DISCUSSION PAPER SERIES

No. 5841

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INTERNATIONAL TRADE

Centre for Economic Policy Research

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Available online at: **www.cepr.org/pubs/dps/DP5841.asp**

ISSN 0265-8003

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Discussion Paper No. 5841
September 2006

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CEPR Discussion Paper No. 5841

September 2006

ABSTRACT

Multinationals' Productivity Advantage: Scale or Technology*

The first aim of this paper is to decompose the productivity advantage of foreign multinationals into two components: the technology and scale effect. The second aim is to analyse the causal relationship between foreign ownership and these two components of productivity growth. We do so by analyzing the effects of an acquisition of a domestic establishment by a foreign multinational enterprise, using a combined propensity score matching and difference-in-differences estimation. Our empirical analysis is based on plant level data for the UK. From our econometric investigation four broad patterns emerge: (i) any positive impact of ownership change is predominantly due to change in technical efficiency, not scale effects (ii) the pre-acquisition TFP level of the erstwhile domestic plants play a role – positive or negative – in mediating the rate of technology transfer from the MNE parent companies, (iii) the productivity growth effects are not confined to the year of acquisition, and tend to persist through time.

JEL Classification: F23 and L22
Keywords: acquisitions, multinational enterprises, productivity, scale and technical efficiency

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Submitted 10 August 2006

I. Introduction

There is now a substantial body of empirical work that documents a robust and positive correlation between foreign ownership and firm or plant productivity growth across a number of countries (e.g. Globerman et al., 1994; Doms and Jensen, 1998; Girma et al., 2001). The productivity advantage of foreign owned firms is usually seen as reflecting multinationals' technological advantage vis-à-vis domestic firms. Multinationals are assumed to have a firm-specific asset, such as know-how, technology etc. which may be transferred easily across borders from the parent to subsidiaries abroad, which allows them to be more productive than domestic firms (e.g, Markusen, 2002).

However, high productivity growth is not exclusively derived from *technical progress*, at least in theory where the direct link between technology and productivity is only valid in a neoclassical production framework with perfect competition, long run equilibrium, and constant returns to scale. Specifically, the productivity analysis literature highlights the role of changes in scale economies for productivity growth (e.g. Balk, 2001). This is consistent with the notion of learning-by-doing effects as described by Lucas (1988). Intuitively, as output expands, workers and firms gain proficiency at producing particular products. Thus changes in *scale efficiency* can also provide an explanation for the observed productivity advantage of foreign firms.

One aim of this paper is to decompose the productivity advantage of foreign multinationals into these two components: the technology and scale effect. Apart from being of academic interest, this issue is highly policy relevant. Many governments around the world actively promote inward foreign direct investment (FDI) under the assumption that it may lead to an influx of new technology which will ultimately spill over into the domestic economy. Hence, these policies are predicated on technical efficiency in multinationals. If, however, scale efficiency is the dominant component of foreign firms productivity premium in a particular sector, such policies may be misguided. Unfortunately FDI theory gives little guidance as to the relative importance of technological progress and scale efficiency in the productivity premium due to foreign ownership. The empirical literature also appears to have neglected the issue of decomposing the productivity effects of multinationality. Hence, this paper aims to uncover the sources of productivity growth in a panel of domestic and foreign plants.

The second objective of the paper is to contribute to the ongoing debate about the causal relationship between foreign ownership and productivity growth. While a number of papers, as cited above, have established that foreign owned firms may have higher productivity growth than their domestic counterparts, there remains a fundamental problem in identifying the performance difference that is attributable to multinationality *per se*. As Tybout (2000), for example, points out, multinationals may be attracted to more technology intensive industries, which are also more productive and pay higher wages. Hence, there would be an endogeneity problem in the regressions and the wage differential between foreign and domestic firms would be difficult to interpret. The inclusion of some observable industry and firm characteristics, as well as unobservable time invariant effects, might go some way towards reducing this bias, though the inclusion of all possible relevant control variables is a difficult if not impossible task.

In this paper we try to overcome this problem by analyzing the effects of an acquisition of a domestic establishment by a foreign multinational enterprise on productivity growth, decomposed into technology and scale effects. Assuming that an acquisition does not change any of the main characteristics of the takeover target (at least in the short run) a possible effect of the foreign acquisition on productivity growth in the domestic target can be attributed to the change in ownership from domestic to foreign. We attempt to identify the causal effect of a foreign acquisition using a combined propensity score matching and difference-in-differences methodology (see Blundell and Costa Dias, 2000). To our knowledge this is the first study to provide a decomposition of the causal effects of foreign acquisition on productivity growth.[1]

The empirical setting of the paper is the UK manufacturing industry, where FDI is seen as an important device of technology transfer. Some half a billion pounds was paid in grants for internationally-owned companies by the UK government between 1991 and 1995 under the Regional Selective Assistance scheme.[2] We use plant level data covering the period 1980-1994. We focus our analysis on establishments in the UK electronics and food industries.[3] We decided to examine in detail two sectors separately rather than pooling data for the whole manufacturing since recent empirical studies of firm-level productivity dynamics have established that there is large and persistent heterogeneity across firms even within sectors, let alone across heterogeneous sectors (Bartelsman and Doms, 2000). Concentrating on two fairly narrowly defined sectors should allow us to alleviate the problems associated with aggregating over heterogeneous units. The choice of these two sectors is based on two reasons: First, foreign-owned firms are important players in both sectors, accounting for about 19 percent of employment in electronics and 10 percent of employment in the food industry in 1996 (see Griffith and Simpson, 2004, Table 4). Second, we may expect those sectors to be different in their technology usage and, hence, there may be differences in the determinants of productivity for establishments in the two sectors.[4]

[1] In a related paper we use a similar approach to investigate the effect of foreign acquisitions on wages, distinguishing the nationality of foreign acquirers, see Girma and Görg (2006). Arnold and Javorcik (2005) also apply a similar approach to investigate the effect of foreign acquisitions on plant performance in Indonesia.

