Foreign ownership, returns to scale and productivity: Evidence from UK manufacturing establishments

Sourafel Girma* and Holger Görg

University of Leicester and University of Nottingham

Abstract

This paper calculates returns to scale and productivity growth in UK manufacturing establishments in the electronics and food industries. Our results show that foreign establishments tend to have lower returns to scale than their domestic counterparts. We also examine the effect of the acquisition of a domestic establishment by a foreign owner on returns to scale and productivity growth. We use a matching and difference-in-differences methodology which allows us to construct a reasonable counterfactual and to determine the post-acquisition changes in RTS and productivity that can be attributed to the incidence of acquisition, rather than to changes in other external conditions. In both sectors, acquisition has a negative effect on RTS, although the effect appears stronger in the food sector. The effect of foreign acquisition on productivity differs between sectors; establishments in the electronics sector experience a reduction in productivity post acquisition, while plants in the food sector increase productivity.

Keywords: returns to scale, foreign direct investment, acquisitions, productivity
JEL classification: L11, F23

August 2002

* Address for correspondence: Sourafel Girma, Department of Economics, University of Leicester, Leicester LE1 7RH , email: sg116@le.ac.uk
The authors are grateful to the ONS Business Linking Data Project for providing access to the ARD database. Thanks are also due to David Greenaway, Jonathan Haskel, Steve Redding, Eric Strobl, Dieter Urban and participants at seminars at LSE, IUI Stockholm and Lausanne, a CEPR meeting at Turin and an ARD user meeting at Nottingham for helpful comments on earlier drafts of the paper. All remaining errors are, of course, the authors'. Financial support from the European Commission Fifth Framework Programme (Grant No. HPSE-CT-1999-00017) and the Leverhulme Trust (Grant No. F114/BF) is gratefully acknowledged.

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1 Introduction

There has been a surge in the literature on the effects of foreign direct investment (FDI) on host countries recently. This is presumably as much due to the rising importance of FDI in the world economy[1] as it is to the increasing availability of firm and plant-level datasets for different countries which allow careful examination of such issues. Most analyses are concerned with examining productivity differences between foreign-owned firms and domestic firms, and productivity spillovers from foreign to domestic firms in the host country.[2] The expectation is that the former usually have higher productivity (levels or growth), due to their ownership of some sort of firm-specific asset or ownership advantage that leads to higher levels of technology being used in the foreign firms. This technological advantage is then assumed to spill over to domestic firms, allowing them to improve their productivity levels if foreign firms are present in the industry.[3]

A key assumption in this literature is that foreign firms' productivity advantages reflect their technological advantage. This argument is, however, only true in a neoclassical production framework assuming perfect competition, long run equilibrium and, perhaps most importantly, constant returns to scale. In a perfectly competitive framework, if returns to scale were not constant a productivity advantage of a foreign firm could not only be due to technological differences but also

[1] The recent UN World Investment Report (UNCTAD, 2001) for example shows that annual world-wide flows of FDI now exceed US$700 billion while total stocks exceed US$6 billion.
[2] Doms and Jensen (1998) and Griffith and Simpson (2002) are recent examples of the former type of study for the US and the UK respectively, while Aitken and Harrison (1999) and Girma, Greenaway and Wakelin (2001) examine productivity spillovers in Venezuela and the UK, respectively.

differences in the scale of operations and capacity utilisation between the two types of firms. Hence, "conventional" measures of productivity that do not allow for non-constant returns to scale may be problematic as they do not distinguish scale effects from technology effects. The literature on the effects of FDI in particular may be problematic because the frequent conclusion that FDI leads to improvements in domestic productivity via increasing the level of technology may not be appropriate if the assumption of constant returns to scale does not hold.

This paper sets out to calculate returns to scale (RTS) and productivity growth in UK manufacturing establishments allowing for non-constant returns to scale. We compare returns to scale and productivity growth (adjusted for scale effects) in domestic and foreign-owned firms using establishment level data for UK manufacturing industries. Furthermore, we go on to examine the effect of the acquisition of a domestic establishment by a foreign owner on returns to scale and productivity growth. We focus our analysis on establishments in the UK electronics and food industries.[4] Foreign-owned firms are important players in both, accounting for about 19 percent of employment in electronics and 10 percent of employment in the food industry in 1996 (see Griffith and Simpson, 2002, Table 4). We may, however, expect the two sectors to be different in their technology usage and, hence, differences in the determinants of productivity and returns to scale for firms in the two different sectors.[5]

This paper makes a number of contributions to the literature. First, to the best of our knowledge, this is the first attempt to compare returns to scale and productivity

[3] The literature on productivity spillovers has recently been critically reviewed by Görg and Strobl (2001).

[4] 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).

growth in foreign and domestic establishments in a host country. Second, we examine the effect of foreign acquisition on returns to scale and productivity growth in the target firm. We use a matching and difference-in-differences methodology which allows us to construct a reasonable counterfactual and to determine the post-acquisition changes in RTS and productivity that can be attributed to the incidence of acquisition, rather than to changes in other external conditions. To our knowledge this is the first study to use a difference-in-differences methodology combined with a matching estimator to analyse the causal relationship between foreign acquisition and productivity characteristics.[6]

The remainder of the paper is structured as follows. Section 2 sets out the methodology used to calculate returns to scale and productivity. Section 3 describes the dataset while Section 4 presents the results of calculating productivity and returns to scale for foreign and domestic establishments. Section 5 investigates the effect of the acquisition of a domestic establishment by a foreign firm on the acquired firms' development of productivity and returns to scale, using a matching methodology combined with a difference-in-differences estimator. Section 6 presents some conclusions.

