effect.

5 Are our results robust?

Several issues arise when estimating Equation 7. We address them in turn and report the results in table 4.

The first issue concerns the aggregation of all non-US foreign owned plants in one group. This might hide the heterogeneity within this group. Thus, we differentiate the "non US Foreign" group further into various country groups[22]. Column 1 of Table 4 shows that US MNEs are still the productivity leaders together with Norway, Switzerland and other OECD countries (mainly Canada and Australia) and a first glance at the following columns show that only the US leadership is robust to further checks.

A second issue is whether our results are robust to the specification of the production function. In table 4, we have adopted a static Cobb-Douglas specification, but in table 4 we show that our results are robust to the adoption of a more flexible specification, such as the translog production function (column 2 of table 4)[23].

Thirdly, it is likely that the unobserved shock to productivity ε_{it} is correlated with the factor demands used as explanatory variables. A way to deal with the problems of endogeneity of inputs is to use as dependent variable TFP calculated using factor share methods (Baily et al.[3]) as described in appendix A. The results reported in column 4 show that the MNE advantage and the US leadership are robust to this specification[24]. Factor share

[21] cited in footnote 3.

[22] details of the country groups classification can be found in the appendix A.

[23] In unreported estimates we show that our results are also robust to the adoption of a dynamic specification that includes lagged output as regressor to capture adjustment lags in the output following changes in the factors of production. These estimates are available upon request from the authors.

[24] An alternative method to estimate TFP controlling for the endogeneity of inputs would be using GMM (Arellano and Bond, 1991 [2]) and System GMM (Blundell and Bond, 1998

methods assume perfect competition, immediate adjustment of all factors and constant returns to scale.

To avoid these assumptions while also controlling for the endogeniety problem, we proceed as follows: to make less restrictive assumptions regarding the production technology we follow Klette [17] and look at output levels relative to the median firm in each 4 digit industry. We assume that output is produced using a differentiable production function which is homogenous of degree γ:

$$Q_{it} = A_{it}\left[f\left(\mathbf{X}_i t\right)\right]^{\gamma} \tag{8}$$

where $\mathbf{X}_{it}$ is a vector of factor inputs and $f(\cdot)$ is a linear homogenous general differentiable function. Using the mean value theorem we can write output relative to the median firm as:

$$q_{it} = a_{it} + \sum_{z=1}^{Z} \alpha_z x_{zit} \tag{9}$$

where small letters denote log deviations from the median plant in a given year[25],

$$\alpha_z = \gamma f_z(\bar{\mathbf{X}}_{it}) \frac{\bar{X}_{zit}}{f(\bar{\mathbf{X}}_{it})} \tag{10}$$

$f_z(\cdot)$ denotes the partial derivative of $f(\cdot)$ with respect to argument z and $\bar{\mathbf{X}}_{it}$ is some point in the convex hull spanned by $\mathbf{X}_{it}$ and $\mathbf{X}_{i(t-1)}$.

The first order condition of profit maximization implies that

$$P_{it}\gamma \frac{Q_{it}}{f(\mathbf{X}_{it})} f_z(\mathbf{X}_{it}) = \mu W_{zit} \tag{11}$$

[4]). We attempted to use this estimation methods on our sample, but we encountered two problems: firstly the time period of our sample is too short, 5 years, with less than 7 percent of the plants observed over the whole time period; secondly, due to the fact that the ARD surveys small plants randomly, only 12 percent of the plants have continuous time series information.

[25] e.g. $q_{it} = lnQ_{it} - lnQ_{Median_t}$

i.e. prices must be such that the marginal value product is μ times the marginal cost W of each factor. Our demand function implies that

$$\mu = \frac{1}{1 - \frac{1}{\eta}}$$

As pointed out by Klette[17], Equation 11 can only be expected to hold for production factors which are easily adjustable. We assume that this is the case for intermediates and labour, but not for capital so that we get:

$$\alpha_z = \mu \frac{W_z X_{zit}}{P_{it} Q_{it}} = \mu s_{zit} \tag{12}$$

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

$$\alpha_K = \gamma - \alpha_L - \alpha_M \tag{13}$$

and therefore in equation 9:

$$q_{it} = a_{it} + \mu vi_{it} + \gamma k_{it} + a_{it} + \varrho_{it} \tag{14}$$

where

$$vi_{it} = \sum_{z \neq K} \bar{s}_j (x_{zit} - k_{it}) \tag{15}$$

is an index of all variable factors and ρ_{it} is an iid error introduced by the first order conditions not holding exactly[26]. Applying all these results to Equation 1 we get:

$$r_{it} - vi_{it} = \frac{\gamma}{\mu} k_{it} + \omega_{it} + \varrho_{it} \tag{16}$$

The variable factor index vi_{it} can be directly observed from the data. All that is required are variables for factor inputs and revenue shares of the factors.