[2] For more detail see the official report at http://www.dti.gov.uk/regional/evaluationRSA91-95.pdf

[3] More precisely, using SIC 1980 classification, SIC 33 (manufacture of office machinery and data processing equipment), SIC 34 (electrical and electronic engineering), and SIC 41/42 (food, drink and tobacco).

[4] According to an OECD classification "electronics and communication" are classified as high-tech, while "food and beverages" are low-tech industries

The paper proceeds with Section II where the productivity growth decomposition and the propensity score matching methodologies are discussed. Section III presents the data. Section IV compares the sources of productivity growth between foreign and domestic plants, and decomposes the productivity growth effects of foreign acquisitions. Section VI concludes.

II. Empirical strategy

II.a. Decomposing productivity changes: the analytical framework

The productivity analysis literature abounds with productivity growth decomposition methodologies, ranging from nonparametric techniques (see for example, Färe et. al, 1994; Grifell and Lovell, 1997) to fully parametric techniques (e.g. Koop et al., 1999, Balk, 2001; Orea, 2002). This paper employs a parametric method of decomposing an *a Divisa* index of total factor of productivity growth based on the estimation of a translog production function (see Heshmati, 2003 for a review).

Let y, x_1, x_2, x_3 and x_4 denote output, skilled labour, unskilled labour, capital and material inputs respectively,[5] and let t index a time trend variable. For plant i at time t, the translog production function is expressed as

$$\ln y_{it} = \alpha_0 + \sum_{k=1}^{4} \alpha_k \ln x_k + \frac{1}{2}\sum_{k=1}^{4}\sum_{h=1}^{4} \alpha_{kh} \ln x_k \ln x_h^t + \psi_0 t + \frac{1}{2}\psi_{00} t^2 + \sum_{k=1}^{4} \xi_k t \ln x_k + \nu_{it} \qquad (1)$$

where ν is a disturbance term that is potentially correlated with the inputs. Compared to a simple Cobb-Douglas production function, this approach has the major advantage of allowing for varying returns to scales across plants and time periods.

[5] Output is defined as gross output. Skilled and unskilled labour are the number of non-production and production workers, respectively. Capital is defined as capital stock obtained using investment data (as described in Griffith, 1999) and material as cost of materials and fuel used. All variables are in logs.

Defining an index of total factor productivity growth as the difference between the rate of output growth and the rate of input growth, $\Delta TFP = \Delta \ln y - \Delta \ln x$, and totally differentiating (1), total factor productivity growth can be decomposed as

$$\Delta TFP = \Delta T + (\varepsilon - 1)\sum_{k=1}^{n}\left(\frac{\varepsilon_k}{\varepsilon}\right)\Delta \ln x_k \qquad (2)$$

where $\Delta T = \dfrac{\partial \ln y}{\partial t}$, $\varepsilon_k = \dfrac{\partial \ln y}{\partial x_k}$. $\varepsilon = \sum_{k=1}^{4}\varepsilon_k$ denotes returns to scale.

The first term on the right hand side of (2) is the rate of technical change (the derivative of log output with respect to the time trend) while the second term captures the contribution of changes in scale efficiency. Note that scale efficiency at a point in time can be thought of as productivity relative to what is attainable under constant returns to scale.

To implement this decomposition empirically we estimate equation (1) separately for each two-digit industry via instrumental variables methods to account for the potential endogeneity of inputs.[6] Furthermore we allow for different factor elasticity coefficients for domestic and foreign-owned plants in the estimation, by interacting all production function coefficient with a foreign ownership dummy. Thus a foreign acquired plant is allowed to have different coefficients in the production function before and after the acquisition year.[7]

II.b. Identifying the causal effects of foreign acquisition on productivity growth

Having decomposed productivity growth, the next step is to analyse whether there is a causal effect from an acquisition of a domestic establishment by a foreign owner on either or both of the components (technical change or scale efficiency). In other words, the empirical modelling problem is the evaluation of the causal effect of foreign acquisition on

[6] Twice lagged values of the factor inputs are used as instruments.
[7] The point estimates of the production function are reported in Table A4 of the appendix along with p-values from the Sargan tests for the validity of the instrumental variable candidates.

y, where y represents total productivity growth or one of its components in the domestic target.

Let $ACQ_{it} \in \{0,1\}$ be an indicator of whether a domestic plant i is acquired by a foreign establishment at time period t, and let y^1_{it+s} be the productivity growth at time t+s, $s \geq 0$, following acquisition. Also denote by y^0_{it+s} the productivity growth of the plant *had it not been acquired*. The causal effect of foreign ownership for plant i at time period $t + s$ is defined as:

$$y^1_{it+s} - y^0_{it+s} \tag{3}$$

The fundamental problem of causal inference is that the quantity y^0_{it+s} is unobservable for plants that have been acquired (i.e., for which we observe y^1_{it+s}). Thus the analysis can be viewed as confronting a missing-data problem. Following the microeconometric evaluation literature (e.g. Heckman et al, 1997), we define the *average* effect of acquisition on the acquired plants as

$$E\{y^1_{t+s} - y^0_{t+s} \mid ACQ_{it} = 1\} = E\{y^1_{t+s} \mid ACQ_{it} = 1\} - E\{y^0_{t+s} \mid ACQ_{it} = 1\} \tag{4}$$

Causal inference relies on the construction of the counterfactual for the last term in equation (4), which is the outcome the acquired plants would have experienced, on average, had they not been acquired. This is estimated by the average productivity growth (or its components) of the plants that remained in domestic hands, $E\{y^0_{it+s} \mid ACQ_{it} = 0\}$.

An important feature in this exercise is the selection of a valid control group. One way of doing so is by employing matching techniques. The purpose of matching is to pair each foreign acquired plant with a domestic plant that has not undergone any ownership change on the basis of some observable variables, in such a way that the control plants' productivity growth trajectories can be studied to generate the counterfactual for the acquired plant.