2 Measuring returns to scale

A fairly large literature has developed over the last decades on the measurement of returns to scale.[7] Two issues stand out: whether to use production or cost functions;

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[5] According to an OECD classification as cited by Kearns and Ruane (2001) "electronics and communication" are classified as high-tech, while "food and beverages" are low-tech industries

[6] Using also establishment-level data for UK manufacturing, Harris and Robinson (2002) analyse the effect of foreign acquisition on productivity growth of the acquired plants using the full sample of domestic and acquired establishments.

[7] For example, Basu and Fernald (1997), Morrison and Siegel (1997) and Basu, Fernald and Shapiro (2001) use industry level data for the US. Caves, Christensen and Swanson (1981) and Callan (1988) use data for railroads and electric utilities in the US, respectively. For the UK, Oulton (1996) uses industry level data. See also Park and Kwon (1995) and Nadiri and Kim (1996) using industry level

and whether to use industry or firm/plant level data. As regards the former, from duality theory we know that a restricted cost function should be sufficient to infer the structure of production (see Lau, 1976). Hence the choice between production or cost function appears to be largely determined by the availability of data for the estimation of either. The choice to opt for the former rather than the latter then is mainly driven by the unavailability of data on input prices. We have establishment level data on prices for skilled and unskilled labour, as well as four-digit level price indices which allow us to estimate cost functions. As regards the choice between industry and firm/plant level data, industry level data may lead to biased results as they aggregate over potentially heterogenous units. As returns to scale and productivity are micro phenomena the use of micro data is superior to industry level data. We, therefore, use establishment level to estimate cost functions.

Assuming that the firm does not minimise cost with respect to all inputs but only with respect to a subset of inputs conditional on the levels of other inputs (quasi-fixed factors), we start with a variable cost function of the following form

$$(1)\quad \ln VC = VC(\ln Y, \ln P_s, \ln P_u, \ln P_m, \ln K, T)$$

where Y is gross output, the P_x denote the prices of three variable inputs, namely skilled and unskilled labour, and materials, K is capital which is assumed to be a quasi-fixed factor and T is a time trend to proxy the impact of technological change over time.

Following Caves, Christensen and Swanson (1981) we can derive expressions for returns to scale (*RTS*) and two measures of productivity growth from the variable cost function:

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data for Korea, and the US, Japan and Korea, respectively, and Fikkert and Hasan (1998) and Tybout and Westbrook (1995) using plant level data for India and Mexico respectively.

(2) $RTS = (1-(\partial \ln VC / \partial \ln K)) / (\partial \ln VC / \partial \ln Y)$

(3) $PGY = -(\partial \ln VC / \partial t) / (\partial \ln VC / \partial \ln Y)$

(4) $PGX = -(\partial \ln VC / \partial t) / (1-(\partial \ln VC / \partial \ln K))$

PGY gives the rate of output growth over time holding inputs fixed, while *PGX* represents the rate at which inputs can be decreased over time, holding output fixed.[8]

We choose a translog cost function as the functional form for the estimation of the variable cost function. As apparent from equation (1) there are three variable factors of production and we choose to normalise *VC*, P_s and P_u by P_m, thus imposing homogeneity of degree one in the input prices on the cost function. Hence, the cost function takes the following form:

$$
(5) \quad \begin{aligned}
vc_{it} &= \beta_0 + \beta_y y + \beta_k k + \beta_t T + \sum_g \beta_g p_g \\
&+ \tfrac{1}{2}\sum_g \sum_h \beta_{gh} p_g p_h + \tfrac{1}{2}\beta_{yy} y^2 + \tfrac{1}{2}\beta_{kk} k^2 + \tfrac{1}{2}\beta_{tt} T^2 \\
&+ \sum_g \beta_{gy} p_g y + \sum_g \beta_{gk} p_g k + \sum_g \beta_{gt} p_g T \\
&+ \beta_{yk} yk + \beta_{yt} yT + \beta_{kt} kT + \varepsilon_{it}
\end{aligned}
$$

with *g,h* = *u,s*. In order to reduce potential confusion we used lower case letters to denote variables in natural logs. Also, we suppressed subscripts for establishment *i* and time *t*.

Given the large number of parameters to be estimated we can improve efficiency of the estimates through estimating also the cost share equations implied by the translog cost function. Since we impose the restriction of homogeneity in factor prices we can,

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8 Caves et al. (1981) show that PGY = RTS * PGX, implying that PGY = PGX iff RTS = 1.

using Shephard's lemma, derive the following two cost share functions for the variable factors skilled and unskilled labour:[9]

$$(6)\ \ S_s = \left(P_s L_s / VC\right) = \alpha_0^s + \beta_{ss} p_s + \beta_{su} p_u + \beta_{sy} y + \beta_{sk} k + \beta_{st} T + v_{it}^s$$

$$(7)\ \ S_u = \left(P_s L_s / VC\right) = \alpha_0^s + \beta_{su} p_s + \beta_{uu} p_u + \beta_{uy} y + \beta_{uk} k + \beta_{ut} T + v_{it}^u$$

Equations (5) to (7) represent a system of three equations which is estimated simultaneously using iterative three stage least squares estimation to obtain efficient estimates of the parameters.[10]

There are at least two econometric problems which arise when estimating these cost equations, namely, simultaneity and measurement error. Firstly, increases in expected output may cause plants to grow. If current levels of output and inputs are correlated with expected output this will lead to endogeneity of the regressors. Secondly, measurement error in the regressors may bias estimated returns to scale downward (Tybout and Westbrook, 1995). This is particularly likely to be the case for capital which is likely to be poorly estimated in our data. To overcome these problems we choose to instrument for output and capital (as the quasi-fixed factor) using second lags of the respective variables as instruments.