[26] Another interpretation for ϱ_{it} is measurement error in labour and materials which for example could come from not observing the skill level of the employees. Martin[22] shows how the current framework can easily be extended to correct for such measurement error problems.

Consequently all that is still required to calculate ω_{it} is an estimate of $\frac{\gamma}{\mu}$. The endogeneity problem now reduces to a potential correlation between ω_{it} and k_{it}. We address this problem using a modified version of the approach of Olley and Pakes[24]. Following them we assume that ω_{it} evolves as a first order Markov Process:

$$\omega_{it} = E\{\omega_{it}|\omega_{it-1}\} + \nu_{it} \tag{17}$$

We also assume that capital is only correlated with the expected component of ω_{it} but not with ν_{it}[27]. Then we can estimate equation 16 if we find a control for $E\{\omega_{it}|\omega_{it-1}\}$. In Appendix B we show that conditional on capital and assuming that markups μ are constant across firms in a narrowly defined sector (four digit) there is a monotone relationship between profits – defined as revenue minus variable costs – and ω. Consequently we can invert the profit function and write

$$\omega_{it} = \phi_{\omega}\left(k_{it}, \Pi_{it}\right) \tag{18}$$

We do not know what functional form $E\{\omega_{it}|\cdot\}$ takes, but in equation 18 we have found a way to express it in terms of observables so that we can rewrite 16 as

$$r_{it} - vi_{it} = \frac{\gamma}{\mu}k_{it} + g(k_{it-1}, \Pi_{it-1}) + \nu_{it} + \varrho_{it} \tag{19}$$

where $g(\cdot) = E\{\omega_{it}|\phi(\cdot)\}$ is a function of unknown form. To estimate 19 we can either employ a semi-parametric procedure or approximate $g(\cdot)$ by a third order polynomial which, for simplicity, is our strategy. An estimator for ω_{it} can then be obtained as[28]

$$\hat{\omega}_{it} = r_{it} - vi_{it} - \widehat{\left(\frac{\gamma}{\mu}\right)}k_{it} \tag{20}$$

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

[28] Formally this provides an estimator of $\omega_{it} + \varrho_{it}$. But if we have no reason to believe that ϱ_{it} is correlated with the MNE ownership variables we want to regress ω_{it} in the second stage this is not a problem

Compared to Olley and Pakes[24] the main innovation of our approach is to use profits and not investment as predictor for ω_{it}. This has a number of advantages. First, a major criticism of the Olley and Pakes framework is that investment might be a very poor predictor of the fixed component of ω_{it}[29]. If firms are essentially in the steady state and the capital stock in period t reflects the firm's knowledge about ω_{it} at $t-1$ the variation in investment reflects primarily adjustments to news about ω from period t. Our approach – in common with Levinsohn and Petrin's [18] who use material inputs instead of investment – does not suffer from this problem. Plants with high ω will have higher profits whether or not they are in the steady state. Second, compared to Levinsohn and Petrin, we can identify all relevant parameters from a moment condition on capital alone without having to assume separability in intermediate inputs or relying on instrumental variable techniques. Also, we do not require any assumptions on the substitutability between various variable production factors[30].

Column 4 in table 4 shows that when we estimate productivity as described above, US are still the productivity leader and the MNE effect is strong and significant. Therefore, the results shown in table 4 seem to be robust: US MNEs are the most productive with British MNEs and foreign Non US MNEs alternating each other in the second position. UK plants that are not part of an MNE are the least productive. In the next section we shed more light on the factors which drive these differences[31].

[29]see Griliches and Mairesse [14]

[30]For an more elaborate discussion of our approach see Martin[22].