Since matching involves comparing acquired and non-acquired plants across a number of observable pre-acquisition characteristics (e.g. pre-acquisition productivity, size and age), it would be difficult to determine along which dimension to match the plants, or what type of weighing scheme to use. It is therefore desirable to perform the matching on the basis of a single index that captures all the information from those variables. In this paper we adopt the method of propensity score matching due to Rosenbaum and Rubin (1983), which suggests the use of the probability of receiving treatment (foreign acquisition in the present context) conditional on those characteristics, to reduce the dimensionality problem. Accordingly, we first identify the probability of being acquired (or 'propensity score') using the following logit model

$$P(ACQ_{it} = 1) = F(X_{it-1}, D_{it}) \tag{5}$$

where D is the full set of industry and time dummies, and the vector X consists of the pre-acquisition level and growth of TFP, returns to scale (which is calculated from the instrumental variable translog production function estimates), plant size (proxied by log of fixed capital), age, and an indicator of whether the plant is located in an officially designated assisted area. The choice of these variables is motivated by the existing literature on ownership change, e.g., Lichtenberg and Siegel (1987), McGuckin and Nguyen (1995), Conyon et al. (2002), Harris and Robinson (2002).

Now let P_{it} denote the predicted probability of being acquired at time *t* for plant *i* (which is an actual take-over target). A non-acquired plant *j*, which is 'closest' in terms of its propensity score (or probability of being a foreign take-over target) to an acquired plant, is then selected as a match for the latter using the 'caliper' matching method.[8] The caliper method employs the nearest control plant whose propensity score falls within a pre-

[8] The matching is performed in Stata Version 9 using the PSMATCH2 software provided by Leuven and Sianesi (2003).

specified radius as a match for an acquired plant. More formally at time period t and for each newly acquired plant i, a domestic plant j is selected such that[9]

$$\lambda > \left| P_{it} - P_{jt} \right| = \min_{k \in \{domestic\}} \{ | P_i - P_j | \} \tag{6}$$

where λ is a pre-specified scalar, which is set at 0.01 in our analysis. Furthermore we impose the so-called common support condition in the matching algorithm. This involves dropping acquired plant observations whose propensity score is higher than the maximum or less than the minimum propensity score of the control group of plants.

Having constructed the comparison group (C) of plants that are similar to the acquired plants (A), we exploit the panel nature of our data and employ a difference-in-differences estimator.[10] This is motivated by recent studies which argue that standard matching estimators are usually unsatisfactory, but in combination with difference-in-differences methodology can have the potential to "...improve the quality of non-experimental evaluation results significantly" (Blundell and Costa Dias, 2000, p. 438).

At its simplest, the combined matching and difference-in-differences estimator we use can be described as follows. Firstly, the difference between the average productivity before and after the change of ownership, say $\Delta^a y$, is calculated. Then this difference is further differenced with respect to the before and after difference for the comparison control group, say Δy^c, to obtain the difference-in-differences estimator $\delta = \Delta^a y - \Delta^c y$. Defining ACQ as a vector of dummy variables for the post-acquisition period, the regression

$$\Delta y_{it} = \phi + \delta ACQ_{it} + u_{it} \tag{7}$$

[9] A non-acquired g plant can be match to more than one acquired plants. By the same token it can happen that an acquired plant may not have a match.

[10] The simplest form of a matching estimator of the causal effect of foreign acquisition can be written as $\delta = \sum_{i \in A} \left(y_i - \sum_{j \in C} w(p_i, p_j) y_i \right)$ where the $w(p_i, p_j)$ are the weights placed on the comparison plant j, generated by the matching algorithm.

on the matched sample of plants should produce a coefficient δ that can be interpreted as the average change in y that can be attributed to foreign acquisitions. In order to allow for differential acquisition effects across time we consider two lags of the foreign acquisition dummy in addition to the contemporaneous effect. Furthermore to control for possible observable factors that may be correlated with changes in total factor productivity growth, we extend this basic framework by including a vector of regressors which consists of plant age and size and full sets of time and four digit sectoral dummies.

It has been noted in the literature that the degree of technology transfer from parent company to new subsidiary is likely to be a function of the acquired plant's existing technological capability, or absorptive capacity (e.g., Lapan and Bardhan, 1973; Wang and Blomström, 1992). Some threshold level of absorptive capacity or technological congruity might be needed for the acquired plants to benefit fully from their new association with multinationals. But it can also be argued that a domestic plant that operates nearer the technological frontier might have less to learn from their association with multinationals than otherwise equivalent plants. To explore the above conjectures, we also interact the acquisition dummy variables with the pre-acquisition or initial level of TFP (*ITFP*). Our final estimating equation can then be expressed as

$$\Delta y_{it} = \phi + \beta_1 age_{it} + \beta_2 size_{it} + \sum_{s=0}^{2}(\delta_{1s} ACQ_{it-s} + \delta_{2s} ACQ_{it-s} * ITFP_i) + D_t + D_{\sec} + u_{it} \quad (8)$$

II.c. Testing the reliability of the propensity score matching method

The propensity score matching method will provide a reliable and robust method for estimating the effects of foreign acquisitions, if, conditional on the propensity score, the distribution of the pre-acquisition covariates is independent of the incidence of being acquired. This can be achieved by choosing a specification of the propensity score model (equation 5) that 'balances' the pre-acquisition variables between the treatment and control groups conditional on the propensity score. As emphasised by Rosenbaum and Rubin (1983), Dehejia and Wahba (2002) and Todd and Smith (2005a), amongst others, it is important to verify that this balancing condition is satisfied by the data.

In this paper we perform two tests to satisfy ourselves that the balancing conditions are not violated. The first is to conduct two sample t-tests of equality of the covariates between the treatment and control groups. The second balancing test we explore is suggested by Todd and Smith (2005b) and it is cast within a regression framework. Let $\hat{P}(X)$ denote the estimated propensity score and let ACQ be a dummy variable assuming a value of 1 if a firm is foreign acquired. Then for each variable included in the matching algorithm, the following regression function that is quartic in $\hat{P}(X)$ is estimated (using the *TFP* variable as an example):

$$TFP = \beta_0 + \sum_{k=1}^{4} \beta_k \hat{P}(X)^k + \sum_{k=1}^{4} \gamma_k ACQ\hat{P}(X)^k + \varepsilon \qquad (9)$$

and the joint significance of the coefficients on the terms involving the programme participation dummy (that is the γs) is tested. As explained by Todd and Smith (2005b), if the propensity score satisfies the balancing condition, the treatment dummy (acquisition dummy in our case) should not provide any additional information and we should expect the γs to be jointly statistically insignificant.