3 Data

We use data from the Annual Respondents Database (ARD) provided by the Office for National Statistics in the UK under controlled conditions. The dataset consists of individual establishments' records underlying the Annual Census of Production and the data used cover the period 1980 to 1994. As Griffith (1999) and Barnes and

[9] The materials equation is dropped as the cost shares sum to unity.
10 The iterative procedure produces estimates asymptotically equivalent to maximum likelihood estimates.

Martin (2002) provide useful introductions to the data set, we only include a brief discussion of some of its features relevant to the present work.[11]

The ARD gives a nationality indicator for establishments, and an indigenous establishment is identified as being foreign acquired at time *t* if its status changes from being domestic to being a subsidiary of a foreign firm. Establishments that appear to have experienced more than one change of ownership between 1980 and 1993 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. The final sample consists of 182 foreign acquisitions in the electronics industry, and 86 in the food industry.

Before estimating the translog cost function we present some summary statistics on input prices, variable costs and cost shares of the three variable inputs by sector and nationality group in Table 1. We can obtain almost all variables at the establishment level from the ARD database, the only exception being the price of materials. We, therefore, use four digit industry material price deflators, available from the ONS, as proxies for P_m. Two points related to the summary statistic are particularly noteworthy. First, there is substantial variation in the price of materials between establishments even in those narrowly defined eight categories. This suggests that the use of four-digit price deflators does not imply that there is little variation across establishments in the materials price. As a matter of fact, most of the variation in the materials price is between establishments in all eight categories. Second, the materials share is by far the most important cost component in all eight sub-groups; in the food industries more than 80 percent of variable costs are costs of materials, while this share is about 70 percent for the electronics industries. Furthermore, note that the

[11] See also the data appendix for a discussion of some of the details of how the data are collected.

cost share devoted to skilled workers is higher in electronics than in food, suggesting that the former is more skill intensive.

[Table 1 here]

4 Estimation results on returns to scale and productivity

In order to be able to compare returns to scale and productivity across establishments of different nationality and in different sectors we estimate the system of equations described in equations (5) to (7) separately for each of the four two-digit sectors and the two nationality groups (domestic vs. foreign-owned). This gives eight estimations, the results of which are reported in the appendix. Table A1 reports the results of the iterative three stage estimations using instruments for capital and output as described above. In order to be able to assess the possible bias that we would have experienced without using instruments we also report estimates of the iterative three stage estimation without instruments in Table A2. Furthermore, the results of a simple OLS regression of equation (5) are shown in Table A3.

Comparing the three sets of results we find that there are quite substantial differences in the estimates, in particular on the direct effects of input prices, output, capital and time trend (β_s, β_{us}, β_y, β_k, β_t). To test whether the use of instruments improves our estimation we compare results from a simple OLS regression and an IV regression on equation (5) using a Hausman test. We also test for the validity of instruments in this estimation using a Sargan test.[12] The results of these two tests for the eight estimations are reported in Table A4. For most cases, these tests support the use of instruments. Since there are strong theoretical arguments for instrumenting for output and capital we ultimately adopt the iterative three stage estimator including instrumental variables as our preferred estimator. The following analysis is, hence, based on results produced using that estimation procedure.

Returns to scale and productivity growth can be computed from equations (2) to (4). Estimates for RTS averaged over all establishments in the two digit-sector are presented in Table 2. Note that in all four sectors, most of the variation in the data is due to variation between rather than within establishments over time. These aggregate statistics do not suggest any major differences between foreign and domestic establishments in their returns to scale. It is noteworthy from the table that we can only reject the hypothesis that RTS = 1, i.e., that there are constant returns to scale, in one of the four two-digit sectors. This finding is in line with the result by Oulton (1996) who, using industry-level data for 124 UK manufacturing industries concludes that "only a handful of cases" (p. 107) showed evidence of increasing returns to scale. Basu and Fernald (1997) calculate returns to scale using industry data for US manufacturing also find "that a typical (roughly) two-digit industry in the United States appears to have constant or slightly decreasing returns to scale" (p. 249).[13] Basu and Fernald also show, however, that the level of aggregation at which returns to scale are calculated can explain this result; their estimates of RTS are different at different levels of aggregation. This is not surprising as it is well known that the use of aggregate data to study activities at the micro level can lead to biases if there is heterogeneity across the micro level unit, i.e., plants in our case (see Griliches and Ringstad, 1971).

[Table 2 here]

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[12] Estimations for the Sargan test include third lags of the variables as instruments also as the test requires the presence of more instruments than exogenous variables.

[13] Caballero and Lyons (1990) using industry-level data for four European countries, including the UK, also find that returns to scale at the industry level were, on the whole, unimportant. Furthermore,

Since we have establishment level data available we can examine the actual distribution of returns to scale at the level of the establishment. Figure 1 plots the Kernel density estimates for returns to scale for the four two digit sectors. The vertical line indicates RTS = 1. As one can see, the majority of observations in all four sectors is in the region of RTS > 1, i.e., most observations indicate increasing returns to scale at the level of the establishments. Figure 2 presents a breakdown by nationality of ownership of the establishment for the four two-digit sectors. Apart from one sector (SIC 33), foreign establishments appear to show lower levels of returns to scale than their domestic counterparts.