[31]Other unreported robustness checks, available upon request, include weighted regressions, and a version of equation 7 with average wage as a proxy for the average skill level in the plant, even though, unlike previous studies (e.g. Rachel Griffith et al [12]) we cannot further distinguish between average wage for operatives and average wage for administrative employees because since 1996 this information has not been reported in the ARD.

Table 5: Status changes in the data
(Transitions in ownership and MNE status in sample 1996-2000)

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

Notes: The table reports in panel one the number of plants that change their MNE status; in panel two the subset of these that also experienced an ownership change. For example Row 1 Column 2 reports that there are 589 transitions from GB non MNE to GB MNE. Row 5 Column 2 reports that in 255 cases these transitions also involved a takeover. Number of observations in the sample is 38,501. The period considered is 1996-2000. Source: Authours' calculation using the ARD AFDI matched data.

6 Explaining the US productivity leadership

What makes multinationals more productive than domestic plants? And what makes US MNEs more productive than other MNEs? Using the time dimension of the current data we try to distinguish between 3 hypotheses on the sources of the MNE and US advantage. Firstly, plants owned by MNEs might be more productive because multinational firms takeover the best plants in any country. We call this the *plant picking* effect. A second hypothesis is that multinational firms are characterised by superior shared assets that improve the performance of any plant they takeover[32]. Examples of these superior shared assets include international distribution networks, special management techniques and reputation effects. We refer to this as the *best firm* effect. Finally, multinational firms might gain a lead over other

[32] 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.

Table 6: 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 US firm	-0.002	-0.012	
	(0.017)	(0.020)	
ever US plant	0.098	0.100	0.121
	(0.016)***	(0.022)***	(0.024)***
ever other for firm	0.017	0.002	
	(0.014)	(0.014)	
ever other for plant	0.048	0.022	0.035
	(0.015)***	(0.022)	(0.020)*
ever MNE firm	0.066	0.013	
	(0.013)***	(0.015)	
ever MNE plant	0.155		0.160
	(0.025)***		(0.025)***
green dom	-0.007	0.034	0.001
	(0.010)	(0.032)	(0.012)
green mult	0.037		0.081
	(0.016)**		(0.057)
green US	0.006		-0.087
	(0.030)		(0.072)
green other	0.001		-0.010
	(0.024)		(0.072)
obs	38501	3334	25558

Notes: Bootstrapped standard errors in parentheses. Row 1 (MNE) reports first-stage estimates of the going global effect. Row 2 and below: coefficients and standard errors are from the second-stage of our estimation procedure. Dependent variable is fixed effects estimated in the first step. **ever MNE firm** equals 1 if the plant belongs at time t to a firm which is MNE. **ever MNE plant** is 1 if the plant has ever been owned by a MNE over the course of the sample period. Similarly for the ever US and ever other foreign dummies. **green** dummies take value one for all plants that are established during the course of the sample period (1996-2000), **green dom** is one for plants owned by domestic firms when established. **green mult** is one for plants owned by MNE firms when established. **green US** (**green other**) is one for plants owned by US (other foreign) firms when established. Column 1 use the whole sample of 38,501 observations. Column 2 only includes plants that incur a change in status over the period they are present in the sample. Column 3 only keeps observations of non MNE plants and of MNE plants when owned by non MNE firms.

* significantly different from zero at the 10 percent level. ** significantly different from zero at the 5 percent level. *** significantly different from zero at the 1 percent level.

firms as a direct consequence of starting to invest abroad, because of cheaper options to hedge against exchange rate risk, for example. We call this the *going global* effect.

We express these hypotheses formally using the following equation:

$$Prod_{it} = \alpha_i + \mu_{t,J(i,t)} + \varepsilon_{it} \qquad (21)$$

where $\mu_{t,J(i,t)} = \mu_{J(i,t)} + \beta_{MNE} MNE_{J(i,t)}$; i.e. productivity of plant i at time t can be decomposed in an effect $\mu_{t,J(i,t)}$ due to the parent firm of plant i at time t and a plant specific effect α_i.[33] $\mu_{t,J(i,t)}$ is then decomposed further in a time invariant firm specific effect $\mu_{J(i,t)}$ and the time varying going global effect: β_{MNE}. The *picking effect* can be expressed in this framework as:

$$E\{\alpha_i | i \in MNEPlants\} - E\{\alpha_i | i \in nonMNEPlants\} > 0$$

whereas the *best firm* effect can be expressed as:

$$E\{\mu_J | J \in MNE\} - E\{\mu_J | J \in nonMNE\} > 0$$

We separately identify the three effects from changes in multinational status and ownership that we observe in the course of our sample period. We identify β_{MNE} from domestic firms that start investing abroad while we observe them. We rely on takeovers of domestic plants by MNEs to identify the *plant picking* as opposed to *best firm* effect. If, subsequent to a takeover by an MNE, the performance of domestic plants improves, this is evidence for a best firm effect.