III. Database description and sample characteristics

We use confidential micro data from the Annual Respondents Database (ARD) provided by the Office for National Statistics (ONS) in the UK under controlled conditions. The dataset consists of individual establishments' records underlying the Annual Census of Production. As Barnes and Martin (2002) provide a very useful introduction to the data set, we only include a brief discussion of some of the features of the data that are relevant to the present work.

For each year the ARD consists of two files. What is known as the 'selected file' contains detailed information on a sample of establishments that are sent inquiry forms. The second file comprises the 'non-selected' (non-sampled) establishments and only basic information such as employment, location, industry grouping and foreign ownership status is recorded. Some 14,000-19,000 establishments are selected each year, based on a stratified sampling scheme. The scheme tends to vary from year to year, but for the period under consideration establishments with more than 100 employees were always sampled.

In the data, an establishment is defined as the smallest unit that is deemed capable of providing information on the Census questionnaire. Thus a 'parent' establishment reports for more than one plant (or 'local unit' in the parlance of ARD). For selected multi-plant establishments, we only have aggregate values for the constituent plants. Indicative information on the 'children' is available in the 'non-selected' file. In our sample period, about 95 percent of the establishments in these industries are single-plant firms. In the actual sample we used for the econometric estimation this figure is around 80 percent. Hence, most of the data used is actually plant level data and we, therefore tend to use the terms plant and establishment interchangeably.

This paper uses data for two broad industries, electronics and food and drinks, spanning 49 four-digit SIC80 industries[11] over the period 1980-1994.[12] A consistently defined nationality indicator identifies whether an establishment is domestic or foreign owned. Table 1 gives the frequency distribution of plants by year and ownership in the two industries under consideration. We define the incidence of foreign acquisition in year t as an establishment that has been in domestic hands up to year *t-1* and becomes a subsidiary of

[11] These are SIC80 two-digit industries 33 and 34 (electronics) and 41 and 42 (food and drinks). We sometime refer to the latter as simply "food" throughout the paper. In the SIC80, the tobacco industry is also classified in the food sector. However in our analysis we do not consider tobacco manufacturing plants.
[12] The motivation for concentrating on these two industries was discussed in the introduction.

a foreign-based multinational, as identified by a change in its nationality indicator.[13] Since the matching process described in the previous section requires data on the pre-acquisition period, we consider foreign take-overs that took place between 1981 and 1994. Table 2 provides the frequency distribution of foreign acquisitions. It can be seen that most of these occurred in the electronics industry.

[Tables 1 and 2 here]

Table 3 reports some summary statistics of the main variables of interest, namely TFP growth as well as its two components, technical change and scale effects. These variables are calculated from the instrumental variables translog production function estimates, as described in section II.a. Economically significant average productivity growth is observed in the office machinery and data processing equipment sector (SIC2 33) where technical progress accounts for most of this growth. Also foreign plants enjoy a higher productivity growth and technical progress than domestic plants in this sector. By contrast we find an average negative effect of technical change in both food sectors. This may at least be partly due to low innovation activity in that sector; e.g., Morgan et al. (2003) discuss the low R&D intensity in the food industry compared to other manufacturing sectors in the UK.[14]

[Table 3 here]

IV. Empirical results

To investigate more closely whether there are productivity growth differentials between foreign and domestic plants we start our econometric analysis by decomposing the

[13] Establishments that appear to have experienced more than one change of ownership between 1980 and 1994 are excluded from the analysis. This is partly to avoid conflating the effects of different events, and partly because we suspect the presence of measurement error problems.
[14] They report that the R&D intensity in the food industry was 0.3% compared to a manufacturing average of 2.1% in 1997.

productivity growth differentials for the two types of plants. These results are reported in Table 4. For each industry we run three sets of regressions separately: explaining TFP growth, as well as its components technical change and scale effects. Our results show that, controlling for plant age, size as well four-digit industry and time effects, foreign-owned plants exhibit higher total factor productivity growth in the electronics industry. However there are some noteworthy differences between the two two-digit sectors of this industry. In the office machinery and data processing equipment sector (SIC2 33), the TFP of foreign plants grows by 1.2 percentage points faster than domestic plants, and this advantage is entirely due their higher rates of technical change. By contrast, foreign plants in the electrical and electronic engineering sector (SIC2 34) enjoy a more modest productivity growth advantage over their domestic counterparts, at just above half a percentage point. It is worth noting that technical progress accounts for just a third of this TFP growth differential, while scale effects appear to be a much more important component in this sector.

The picture that emerges from the food industry is more mixed. In the food manufacturing sector (SIC2 41) foreign plants have a 1.1 percentage points productivity growth advantage, and this is entirely explained by technical efficiency. In sharp contrast, the TFP of domestic plants in the confectionary and drink manufacturing sector (SIC2 42) grew by more than 1.24 percentage points faster than that of foreign plants. Interestingly the contribution of scale efficiency to this TFP growth advantage is quite small, and faster technical progress appears to be the major factor responsible for this finding.

[Table 4 here]

The above discussion focused on the importance of the various sources of productivity growth to the average domestic and foreign plants TFP differential. As discussed in the introduction, it is in appropriate to draw any conclusions about causal relationships from this type of analysis. In what follows we, hence, examine whether there is a more direct relationship between *ownership change* and the sources of productivity growth. To this end, we employ the difference-in-differences estimator based on propensity score matched plants described in Section II.b.

Table A1 in the Appendix reports the marginal effects from logit regressions of the determinants of foreign acquisitions to illustrate the procedure used to calculate the propensity scores. Foreign multinationals appear to target older plants and plants with either lower level of productivity (in the electronics industry) or lower productivity growth (in the food industry). Furthermore, in the electronics sector, domestic plants with higher levels of returns to scale are more likely to be acquired.