[Figures 1 and 2 here]

This result is confirmed in a simple OLS regression of returns to scale on a dummy equal to one if the plant is domestic and zero otherwise, controlling for size (in terms of gross output) and age of the plant.[14] The results of this estimation are presented in Table 3. The estimates indicate that, in all four sectors, returns to scale for domestic establishments are, on average, between 0.02 and 0.05 units higher than for foreign plants of similar size and age. In a perfectly competitive production framework we can interpret increasing returns to scale as indicating that plants can benefit from increasing the scale of production. This suggests that domestic establishments in particular show signs of unused capacity.[15] A particular question we address in the following section is whether the acquisition of such domestic plants by foreign establishments leads to a reduction of such excess capacity.

Fikkert and Hasan (1998) use firm level data for six manufacturing industries in India and find average returns to scale not significantly different from 1.

[14] Theory suggests that for a given technology and all other things equal, large plants should have lower economies of scale than small plants. This seems to be borne out by the data as the regression results in Table 4 suggest. Allowing for plant-specific effects in a fixed or random effects estimation produces results very similar to those of the OLS regression; results are available upon request from the authors.

[15] A similar argument is made by Fikkert and Hasan (1998) for Indian manufacturing firms.

[Table 3 here]

Before turning to this question we also present some summary data on the two measures of productivity growth calculated from the translog cost function. Table 4 shows means for these two measures across plants in the four two-digit sectors and by nationality of ownership. Given that the aggregate data on RTS shown above were close to one in most cases we would not expect major differences between PGY and PGX; this is indeed what the data show. We do, however, find interesting differences between the four sectors, in particular between the two electronics, which show high positive growth, and the two food sectors where productivity growth on average has been negative between 1980 to 1994. Only in one of the two-digit food industries do we find substantial differences in average productivity growth between foreign and domestic plants, with the former showing positive growth of around 1 percent while the latter exhibit negative average productivity growth rates. Note that these rates of productivity growth are corrected for returns to scale. They are therefore not due to scale effects but are driven by changes in technology or other factors external to the production function.

[Table 4 here]

5 Estimating the effect of foreign acquisition on returns to scale and productivity

We now turn to investigating whether the acquisition of domestic establishments by foreign owners has any effect on that establishment's returns to scale and productivity growth. The important issue in this context is how to establish what would have happened to the plant had it not been acquired by the foreign establishment. This analysis of evaluating the causal effect of foreign acquisitions can be viewed as confronting a missing-data problem, since productivity and returns to scale information for the acquired firms had they remained in domestic hands is obviously not available. This implies that a direct pre- versus post-entry comparison cannot be made. The construction of the missing information (or the counterfactual) is therefore at the heart of our analysis.[16]

We address this point by comparing establishments that were acquired with those that are very similar in terms of a number of plant-specific characteristics but did not experience an acquisition. To be more precise, we match establishments that experienced a foreign acquisition with one that did not but that had a similar probability of being acquired. We match these establishments using the propensity score from a probit estimation of the probability of being acquired by a foreign establishment. After matching the establishments we can then compare the development of returns to scale and productivity growth in these two groups of establishments (the "acquired" and "control" groups) using a difference-in-differences methodology, regressing returns to scale (or productivity growth) on an acquisition dummy and other control variables.

An important feature in the construction of the counterfactual is the selection of a valid control group as similar as possible to the acquired firms, the only difference being that the latter are eventually taken over by foreign establishments. We adopt the propensity score matching method of Rosenbaum and Rubin (1983) to select appropriate firms out of the reservoir of firms that are never acquired. Thus we first identify the probability (or propensity score) of being acquired by a foreign owner for all firms via a probit regression on the sample of foreign-acquired and purely domestic plants. We then predict the propensity score for each plant and match each

[16] For a comprehensive review on how best to construct counterfactuals in typical economic problems see Blundell and Costa Dias (2000).

acquired establishment to its nearest neighbour in terms of the propensity score.[17] The nearest neighbours are then selected into the control group.[18]

The choice of what variables to include in the probit estimation is not straightforward. From economic theory it is not clear what establishment level characteristics may be expected to determine the probability of being taken over by a foreign establishment. Productivity before acquisition has been suggested in the literature but it is not clear what direction the effect should be. For example, Lichtenberg and Siegel (1987) argue that ownership changes are driven by perceived low levels of efficiency in the plant, hence there should be a negative relationship between pre-acquisition productivity and the probability of acquisition. McGuckin and Nguyen (1995) however argue that acquisitions are aimed at acquiring high productivity establishments, hence there should be a positive relationship between productivity and acquisitions. Most of the theoretical work on acquisitions does not, however, concern itself particularly with foreign, as opposed to domestic, ownership changes.

We choose to include the following pre-acquisition variables in our probit estimation to explain the probability of foreign acquisition: plant age, size (measured in terms of capital), productivity growth and returns to scale. Furthermore, we include a time trend and a dummy equal to one if the plant is located in an assisted area in order to control for possible regional effects.