Table 5 reports the occurrence of all these changes in our dataset. The upper panel reports the number of status changes for each possible transition between GB non MNE, GB MNE, US MNEs and Non US Foreign MNEs. For example the cell in row 1, column 2 reports that there are 589 transitions from GB non MNEs to GB MNEs in our sample. The lower panel reports

[33] For simplicity we abstract for the time being from differences between various types of MNEs.

only the number of status changes that also involved 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 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[34]. The lower panel shows that 784 of those involved a change in ownership, i.e. a takeover.

Our estimation strategy proceeds in two steps. In the first step our objective is to obtain a consistent estimate of β_{MNE}. Given the assumptions of our model the econometric problem is the potential correlation between the unobserved effects α_i and μ_J and the variable of interest $MNE_{J(i,t)}$[35]. Note that if we apply the following transformation on our dependent and explanatory variables the two fixed effects vanish:

$$\widetilde{x}_{it} = x_{it} - \frac{1}{\#\left[iJ(i,t)\right]} \sum_{\tau \text{ s.t. } J(i,\tau)=J(i,t)} x_{i\tau} \tag{22}$$

i.e. we take deviations from the mean across all observations of a specific firm plant combination. This is like running fixed effects where the cross sectional units are not the plants nor the firms but each firm-plant combination in the dataset.

Consequently running a least squares regression on

$$\widetilde{Prod}_{it} = \widetilde{MNE}_{it}\beta + \widetilde{\varepsilon}_{it} \tag{23}$$

will give us a consistent estimate of β which we can use to get estimates of a fixed effect for all firm-plant combinations[36]:

$$\widehat{\mu_{J(i,t)} + \alpha_i} = Prod_{it} - \hat{\beta}_{MNE} MNE_{J(i,t)} \tag{24}$$

[34] i.e. summing the off diagonal elements of row 1 and column 1 in the upper panel

[35] Note that we are assuming $E\{\varepsilon_{it}|MNE_{J(i,t)} = 0\}$, i.e. changes in MNE status are not correlated with the time varying shocks. We discuss this assumption further later in this section.

[36] One crucial assumption underlying equation 23 is that the change in MNE status is not correlated with the time varying part of the error term. This implies the assumption

In principle we could now use a double fixed effects estimator as it has been done in the literature on matched employer-employee panels to get an estimate for each single α_i and μ_J. This is not without problems regarding identification, precision of the estimates and computing time[37]. However, as we are only interested in the average performance of MNEs as opposed to non MNEs, it is not necessary to compute each and every plant and firm fixed effect. Rather, in the second stage we estimate the following regression:

$$\widehat{\mu_{J(i,t)} + \alpha_i} = \beta_{MNE^{ever}_{Firm}} MNE^{ever}_{J(i,t)} + \beta_{MNE^{ever}_{Plant}} MNE^{ever}_i \quad (25)$$

i.e. we regress the fixed effects, estimated in the first stage, on two dummy variables defined as follows: $MNE^{ever}_{J(i,t)}$ is equal to one if plant i belongs at time t to a firm which is multinational. This dummy is always equal to one for foreign firms. It is also equal to one for British MNEs even before they start investing abroad. MNE^{ever}_i is one if plant i has ever been owned by a MNE over the course of the sample period.