Also in the Appendix, Tables A2 and A3 summarise the results from the balancing tests for the propensity score matching method, and reassuringly we find that the balancing conditions are met in both sectors. Thus the tests give robust support for the soundness of the matching approach adopted in this paper.

Table 5 provides a decomposition of the productivity growth effects of foreign acquisitions, and three broad patterns emerge: (i) Any positive impact of ownership change is predominantly due to change in technical efficiency, (ii) the pre-acquisition TFP level of the erstwhile domestic plants play a role - positive or negative – in mediating the rate of technology transfer from the MNE parent companies, and (iii) the productivity growth effects are not confined to the year of acquisition, and tend to persist through time. We now provide a more detailed discussion of the results.[15]

Keeping the pre-acquisition level of productivity constant, ownership change brings a statistically and economically significant benefit to the acquired firms in the office machinery and data processing equipment sector (SIC2 33). Within two years of

[15] Throughout insignificant coefficients will be ignored when calculating the magnitudes of the acquisition effects.

acquisition, technical efficiency is growing by about (0.0095+0.007+0.0085=) 2.5 percentage points more than would otherwise be the case. Furthermore, we detect a negative and statistically significant initial TFP-acquisition interaction term one year after ownership change. This indicates that domestic plants that were further behind the technology frontier appear to benefit more from their new associations with multinationals. On the other hand, the impact of foreign acquisition in the electrical and electronic engineering sector (SIC2 34) is less pronounced. Within two years of ownership change, the average effect (holding initial TFP constant) on technical change is about 0.65 percentage points. Also, domestic plants with lower or higher levels of initial TFP do not seem to derive any differential benefits from their new status as subsidiaries of multinationals. In both sectors, scale effects appear to play little or no role for overall productivity growth.

Focusing on the food sector, the unconditional TFP growth effect of foreign acquisitions in the food manufacturing sector (SIC2 41) appears to take place within a year of acquisition. On average, new foreign ownership is associated with a 1.88 percentage points premium in the rate of technical change. However, conditioning on the pre-acquisition level of TFP, the higher this level of TFP the less marked the rate of technology transfer appears to be. In sharp contrast, the results from the confectionery and drink manufacturing (SIC2 42) are quite different from the ones considered thus far. Ownership change is initially detrimental to the TFP growth trajectory of the acquired plants. Holding initial TFP constant, the rate of technical change is slower by 1.27 percentage points within a year of acquisition, than would otherwise be the case. We also detect a decline in TFP growth due to a loss in scale efficiency a year into ownership change, and this loss is higher, the higher the level of initial TFP of the plant. However, we observe an unconditional positive and effect of 1.02 percentage points increase in the technical progress two years after acquisition. This suggests that, while there may be losses in the short run, these seem to be significantly counteracted by positive effects two years after the acquisition.

V. Concluding remarks

This paper has two objectives: firstly, to decompose the productivity advantage of foreign multinationals into two components: the technology and scale effect – arguably a highly policy relevant issue, that, however, has been neglected in academic research thus far. Secondly, the paper contributes to the ongoing debate about the causal relationship between foreign ownership and productivity growth. We do so by analyzing the effects of an acquisition of a domestic establishment by a foreign multinational enterprise on productivity growth, decomposed into technology and scale effects. In order to identify a causal effect we use a combined propensity score matching and difference-in-differences estimation approach.

We analyse separately plant level data for the UK data for the electronics and food industries, which unearths substantial sectoral heterogeneity that would be lost if pooling data for the whole manufacturing industry. From our econometric investigation we draw three major conclusions: (i) any positive impact of ownership change is predominantly due to change in technical efficiency, not scale effects (ii) the pre-acquisition TFP level of the erstwhile domestic plants play a role - positive or negative – in mediating the rate of technology transfer from the MNE parent companies, (iii) the productivity growth effects are not confined to the year of acquisition, and tend to persist through time.

References

Arnold, J. and B.S. Javorcik. (2005) "Gifted Kids or Pushy Parents? Foreign Acquisitions and Plant Performance in Indonesia." CEPR Discussion Paper 5065.

Balk, B.M (2001). 'Scale efficiency and productivity change', *Journal of Productivity Analysis,* 15, 159-183.

Barnes, Matthew and Ralf Martin (2002), "Business data linking: An introduction", *Economic Trends*, No. 581, pp. 34-41.

Bartelsman, E.J. and M. Doms (2000), "Understanding productivity: lessons from longitudinal microdata", *Journal of Economic Literature*, Vol. 38, pp. 569-595.

Blundell, Richard and Monica Costa Dias (2000), "Evaluation methods for non-experimental data", *Fiscal Studies*, Vol. 21, pp. 427-468.

Caves, D.W., Christensen, L.R. and Diewert, W. (1982). 'The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity', *Econometrica*, 50, 1393-1414.

Conyon, Martin J., Sourafel Girma, Steve Thompson and Peter W. Wright (2002), "The productivity and wage effects of foreign acquisition in the United Kingdom", *Journal of Industrial Economics*, Vol. 50, pp. 85-102.

Dehejia, R. and S. Wahba (2002), 'Propensity score matching methods for non-experimental causal studies', *Review of Economics and Statistics*, 84: 151-161.

Diewert, W. (1976). 'Exact and Superlative Index Numbers', *Journal of Econometrics*, 4, 115-145.

Doms, Mark E. and J. Bradford Jensen (1998): "Comparing wages, skills, and productivity between domestically and foreign-owned manufacturing establishments in the United States", in R. Baldwin, R. Lipsey and J.D. Richardson (eds.), *Geography and Ownership as Bases for Economic Accounting*, Chicago: Chicago University Press, pp. 235-255.

Färe, R., Grosskopt, S., Norris, M. and Zhang. Z. (1994). 'Productivity growth, technical progress and efficiency change in industrialized countries', *American Economic Review* 84, 66-83.

Girma, S. and H. Görg. (2006), "Evaluating the foreign ownership wage premium using a difference-in-differences matching approach." *Journal of International Economics*, forthcoming.

Girma, Sourafel; David Greenaway and Katharine Wakelin (2001): "Who benefits from Foreign Direct Investment in the UK?". *Scottish Journal of Political Economy*, Vol. 48, pp. 119-133.