The results of the probit estimations are presented in Table 5. We estimated the model separately for the electronics and food industries.[19] The results in terms of the

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[17] Strictly speaking, we have to assume that the subsequent outcomes in non-acquired firms are independent of the probability of being taken over, conditional on the observables included in the probit estimation. That is, there is selection on observables (Blundell and Costas Dias, 2000). If this were not the case the use of this propensity score matching technique could be problematic.

[18] The matching is performed in Stata Version 7 using the nearest-neighbour-matching estimator as described in Sianesi (2001).

effect of age and size on the probability of foreign acquisition are similar in the two manufacturing sectors; younger and larger firms are more likely to be acquisition targets (although this effect is non-linear in both cases). Establishments with high productivity growth also seem more likely to be acquired; however, the impact of productivity appears much stronger in the food than in the electronics sector. The effect of returns to scale is quite different in the two sectors; in electronics, there is a negative relationship between RTS and foreign acquisition, while this relationship is positive in the case of food sector establishments. If plants with high returns to scale are acquisition targets, as it appears to be the case in the food industry, this may suggest that foreign acquisitions are aimed at exploiting returns to scale by expanding capacity. This is an issue we return to below.

[Table 5 here]

Based on the propensity scores from the probit estimation a non-acquired firm, which is 'close' (in terms of its propensity score) to an acquired firm is then selected as a match for the latter. This type of matching procedure is preferable to randomly or indiscriminately choosing the comparison group because it is less likely to suffer from selection bias by picking firms with markedly different characteristics. In the final analysis we have selected 146 (76) purely domestic firms as a match for the 182 (86) foreign acquisitions in the electronics (food) sector.[20]

Having selected the comparison group, we adopt the difference-in-differences methodology (as reviewed by Meyer, 1995) to isolate the role of foreign acquisition in the performance dynamics of firms. This approach proceeds in two steps. Firstly, the

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[19] We also compared the results of these pooled probits with those of random effects probits which allows for a plant-specific effect in the error term. Results of both estimation procedures are similar in terms of magnitude and statistical significance and we, therefore, chose to use the pooled model to predict the propensity scores for constructing the control group.

[20] Note that a domestic firm that was not acquired can be a match to more than one acquisition.

difference between the average productivity growth rates or returns to scale before and after the change of ownership, say $\Delta^a \dot{Z}$ is calculated. However this difference cannot be exclusively attributed to acquisition since the post-acquisition period growth rate might be affected by factors that are contemporaneous with ownership change. To cater for this, the difference obtained at the first stage is further differenced with respect to the before and after difference for the control group of the purely domestic firms.[21] The resulting difference-in-differences estimator $\delta = \Delta^a \dot{Z} - \Delta^c \dot{Z}$ therefore removes effects of common shocks, and provides a more accurate description of the impact of acquisition.

Following this approach, a regression of

$$(8)\ \dot{Z}_{it} = \phi + \delta A_{it} + \gamma X_{it} + u_{it}$$

where $\dot{Z}$ is returns to scale or productivity growth, A is a vector of post-acquisition dummies and X is a vector of control variables, should produce a coefficient δ as the average percentage point change in returns to scale (productivity growth) that can be attributed to foreign acquisition.

To allow for differential acquisition effects across the years we construct two separate dummies: a contemporaneous dummy equal to one in the year of acquisition and a second dummy equal to one for the period starting from one year after the ownership change. In order to control for possible observable effects that may be correlated with changes in returns or productivity we include establishment age and size (in terms of capital) as well as time and four-digit industry dummies in the regression. The regressions are estimated on samples for the four two-digit industries described above.

[21] Hence the name, difference-in-differences.

The regression results for the effect of foreign acquisition on returns to scale are presented in Table 6. Note that we find a negative coefficient on the acquisition dummies in all four sectors although the effect appears stronger in the two food sub-sectors than in electronics. In the latter sectors the combined effect is around –0.05, compared to around –0.02 in the electronics sub-sectors. We can calculate the long run effect of the ownership change by estimating the extended form of equation (8), including also a lagged dependent variable. The long run effect can then be retrieved by calculating $\delta_{LR} = \delta/\beta_{X-1}$. The results of these estimations are reported in Table 7. From these estimates we can compute the long run effect for, for example, SIC 42 as –0.14 while it is –0.11 for SIC 33. In a perfectly competitive production framework, these reductions in returns to scale suggest that the foreign acquisition leads to a reduction of excess capacity in the acquired establishment.

[Tables 6 and 7 here]

We can say something more about how a firm adjusts its scale by examining more closely the post-acquisition development of the growth of inputs and output. We ran regressions of equation (8) using growth rates of input shares and output as dependent variables in turn for the electronics sector and food sector separately. The estimation results are reported in Table 8. Inspection of the table shows that in the electronics sector adjustment comes through increases in the growth of the share of materials used and reductions in the use of skilled and unskilled labour post acquisition. There is no increase in output growth apparent, however. This is different in the food sector, where output growth is higher post acquisition. In terms of inputs also the growth of materials and unskilled labour are affected in the same direction as in electronics, although the magnitude of the effect appears smaller in the food sector.

[Table 8 here]

Next we turn to look at the effects of foreign acquisition on productivity growth, using the two measures of productivity as defined above which capture the effects not due to changes in scale. Table 9 presents the results of estimations similar to equation (8) with productivity growth (*PGX* or *PGY*) as the dependent variable. For the electronics sector we find in the static model that foreign acquisitions lead to small reductions in productivity growth in the acquired firm, with an acquired firm having an 0.001 percentage point lower productivity growth than a control-group firm. On the other hand, an acquisition of a food sector firm leads to productivity improvements of about 0.007 percentage points in the growth rate. Note that results are very similar for both measures of productivity growth.