What do the coefficients on these dummies capture? Least squares provide an estimate of the expected value of the dependent variable conditional on the explanatory variables:

$$E\{\mu_{J(i,t)} + \alpha_i | MNE^{ever}_{J(i,t)}, MNE^{ever}_i\} \quad (26)$$

that the timing of the MNE status change is exogenous. A scenario where this might be violated is as follows: plants could have a higher probability of being taken over in years where they suffer from idiosyncratic large negative shocks. To examine the relevance of this scenario we run probit regressions of the probability of changing status to MNE on time dummies and TFP growth in the previous year. The results show that productivity growth is not significantly correlated with the probability of being taken over by a MNE. Also, since we do not have good instruments for changes in MNE status we thought of controlling for the endogeneity of MNE status changes using GMM methods. However, we cannot use these estimation methods as explained in footnote 24.

[37] We experimented with double fixed effects estimators. In the appendix we discuss the results and problems.

Consequently $\beta_{MNE^{ever}_{Plant}}$ captures the difference between MNE plants in non MNE firms and non MNE plants in non MNE firms:

$$\beta_{MNE^{ever}_{Plant}} = E\{\mu_{J(i,t)} + \alpha_i|0,1\} - E\{\mu_{J(i,t)} + \alpha_i|0,0\} \tag{27}$$

If

$$E\{\mu_{J(i,t)}|0,1\} - E\{\mu_{J(i,t)}|0,0\} = 0 \tag{28}$$

i.e. if non MNE firms that own MNE plants are not systematically different from non MNE firms that do not own MNE plants, $\beta_{MNE^{ever}_{Plant}}$ provides an estimate of the expected difference of MNE and non MNE fixed plant effects. What if condition 28 does not hold? This could for example be the case if MNEs do not select individual plants but takeover whole firms with above average performance. In this case, $\beta_{MNE^{ever}_{Plant}}$ would measure a composite superior firm and plant effects, rather than the pure difference in plant fixed effects. Thus $\beta_{MNE^{ever}_{Plant}}$ is still a good measure of the relevance of picking by MNEs of either plants or whole firms.

Further, note that given our model formulation $\beta_{MNE^{ever}_{Plant}}$ is equally a measure of how MNE plants perform in MNE firms relative to non MNE plants in MNE firms[38]

$$\beta_{MNE^{ever}_{Plant}} = E\{\mu_{J(i,t)} + \alpha_i|1,1\} - E\{\mu_{J(i,t)} + \alpha_i|1,0\} \tag{29}$$

This implies that our estimate of the picking effect might be inconsistent to the extent that there are systematic interactions between firm and plant effects among MNE firms. To examine the robustness of our results to this class of problems we run a regression using only observations involving non MNE firms.

Consider next the interpretation of $\beta_{MNE^{ever}_{Firm}}$:

$$\beta_{MNE^{ever}_{Firm}} = E\{\mu_{J(i,t)} + \alpha_i|1,1\} - E\{\mu_{J(i,t)} + \alpha_i|0,1\} \tag{30}$$

[38]The possibility of a non MNE plant in an MNE firm can arise if a prospective British MNE owns plants that are sold before the firm goes global.

In order for $\beta_{MNE^{ever}_{Firm}}$ to be an estimate of the marginal difference between MNEs and non MNEs *firms* we need the following restriction:

$$E\{\alpha_i|1,1\} - E\{\alpha_i|0,1\} = 0 \tag{31}$$

which is true if plants that are always owned by MNE firms are not systematically different from plants that are owned at least in some period by non-MNE firms. One important case which might violate this condition concerns greenfield investments by multinationals. Suppose that MNEs only manage to embody the superior performance of their shared assets in plants they actually setup themselves rather than takeover. To account for this case we also include dummies which indicate if a plant was setup by an MNE. For the majority of plants – more than 80 percent – we do not know by whom they are setup because they were born before our sample started, however.

We report the results of our two-step procedure in Table 6. Row 1 reports the coefficient β_{MNE} estimated in the first step. Column 1 reports the estimates obtained using the whole sample. The actual regression we run includes not only dummies for MNE plant and firm effects but also dummies for US and other foreign plant and firm effects. The definitions of these dummies are equivalent to the dummies for MNEs in general which we discussed above.

The coefficients' estimates show the following: there is no significant positive *going global effect*, as shown by the insignificant estimate of 0.007 in row 1. The MNE advantage seems to be due to both a *plant picking* effect and a *best firm* effect, as shown by the significant coefficient estimates of 0.066 and 0.155 respectively. We also have evidence that the additional US MNEs advantage is likely to be due to *plant picking* rather than a *best firm* effect: Plants that are at some point US owned have an average advantage of about 10 percent over MNE plants in general. Similarly we find a significant non US MNE plant effect of about 5 percent.