Globerman, Steven, John C. Ries and Ilan Vertinsky (1994), "The economic performance of foreign affiliates in Canada", *Canadian Journal of Economics*, Vol. 27, pp. 143-156.

Griffith, Rachel (1999), "Using the ARD establishment level data to look at foreign ownership and productivity in the United Kingdom", *Economic Journal*, Vol. 109, pp. F416-442.

Griffith, Rachel and Helen Simpson (2004), "Characteristics of foreign-owned firms in British manufacturing", in R. Blundell, D. Card and R. Freeman (eds.), *Creating a Premier League Economy*, Chicago: Chicago University Press.

Heckman, J., H. Ichimura, , J. Smith, and P. Todd, 1997, Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Programme, Review of Economic Studies, Vol. 64, pp.605-654.

Heshmati, A (2003), “Productivity growth, efficiency and outsourcing in manufacturing and service industries”, Journal of Economic Surveys Vol. 7(1), 79-112.

Koop, G., Osiewalski, J. and Steel, M.F.J (1999). ‘The components of output growth: A stochastic frontier analysis’. *Oxford Bulletin of Economic and Statistics,* 61(4), 455-487.

Lapan, H. and P. Bardhan (1973), “Localised technical progress and the transfer of technology and economic development”, *Journal of Economic Theory*, Vol. 6, pp. 585-595.

Leuven, E. and Sianesi, B. (2003). "PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing" http://ideas.repec.org/c/boc/bocode/s432001.html.

Lichtenberg, Frank and Donald Siegel (1987), “Productivity and changes in ownership of manufacturing plants”, *Brookings Papers on Economic Activity: Microeconomics*, pp. 643-673.

Lucas, R.E. (1988). ‘On the mechanics of economic development’. *Journal of Monetary Economics*, 22(1), 3-42.

Markusen, J.R., 2002, *Multinational Firms and the Theory of International Trade*, MIT Press

McGuckin, Robert H. and Sang V. Nguyen (1995), “On productivity and plant ownership change: new evidence from the longitudinal research database”, *Rand Journal of Economics*, Vol. 26, pp. 257-276.

Meyer, B. (1995), “Natural and quasi-experiments in economics”, *Journal of Business and Economic Statistics*, Vol. 13, pp. 151-162.

Morgan, C.W., Blake, A. and Poyago-Theotoky, J. (2003) "Managing Technological Change in the Food Industry: some Case Studies", *International Journal of Biotechnology*, 5 (3/4) pp. 334-53

Orea, L (2002). ‘Parametric decomposition of a generalised Malmquist productivity index’, *Journal of Productivity Analysis*, 18, 5-22.

Rosenbaum, P. and D. B. Rubin (1983), “The central role of the propensity score in observational studies for causal effects”, *Biometrika*, Vol. 70, pp.41-55.

Rosenbaum, P and DB Rubin (1985), ‘Constructing a Control Group Using a Multivariate Matched Sampling Method that Incorporates the Propensity Score’, *The American Statistician*, 39: 33-38.

Smith, J and P Todd (2005b), ‘Does matching overcome Ladonde’s critique of nonexperimental estimators?’, *Journal of Econometrics*, 125: 305-353

Smith, J and P Todd (2005b), ‘Rejoinder’, *Journal of Econometrics*, 125: 365-375.

Tybout, J. (2000). ‘Manufacturing firms in developing countries: How well do they do, and why?’, *Journal of Economic Literature*, Vol. 38, pp. 11-44.

Wang, J-Y. and M. Blomström (1992), “Foreign investment and technology transfer: A simple model”, *European Economic Review*, Vol. 36, pp. 137-155.

Table 1
Frequency distribution of plants by year and ownership

	Electronics			Food		
Year	**Foreign**	**Domestic**	**Total**	**Foreign**	**Domestic**	**Total**
1980	172	830	1,002	63	1,103	1,166
1981	183	827	1,010	67	1,068	1,135
1982	170	866	1,036	62	1,074	1,136
1983	170	859	1,029	63	1,041	1,104
1984	186	1,168	1,354	67	1,439	1,506
1985	173	935	1,108	61	1,098	1,159
1986	170	936	1,106	55	1,066	1,121
1987	180	957	1,137	50	1,010	1,060
1988	187	985	1,172	55	1,046	1,101
1989	221	1,360	1,581	73	1,387	1,460
1990	197	1,031	1,228	69	1,067	1,136
1991	238	979	1,217	84	1,038	1,122
1992	261	979	1,240	70	1,014	1,084
1993	242	952	1,194	62	1,042	1,104
1994	226	804	1,030	58	737	795
Total	3,098	15,274	18,372	1,032	17,585	18,617

Table 2
Frequency of foreign acquisitions

Year	Electronics	Food
1981	11	3
1982	7	4
1983	6	9
1984	32	12
1985	10	1
1986	6	3
1987	15	5
1988	18	5
1989	30	14
1990	14	5
1991	41	15
1992	34	5
1993	24	10
1994	21	6
Total	269	97

Table 3
Summary statistics for productivity growth

Variable	SIC2 = 33				SIC2 = 34			
	Foreign		Domestic		Foreign		Domestic	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
TFP Growth	0.070	0.033	0.059	0.034	0.000	0.010	0.006	0.027
Technical change	0.071	0.012	0.055	0.011	0.000	0.006	0.002	0.009
Scale effect	-0.001	0.031	0.004	0.031	0.000	0.008	0.004	0.026
	SIC2 = 41				SIC2 = 42			
	Foreign		Domestic		Foreign		Domestic	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
TFP Growth	0.000	0.034	-0.011	0.007	-0.029	0.017	-0.016	0.021
Technical change	-0.001	0.019	-0.011	0.006	-0.028	0.006	-0.017	0.007
Scale effect	0.001	0.027	0.000	0.005	-0.001	0.016	0.001	0.020

Table 4:
Decomposing productivity growth differentials between foreign and domestic plants