[Table 9 here]

We pointed out at the outset of the paper that "conventional" productivity measures do not allow the researcher to distinguish properly between scale and technology effects leading to productivity improvements. In our estimation we can distinguish these two issues and are therefore able to say that the productivity effects calculated in Table 9 are not due merely to changes in the scale of the firm. To illustrate our argument more forcibly we can also calculate the effect of foreign acquisitions on conventional measures of total factor productivity (TFP) growth for our sample of acquired and control group firms and compare those results to the results in Table 9.

Table 10 presents the results of estimations of foreign acquisition on productivity using conventional definitions of TFP. First we calculated TFP as the Solow residual in a production function and used this as the dependent variable. Secondly we also estimated an augmented production function including firm specific fixed effects. The results show that, for the electronics sector we do not find any statistically significant effects of foreign acquisition on productivity, which is in contrast to the estimations above where we found a negative effect of the acquisition on productivity growth in the acquired establishment. For the food sector we find that results are broadly similar in terms of the direction of the effects, although in the augmented production function estimation coefficients are much higher than those we obtained in the regressions reported in Table 9. In other words, if we were to rely on the results of the augmented production function we would grossly overestimate the effects on productivity that are not due to scale effects.

[Table 10 here]

6 Conclusions

This paper calculates returns to scale and productivity growth (allowing for non-constant returns to scale) in UK manufacturing establishments using data from the ARD database. Our results show that returns to scale differ between foreign and domestic establishments. The latter tend to have higher returns to scale which suggests that they could benefit from increasing capacity utilisation. We also find that the incidence of acquisition of a domestic establishment by a foreign firm impacts on this establishments returns to scale. In both sectors, acquisition has a negative effect on RTS, possibly indicating that plants are better able to utilise capacity, although the effect appears stronger in the food sector. The effect of foreign acquisition on productivity differs between sectors; establishments in the electronics sector experience a reduction in productivity post acquisition, while plants in the food sector increase productivity.

Overall, our results suggest that returns to scale need to be taken into account for more accurate descriptions of productivity dynamics and in order to distinguish technological from capacity utilisation effects. The paper also has implications for the large literature on productivity spillovers from FDI, to which our work relates. In a study of productivity spillovers using "conventional" measures of productivity one cannot easily distinguish whether the improvement in productivity following increased foreign presence in the sector is due to technology or scale effects. Hence, in order to be able to target policy at increasing technology rather than expanding capacity one ought to take account of returns to scale in productivity estimations.

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Data Appendix

In the period covered by our data, 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. During our study period, 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 over the period under consideration establishments with more than 100 employees were always sampled.

In the ARD, 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 the sample period considered in this paper over 95 percent of the establishment in both the electronics and food industries are single-plant firms. In the actual sample we used for the econometric estimation this figure is around 80 percent for both sectors. Thus most of the data we used is actually plant level data. As a result we tend to use the terms plant and establishment interchangeably for what are termed establishments in the ARD.

Table 1: Summary statistics on input prices, variable cost and cost shares

	SIC nationality	33 foreign	33 domestic	34 foreign	34 domestic	41 foreign	41 domestic	42 foreign	42 domestic
P_m	mean	0.356	0.378	0.303	0.296	0.263	0.250	0.248	0.235
	st.dev.	0.220	0.201	0.191	0.185	0.152	0.151	0.154	0.156
	between	0.265	0.232	0.237	0.226	0.195	0.189	0.192	0.194
	within	0.120	0.102	0.110	0.115	0.091	0.092	0.097	0.094
P_s	mean	9.045	9.001	8.948	8.854	8.913	8.683	8.973	8.838
	st.dev.	0.278	0.286	0.285	0.320	0.346	0.420	0.311	0.340
	between	0.269	0.262	0.274	0.308	0.323	0.414	0.292	0.351
	within	0.163	0.183	0.176	0.197	0.216	0.244	0.178	0.188
P_u	mean	8.587	8.522	8.513	8.441	8.518	8.317	8.611	8.506
	st.dev.	0.359	0.357	0.326	0.334	0.348	0.436	0.355	0.367
	between	0.326	0.348	0.308	0.325	0.347	0.422	0.316	0.365
	within	0.195	0.199	0.175	0.159	0.155	0.184	0.173	0.156
VC	mean	16.301	14.672	15.497	14.515	16.210	15.001	16.380	15.514
	st.dev.	1.699	1.373	1.252	1.349	1.240	1.493	1.377	1.391
	between	1.678	1.329	1.301	1.365	1.348	1.569	1.417	1.485
	within	0.481	0.323	0.335	0.300	0.314	0.272	0.284	0.282
S_s	mean	0.158	0.191	0.146	0.158	0.041	0.044	0.064	0.062
	st.dev.	0.118	0.113	0.082	0.085	0.031	0.035	0.037	0.045
	between	0.101	0.109	0.079	0.080	0.029	0.034	0.038	0.043
	within	0.069	0.049	0.037	0.040	0.015	0.017	0.017	0.020
S_u	mean	0.073	0.126	0.142	0.197	0.109	0.154	0.102	0.105
	st.dev.	0.059	0.110	0.088	0.102	0.082	0.106	0.060	0.075
	between	0.080	0.111	0.087	0.100	0.085	0.101	0.066	0.078
	within	0.021	0.037	0.037	0.042	0.028	0.047	0.019	0.025
S_m	mean	0.769	0.683	0.712	0.645	0.850	0.802	0.834	0.833
	st.dev.	0.139	0.133	0.120	0.119	0.098	0.123	0.076	0.100
	between	0.125	0.132	0.117	0.116	0.100	0.119	0.084	0.102
	within	0.080	0.053	0.051	0.053	0.035	0.049	0.024	0.034