There is no strong evidence of superior performance of plants that are setup by MNEs as opposed to plants that are taken over, although we find a 4 percent advantage which is significant at the 10 percent level.

How credible are the firm and plant effects estimates of column 1? Although identification of firm and plant effects rests on plants changing hands from non MNE to MNE firms, the actual point estimates incorporate information from both, plants that actually change ownership and plants which never change their status.

In column 2 we examine if we can still find a MNE firm effect if we restrict our sample to the sample of plants which were domestic at the beginning of our sample or setup by a domestic firm during the course of our sample period and were subsequently taken over by a multinational firm. It turns out that the MNE firm effect found previously vanishes[39]. A possible explanation could be that the firm fixed effects μ_J are more dynamic than suggested by our simple double fixed effects structure (Equation 21). In particular, it could be the case that for a MNE firm to improve the performance of an existing plant it takes longer than the few years we observe a plant after the takeover. To examine this hypothesis we would require a longer dataset.

Finally, column 3 examines the robustness of the plant effects found in column 1. To avoid the effect of interactions between multinational plant and firm effects we restrict our sample to non MNE plants and observations of MNE plants when they are still owned by non MNE firms. We continue to find a strong and significant advantage of MNE plants in general and an additional advantage of plants owned by US firms during the sample period. This suggests that there is indeed plant picking by MNEs.

7 Conclusions

We find that the US productivity leadership found in cross-country studies is confirmed by microevidence when comparing US-owned plants with other foreign owned and domestic plants in the UK.

[39]Because the sample is restricted to plants born before 1996 and plants setup by non MNE firms we cannot identify all greenfield dummies. Equally we cannot identify the MNE plant dummy because all plants included are MNE plants

Indeed, the ranking of productivity advantage from our level regressions is exactly the same as the one found in the US by Doms and Jensen: US MNEs are the most productive, followed by non US MNEs, both other foreign and UK-owned, and establishments of domestic non-MNEs being the least productive.

When we analyse the nature of the MNE advantage and US leadership using the longitudinal dimension of our data we establish 3 results.

Firstly, there is no evidence for a going global effect.

Secondly, we find a general MNE firm effect, but no evidence of additional US or other foreign MNE firm effects. We have also some circumstantial evidence that the firm effects take several years to unfold.

Thirdly, there is strong evidence of MNE plant effects, as well as additional US plant effects. This suggests that the MNE advantage is driven by both, the sharing of superior firm level assets across plants and the ability to select the better plants in a country. The additional superiority of US firms over other MNEs, on the other hand, seems to be entirely driven by more careful selection of better plants.

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A Variable 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 [21]

- Deflators: to deflate output measures (gross output and value added) we use producer price indices 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:

  EUnorth includes plants owned by Austria, Belgium, Denmark, Finland , Luxembourg, Sweden and Republic of Ireland.

  EUsouth includes plants owned by Italy, Spain and Canary Islands, Portugal and Greece.

  Tax includes plants owned by British Virgin Islands, Channel Islands, Isle of Man, Liechtenstein, Antigua and Barbuda, Cyprus and US Virgin Islands.

  otherEurope includes plants owned by Norway and Switzerland.

  otherOECD includes plants owned by Australia, Canada, Czech Republic, Iceland, Mexico, Poland, South Korea and Turkey.

  other is a residual category that includes plants owned by the rest of the world and plants which are foreign owned but whose nationality is unknown.

- We calculate TFP relative to the 4 digit industry median using the differential TFP formula of Caves et al. [5]; i.e. we calculate TFP as

$$\begin{aligned} lnTFP_{it} &= lnY_{it} - ln\bar{Y}_{It} \\ &\quad -\bar{\alpha}_K(lnK_{it} - ln\bar{K}_{It}) \\ &\quad -\bar{\alpha}_L(lnL_{it} - ln\bar{L}_{It}) \\ &\quad -\bar{\alpha}_M(lnM_{it} - ln\bar{M}_{It}) \end{aligned}$$

  where $ln\bar{Y}_{It}$ denotes the 4 digit industry median and the factor shares are the mean of the plant factor share and the median industry factor share $\bar{\alpha}_K = \frac{alpha_{Kit} + al\bar{p}ha_{KIt}}{2}$.