Electronics sector				Food sector			
	TFP Growth	Technical Change	Scale Effect		TFP Growth	Technical Change	Scale Effect
Foreign* SIC2 = 33	0.0121	0.0166	-0.0045	Foreign* SIC2 = 41	0.0109	0.0100	0.0009
	(0.0038)***	(0.0021)***	(0.0031)		(0.0031)***	(0.0025)***	(0.0017)
Foreign* SIC2 = 34	0.0059	0.0020	0.0039	Foreign* SIC2 = 42	-0.0124	-0.0100	-0.0024
	(0.0007)***	(0.0005)***	(0.0006)***		(0.0011)***	(0.0006)***	(0.0009)***
Size	-0.0002	-0.0003	0.0001	Size	-0.0002	-0.0003	0.0001
	(0.0001)**	(0.0000)***	(0.0001)		(0.0001)*	(0.0001)***	(0.0001)**
Age	-0.0001	0.0001	-0.0002	age	-0.0001	0.0001	-0.0002
	(0.0000)**	(0.0000)***	(0.0000)***		(0.0001)	(0.0000)**	(0.0001)***
Constant	0.0560	0.0538	0.0021	Constant	-0.0036	0.0001	-0.0037
	(0.0026)***	(0.0018)***	(0.0020)		(0.0014)**	(0.0009)	(0.0011)***
Observations	12038	12038	12038	Observations	12178	12178	12178
R-squared	0.45	0.83	0.03	R-squared	0.12	0.40	0.02

Notes:

a. Heteroscedasticity and within-plant serial correlation robust standard errors in parentheses
b. Significant at 10%; ** significant at 5%; *** significant at 1%
c. All regressions include the full set of time and four-digit industry dummies

Table 5:
Decomposing the productivity growth effects of foreign acquisitions:

Electronics sector				**Food sector**			
	TFP Growth	Technical Change	Scale Effect		TFP Growth	Technical Change	Scale Effect
SIC2 = 33				**SIC2 = 41**			
Acquisition year	0.0114	0.0095	0.0001	Acquisition year	0.0113	0.0077	0.0034
	(0.0055)**	(0.0021)***	(0.0060)		(0.0031)***	(0.0019)***	(0.0029)
Acquisition year * initial TFP	0.0106	-0.0043	0.0162	Acquisition year * initial TFP	-0.0199	-0.0398	0.0185
	(0.0116)	(0.0044)	(0.0124)		(0.0177)	(0.0109)***	(0.0162)
After one year	0.0056	0.0070	-0.0029	After one year	0.0115	0.0111	0.0005
	(0.0066)	(0.0025)***	(0.0070)		(0.0058)**	(0.0036)***	(0.0052)
After one year * Initial TFP	-0.0018	-0.0104	0.0088	After one year * Initial TFP	0.0618	0.0052	0.0577
	(0.0137)	(0.0052)**	(0.0142)		(0.0495)	(0.0303)	(0.0442)
After two years	0.0024	0.0085	-0.0076	After two years	0.0965	0.0671	0.0465
	(0.0067)	(0.0026)***	(0.0074)		(0.0685)	(0.0419)	(0.0698)
After two years * Initial TFP	0.0024	-0.0001	0.0034	After two years * Initial TFP	-0.0025	-0.0052	0.0029
	(0.0135)	(0.0051)	(0.0142)		(0.0035)	(0.0021)**	(0.0032)
SIC2 = 34				**SIC2 = 42**			
Acquisition year	0.0031	0.0024	0.0004	Acquisition year	-0.0077	-0.0067	-0.0013
	(0.0015)**	(0.0006)***	(0.0016)		(0.0031)**	(0.0019)***	(0.0028)
Acquisition year * initial TFP	-0.0068	0.0029	-0.0102	Acquisition year * initial TFP	-0.0148	-0.0025	-0.0129
	(0.0056)	(0.0022)	(0.0059)*		(0.0138)	(0.0085)	(0.0129)
After one year	0.0033	0.0025	0.0005	After one year	-0.0115	-0.0060	-0.0058
	(0.0017)*	(0.0006)***	(0.0017)		(0.0036)***	(0.0022)***	(0.0032)*
After one year * Initial TFP	-0.0026	0.0025	-0.0058	After one year * Initial TFP	-0.0282	-0.0022	-0.0271
	(0.0063)	(0.0024)	(0.0066)		(0.0164)*	(0.0100)	(0.0145)*
After two years	0.0049	0.0016	0.0036	After two years	0.0116	0.0102	0.0037
	(0.0018)***	(0.0007)**	(0.0020)*		(0.0071)	(0.0043)**	(0.0078)
After two years * Initial TFP	0.0035	0.0038	-0.0010	After two years * Initial TFP	0.0012	0.0015	0.0009
	(0.0069)	(0.0027)	(0.0077)		(0.0162)	(0.0099)	(0.0146)
Observations	2226	2226	2226	Observations	703	703	703
R-squared	0.35	0.79	0.03	R-squared	0.31	0.55	0.09

Notes:

a. Heteroscedasticity and within-plant serial correlation robust standard errors in parentheses
b. Significant at 10%; ** significant at 5%; *** significant at 1%
c. All regressions include the full set of time and four-digit industry dummies
d. The regressions also control for plant size and age, but the corresponding estimates are omitted to save space.