Note: P_s and P_u are in logs, VC is normalised by P_m

P_m	price of materials
P_s	price of skilled labour
P_u	price of unskilled labour
VC	variable costs
S_s	skilled labour cost share
S_u	unskilled labour cost share
S_m	materials cost share

Table 2: Mean RTS by two-digit sector and nationality

SIC	Nationality	Mean	Std. Dev.		
			overall	between	within
	Electronics				
33	All	1.075	0.133	0.132	0.053
	Foreign	1.090	0.111	0.125	0.035
	Domestic	1.070	0.139	0.134	0.053
34	All	1.089	0.052	0.055	0.018
	Foreign	1.059	0.036	0.036	0.018
	Domestic	1.096	0.053	0.055	0.014
	Food				
41	All	1.028	0.039	0.042	0.018
	Foreign	0.989	0.048	0.057	0.023
	Domestic	1.030	0.037	0.041	0.018
42	All	1.123*	0.032	0.034	0.017
	Foreign	1.082*	0.021	0.022	0.007
	Domestic	1.128*	0.029	0.029	0.015

* denotes different from 1 at least at 5 percent level

Table 3: OLS regression results, dependent variable RTS

	SIC 33	SIC 34	SIC 41	SIC 42
output	0.031	-0.020	-0.019	-0.006
	(0.002)**	(0.000)**	(0.000)**	(0.000)**
age	0.009	0.003	0.005	-0.003
	(0.001)**	(0.000)**	(0.000)**	(0.000)**
domestic	0.050	0.018	0.020	0.032
	(0.008)**	(0.001)**	(0.001)**	(0.001)**
Constant	0.462	1.355	1.289	1.200
	(0.037)**	(0.004)**	(0.003)**	(0.004)**
Observations	1159	16468	11924	5971
R-squared	0.39	0.39	0.65	0.52

heteroskedasticiy consistent standard errors in parentheses
** denotes statistically significant at 1 percent level

Table 4: Mean productivity growth (corrected for scale effects)
by two-digit sector and nationality

SIC	Nationality	PGX Mean	overall	Std. Dev. between	within	PGY Mean	overall	Std. Dev. between	within
33	all	0.092	0.015	0.018	0.004	0.099	0.023	0.022	0.008
	foreign	0.100	0.013	0.020	0.003	0.105	0.010	0.010	0.002
	domestic	0.090	0.016	0.016	0.004	0.097	0.026	0.025	0.007
34	all	0.025	0.004	0.004	0.001	0.027	0.005	0.005	0.001
	foreign	0.026	0.005	0.005	0.001	0.028	0.006	0.006	0.002
	domestic	0.024	0.004	0.004	0.001	0.027	0.004	0.004	0.001
41	all	-0.002	0.009	0.009	0.002	-0.002	0.010	0.010	0.002
	foreign	0.010	0.015	0.016	0.003	0.009	0.015	0.017	0.003
	domestic	-0.002	0.009	0.009	0.001	-0.003	0.009	0.009	0.002
42	all	-0.002	0.006	0.006	0.001	-0.002	0.006	0.007	0.002
	foreign	-0.001	0.001	0.001	0.000	-0.002	0.001	0.001	0.000
	domestic	-0.002	0.006	0.007	0.001	-0.002	0.007	0.007	0.001

Table 5: The probability of foreign acquisitions: Estimates from pooled probit equations

	Electronics (SIC 33 & 34)	Food (SIC 41 & 42)
age	-0.049	-0.030
	(2.03)*	(0.71)
Age squared	0.002	0.000
	(1.64)	(0.09)
Capital	0.406	0.534
	(2.89)**	(2.55)*
Capital squared	-0.011	-0.016
	(2.55)*	(2.55)*
Productivity growth	2.718	22.773
	(1.66)	(3.80)**
Returns to scale	-1.848	3.955
	(2.48)*	(5.15)**
Time trend	0.032	0.042
	(3.02)**	(3.03)**
Assisted area status	0.009	0.003
	(0.14)	(0.03)
Constant	-67.782	-94.519
	(3.24)**	(3.35)**
Observations	9668	11514

Absolute value of z-statistics in parentheses
* significant at 5%; ** significant at 1%

Table 6: The effect of foreign acquisition on plant's return to scale (static estimation)

	(1)	(2)	(3)	(4)
	Electronics I	Electronics II	Food I	Food II
Acquisition year	-0.017	-0.017	-0.025	-0.028
	(7.63)**	(6.08)**	(7.06)**	(8.08)**
Post Acquisition period	-0.007	-0.007	-0.021	-0.023
	(4.25)**	(4.03)**	(8.12)**	(10.15)**
age	-0.000	0.003	-0.001	0.004
	(1.47)	(6.02)**	(3.49)**	(4.18)**
capital	0.010	-0.051	-0.001	-0.061
	(34.32)**	(11.74)**	(1.94)	(11.01)**
Age square		-0.000		-0.000
		(5.48)**		(4.54)**
Capital square		0.002		0.002
		(14.12)**		(10.65)**
Constant	0.905	1.380	1.097	1.576
	(170.90)**	(37.77)**	(106.69)**	(35.30)**
Observations	3341	3341	1602	1602
R-squared	0.43	0.50	0.75	0.78

Notes:
(i) Robust t-statistics in parentheses
(ii) significant at 5%; ** significant at 1%
(iii) All regressions contain time and four-digit industry dummies.