- Weights are calculated using the register employment 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 8 we can write the cost minimization problem as

$$\tilde{C}(\tilde{K}_{it}, \mathrm{w}_{Vit}) = \min_{\tilde{\mathrm{X}}_{Vit}} \sum_{z \neq K} w_{zit} \tilde{X}_{zit} \text{ s.t. } 1 = f\left(\tilde{K}_{it}, \tilde{\mathrm{X}}_{Vit}\right) \tag{32}$$

where $\tilde{K}_{it} = \frac{K_{it}}{\tilde{Y}_{it}}$ with $\tilde{Y}_{it} = \left(\frac{Y_{it}}{A_{it}}\right)^{\frac{1}{\gamma}}$. $\tilde{\mathrm{X}}_{Vit}$ collects the same transformation for all variable production factors in a vector. Total cost become in terms of Equation 32

$$C_{it} = \tilde{C}_{it} \tilde{Y}_{it} \tag{33}$$

Next consider the profit function.

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

Given the demand function 3 and the cost function 33 we can write it as

$$\Pi_{it}(K_{it}, \lambda_{it}, a_{it}, \mathrm{w}_{it}) = \left(\frac{\Lambda_{it} R_t}{P_t}\right)^{\frac{1}{\eta}} P_t Q^{1-\frac{1}{\eta}} - \tilde{C}_{it} \tilde{Y}_{it} \tag{34}$$

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

$$\left(1 - \frac{1}{\eta}\right) \frac{R_{it}}{Q_{it}} = \frac{1}{\gamma} z(\tilde{Y}_{it}, \tilde{K}_{it}) \frac{\tilde{Y}_{it}}{Q_{it}} \tag{35}$$

where

$$z(\tilde{Y}_{it}, \tilde{K}_{it}) = \frac{\partial \tilde{C}_{it}}{\partial \tilde{Y}_{it}} \tilde{Y}_{it} + \tilde{C}_{it} \tag{36}$$

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

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

and

$$\frac{\partial \Pi_{it}}{\partial a_{it}} = z(\tilde{Y}_{it}, \tilde{K}_{it}) \frac{1}{\gamma} \left(\frac{Q_{it}}{A_i t}\right)^{\frac{1}{\gamma}} = \mu^{-1} R_{it} \tag{37}$$

where the last equality follows from the first order condition 35[40] and

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

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

$$d\Pi_{it} = R_{it}\frac{1}{\mu}\left(d\lambda_{it} + da_{it}\right) = R_{it}d\omega_{it} \tag{38}$$

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

[40] This is an application of the envelope theorem

Table 7: Statistics on double fixed effects groups

	(1) obs	(2) plants	(3) firm
min	2	1	1
max	634	201	55
median	3	1	1
groups	6754		
obs	28338		

Notes: The first panel reports summary statistics for the double fixed effects groups (DFG) in our sample. Column 1 row 1 shows that the smallest DFG consists of 2 observations, the largest of 634 and the median group of 3 observations. Columns 3 and 4 report the same statistics for the numbers of plants and firms.

C A double fixed effects approach

We suggested that Equation 21 could also be estimated using a double fixed effects methodology. This section discusses how this could be done and the problems it raises.

Firm and plant effects can be identified separately to the extent that plants move between firms. Abowd et al.[1] have laid out in detail which firm and plant effects we can hope to identify[41]: They define sets of 'double fixed effect groups' (DFG). A DF group DFG_g is defined as the set of all firms and plants which interact over the sample period. A firm and a plant interact simply if the plant is owned by the firm. Two plants interact if they are both owned by the same firm at some but not necessarily the same point in time. Two firms interact if they own the same plant at different points in time.

Abowd et al. [1] show that for each plant and each firm in a DFG one can identify a fixed effect which is informative about its productivity relative to the group average, where the group average includes the fixed effect of an

[41]Abowd et al.[1] work with matched employer-employee panels but their results apply to our problem immediately once plants take on the role of employees and firms the role of employers.