APPENDIX

Table A1
The determinants of foreign acquisitions:
Marginal effects from the logit regressions

	Electronics		Food	
Age	0.008	0.001***	0.003	0.001*
Size	-0.001	0.001	0.000	0.000
TFP	-0.025	0.014*	0.002	0.002
TFP growth	-0.197	0.229	-0.336	0.130***
Return to scale	0.271	0.098*	0.021	0.014
Assisted area	.002	.008	-0.006	.001
Observations	1900		1810	
Pseudo R^2	0.322		0.569	

Notes:

a. Heteroscedasticity robust standard errors in parentheses
b. Significant at 10%; ** significant at 5%; *** significant at 1%
c. All regressions include the full set of time dummies

Table A2
Balancing results test results: Electronics sector

	Paired t-test		Regression-based test	
Variable	t-value	p>|t|	F-value	p>|F|
Age	0.84	0.404	0.36	0.843
Size	1.28	0.203	0.35	0.843
TFP	-1.88	0.062	0.19	0.941
TFP growth	-0.26	0.797	0.58	0.674
Return to scale	-1.06	0.289	0.33	0.857

Table A3
Balancing results test results: Food sector

	Paired t-test		Regression-based test	
Variable	t-value	p>|t|	F-value	p>|F|
Age	-0.03	0.973	1.08	0.377
Size	0.62	0.54	1.79	0.142
TFP	1.25	0.213	0.38	0.823
TFP growth	-1.53	0.13	0.95	0.441
Return to scale	-0.03	0.973	0.79	0.538

Table A4
Instrumental variables translog production function estimates by two-digit industry

	SIC80 two-digit industry			
	33	34	41	42
x1	19.729	-12.637	-5.078	-3.313
	(1.17)	(4.96)***	(1.96)**	(0.59)
x2	20.203	7.136	8.234	10.030
	(1.66)*	(2.55)**	(4.13)***	(2.28)**
x3	-25.105	10.703	-3.219	4.292
	(1.55)	(3.20)***	(2.00)**	(0.89)
x4	-3.613	0.924	1.244	-1.935
	(0.76)	(1.49)	(1.89)*	(0.98)
x1x1	0.027	0.159	0.093	0.057
	(0.36)	(9.96)***	(7.50)***	(2.18)**
x2x2	0.084	0.052	0.081	-0.001
	(2.15)**	(6.41)***	(11.77)***	(0.03)
x3x3	0.167	0.121	0.114	0.090
	(1.93)*	(5.68)***	(19.61)***	(4.51)***
x4x4	-0.005	-0.013	-0.007	-0.014
	(0.46)	(6.21)***	(8.99)***	(5.18)***
x1x2	-0.033	-0.035	-0.015	0.017
	(0.76)	(4.69)***	(1.89)*	(1.11)
x1x3	-0.054	-0.106	-0.092	-0.078
	(0.80)	(5.99)***	(14.02)***	(4.23)***
x1x4	0.021	0.004	0.000	0.017
	(1.56)	(1.67)*	(0.11)	(2.33)**
x1time	-0.010	0.007	0.003	0.002
	(1.12)	(5.49)***	(2.44)**	(0.74)
x2x3	-0.048	-0.029	-0.036	-0.040
	(0.91)	(3.38)***	(8.38)***	(3.15)***
x2x4	0.017	-0.002	0.003	0.005
	(1.65)*	(1.10)	(1.67)*	(1.03)
x2time	-0.010	-0.003	-0.004	-0.005
	(1.60)	(2.38)**	(3.98)***	(2.14)**
x3x4	-0.022	0.006	0.005	-0.005
	(1.49)	(2.71)***	(3.57)***	(0.95)
x3time	0.012	-0.006	0.001	-0.002
	(1.47)	(3.51)***	(1.68)*	(0.91)
x4time	0.002	-0.000	-0.001	0.001
	(0.82)	(1.32)	(1.85)*	(1.10)
F*x1	0.000	0.000	-20.927	0.000
	(.)	(.)	(3.18)***	(.)
F*x2	0.000	-21.512	-6.327	0.000
	(.)	(3.75)***	(1.00)	(.)
F*x3	1.106	5.494	0.000	0.000
	(0.37)	(2.19)**	(.)	(.)
F*x4	0.963	-2.208	-0.201	0.000

	(0.24)	(1.50)	(0.15)	(.)
F*x1x1	-0.048	0.020	0.136	0.014
	(0.41)	(0.42)	(1.31)	(0.12)
F*x2x2	-0.069	0.020	0.145	0.100
	(0.74)	(0.89)	(3.81)***	(1.22)
F*x3x3	-0.090	0.165	0.046	-0.062
	(0.72)	(1.64)	(0.77)	(0.43)
F*x4x4	0.039	-0.001	-0.044	-0.077
	(1.16)	(0.22)	(4.63)***	(2.98)***
F*x1x2	0.081	0.045	-0.081	-0.021
	(0.99)	(1.52)	(1.52)	(0.29)
F*x1x3	0.034	-0.081	-0.011	0.078
	(0.42)	(1.22)	(0.17)	(0.61)
F*x1x4	-0.014	-0.006	0.060	-0.051
	(0.34)	(0.51)	(2.39)**	(0.69)
F*x1time	-0.000	0.001	0.010	-0.000
	(0.39)	(1.13)	(2.95)***	(0.34)
F*x2x3	0.001	-0.045	-0.083	-0.135
	(0.01)	(1.18)	(2.23)**	(1.66)*
F*x2x4	0.026	0.000	0.013	0.088
	(0.80)	(0.04)	(1.27)	(1.55)
F*x2time	-0.000	0.011	0.004	0.000
	(0.68)	(3.87)***	(1.11)	(0.55)
F*x3x4	-0.046	0.003	-0.056	0.073
	(1.73)*	(0.20)	(2.52)**	(1.26)
F*x3time	0.001	-0.004	0.000	0.000
	(0.30)	(3.19)***	(0.37)	(0.18)
F*x4time	-0.000	0.001	0.001	-0.000
	(0.23)	(1.54)	(1.12)	(0.29)
time	1.587	-0.875	1.800	-2.153
	(0.32)	(1.01)	(2.44)**	(1.18)
F*time	-0.029	0.026	0.054	0.008
	(1.35)	(2.03)**	(3.16)***	(1.17)
timetime	-0.001	0.000	-0.001	0.001
	(0.33)	(1.09)	(2.45)**	(1.19)
F*timetime	0.000	-0.000	-0.000	-0.000
	(1.03)	(1.62)	(3.70)***	(0.73)
Observations	538	8834	6288	3462
Sargan-test p-value	0.134	0.213	0.121	0.176

Notes:

a. Dependent variable is output and factor inputs are considered. These are skilled labour (x1), unskilled labour (x2), intermediate inputs (x3) and capital (x4).
b. The prefix F* is used to denotes interaction terms with the oreign ownership dummy.
c. Significant at 10%; ** significant at 5%; *** significant at 1%