Table 8: Double fixed effects regression results

	(1)	(2)
US	-0.031	0.039
	(0.013)**	(0.024)*
MNE	0.002	0.020
	(0.018)	(0.018)
other for	0.026	0.028
	(0.018)	(0.025)
green dom		0.000
		(0.021)
green US		0.030
		(0.054)
green other		0.037
		(0.063)
green mult		-0.001
		(0.037)
obs	2842	2865

Notes: Bootstrapped standard errors in parentheses. Coefficients and standard errors are from the third-stage of the double-fixed effects model. In column 1 the dependent variable is firm fixed effects estimated in the second-stage. ever US firm is 1 for all US firms. ever MNE firm is 1 for all MNE firms. ever other firm is 1 for non US foreign firms. In Column 2 the dependent variable is the plant fixed effects estimated in the second-stage ever MNE plant is 1 for all plants that have ever been owned by a MNE over the course of the sample period. Similarly for the ever US and ever other foreign dummies. The green dummies take value one for all plants that are established during the course of the sample period (1996-2000), green dom is one for plants owned by domestic firms when established. green mult is one for plants owned by MNE firms when established. green US (green other) is one for plants owned by US (other foreign) firms when established.
* significantly different from zero at the 10 percent level. ** significantly different from zero at the 5 percent level. *** significantly different from zero at the 1 percent level.

omitted reference firm, μ_R, and an omitted reference plant α_r. Thus, any estimated fixed effect has to be interpreted as relative to the omitted plant and firm.

Table 7 reports some statistics on these groups. Consider first the second panel which reports that there are in total 6754 such groups in our dataset. Also note that the number of observations has now reduced because we can only use observations from plants we observe at least twice. Panel 1 reports various statistics on these 6,754 groups. We see that the majority of groups is rather small. Both the median number of plants and firms (row 3 in columns 2 and 3) is 1 one which means that our dataset consists mainly of firms that own one plant which is never sold. For these there is no chance of separating firm and plant effects. Our sample thus reduces to those groups which consist of at least 2 plants or firms. This corresponds to about one third of our original sample.

After establishing how many fixed effects can effectively be identified the double fixed effects problem is in principle nothing else but a regression on dummies for each plant and firm whose fixed effect can be identified. However, this runs into computational problems because of the sheer size of the matrices that are to be inverted. Abowd et al. apply some advanced linear algebra techniques to get round this problem. However, since all coefficients' estimates are relative to a group, neither efficiency of consistency is lost if estimates are obtained separately for each group. In our case the largest group consists of 55 firms and 201 plants. This is still in the range feasible for a normal dummy variable regression, which is our strategy. In each group we can then estimate the fixed effects of each plant and firm except for one reference plant and firm:

$$\alpha_i \widehat{- \alpha_r -} \mu_R \quad \text{and} \quad \mu_J \widehat{- \alpha_r -} \mu_R$$

where α_r is the reference plant and μ_R the reference firm.

To examine the existence of MNE firm and plant effects as discussed in Section 6 we regress these estimated fixed effects on MNE plant and firm dummies; i.e. for the firm effect:

$$\widehat{\mu_J - \alpha_r - \mu_R} = \beta_{MNE^{ever}_{Firm}} MNE^{ever}_{J(i,t)} + \varepsilon_{it} \tag{39}$$

Can we hope that $\beta_{MNE^{ever}_{Firm}}$ provides a consistent estimator of

$$E\{\mu_J | MNE^{ever}_{J(i,t)} = 1\} \tag{40}$$

Only if we can assume that there is no systematic correlation between $\mu_J + \alpha_i$ and $MNE^{ever}_{J(i,t)}$. However, this is unlikely because multinational firms are more likely to interact with other multinational firms or with domestic firms which have higher productivity so that $E\{\mu_J|1\} > E\{\mu_J|0\}$. This would introduce a downward bias in our estimate of $\beta_{MNE^{ever}_{Firm}}$. A similar argument applies to our estimate of the MNE plant effect. Given the downward bias we expect that regressions of 39 and the equivalent plant equation lead to lower MNE firm and MNE plant estimates than the results found in Section 6.

Table 8 shows estimates of equation 39 in column 1 and the equivalent plant level equation in Column 2. All point estimates are lower than the comparable estimates in Section 6 and most effects are found to be non significant. Only the US plant effect is still significant at the 10 percent level (column 2, row 1), whereas The US firm effect estimate is now negative and significant at the 5 percent level.