Table 7: The effect of foreign acquisition on plant's return to scale (dynamic estimation)

	Electronics I	Electronics II	Food I	Food II
Lagged returns to scale	0.825	0.817	0.772	0.747
	(33.95)**	(29.16)**	(22.45)**	(20.15)**
Acquisition year	-0.019	-0.019	-0.032	-0.032
	(4.99)**	(4.98)**	(7.47)**	(7.71)**
Post Acquisition Period	-0.001	-0.001	-0.003	-0.004
	(1.21)	(1.23)	(1.93)	(2.74)**
Age	-0.000	-0.000	-0.000	0.002
	(1.19)	(1.26)	(1.77)	(1.68)
Capital	0.001	-0.003	-0.000	-0.015
	(4.21)**	(1.27)	(0.03)	(3.81)**
Age square		0.000		-0.000
		(1.12)		(2.22)*
Capital square		0.000		0.000
		(1.62)		(3.84)**
Constant	0.183	0.227	0.244	0.392
	(7.66)**	(4.98)**	(6.41)**	(6.04)**
Observations	2880	2880	1360	1360
R-squared	0.84	0.84	0.93	0.93

Notes:
(i) Robust t-statistics in parentheses
(ii) significant at 5%; ** significant at 1%
(iii) All regressions contain time and four-digit industry dummies.

Table 8: Post-acquisition trajectories of some variables of interest

	Electronics				
	Skill share	Unskilled share	Material share	Capital growth	Output growth
Acquisition year	-0.008	-0.025	0.033	0.042	0.047
	(1.08)	(3.51)**	(3.46)**	(1.47)	(1.44)
Post acquisition period	-0.012	-0.032	0.045	-0.023	0.004
	(2.84)**	(7.17)**	(7.45)**	(1.83)	(0.27)
Observations	3341	3341	3341	2880	2880
R-squared	0.01	0.03	0.03	0.02	0.04
	FOOD				
Acquisition year	-0.001	-0.009	0.011	-0.005	-0.000
	(0.23)	(1.04)	(0.98)	(0.17)	(0.01)
Post acquisition period	0.005	-0.023	0.018	0.009	0.038
	(1.76)	(4.27)**	(2.66)**	(0.41)	(2.08)*
Observations	1602	1602	1602	1360	1360
R-squared	0.01	0.01	0.01	0.02	0.02

Robust t-statistics in parentheses
* significant at 5%; ** significant at 1%

Table 9: The effect of foreign acquisition on productivity

	Electronics				Food			
	static		dynamic		static		dynamic	
	PGX	PGY	PGX	PGY	PGX	PGY	PGX	PGY
Lagged productivity			0.736	0.762			0.933	0.932
			(8.67)**	(11.15)**			(34.78)**	(34.14)**
Acquisition year	-0.001	-0.001	-0.001	-0.002	0.004	0.004	0.004	0.004
	(2.25)*	(2.95)**	(3.71)**	(3.60)**	(3.50)**	(3.48)**	(5.02)**	(4.88)**
Post Acquisition Period	-0.000	-0.000	0.000	-0.000	0.003	0.003	0.000	0.000
	(0.40)	(0.83)	(0.12)	(0.54)	(5.74)**	(5.57)**	(1.69)	(1.70)
Constant	0.031	0.033	0.008	0.009	0.001	0.001	0.000	0.000
	(76.99)**	(67.65)**	(3.18)**	(3.66)**	(2.18)*	(1.41)	(1.93)	(2.08)*
Observations	3341	3341	2880	2880	1602	1602	1360	1360
R-squared	0.93	0.90	0.98	0.97	0.46	0.45	0.91	0.91

Note:

(i) PGX (PGY) denotes productivity growth defined as the rate at which inputs (output) decreased (increased) with output (inputs) held fixed

(ii) Robust t-statistics in parentheses

(iii) significant at 5%; ** significant at 1%

(iv) All regressions contain time and four-digit industry dummies

Table 10: Foreign acquisitions and productivity:
Estimates based on "conventional" TFP measures

	Electronics		Food	
	Solow Residuals	Fixed effects	Solow Residuals	Fixed effects
Acquisition year	0.038	0.003	0.004	0.044
	(1.87)	(0.17)	(0.16)	(2.41)*
Post acquisition period	-0.000	0.022	0.025	0.069
	(0.03)	(1.65)	(1.96)*	(4.43)**
Skilled labour		0.200		0.053
		(21.23)**		(4.22)**
Unskilled labour		0.188		0.165
		(20.91)**		(10.50)**
Capital		0.038		0.039
		(5.73)**		(4.72)**
Materials		0.596		0.668
		(62.55)**		(45.08)**
Constant	0.016	4.251	-0.037	4.065
	(1.03)	(31.31)**	(2.68)**	(18.29)**
Observations	2880	3341	1360	1602
R-squared	0.03	0.83	0.04	0.82
Number of id		328		162

Notes:

(v) Robust t-statistics in parentheses

(vi) significant at 5%; ** significant at 1%

(vii) All regressions contain time and four-digit industry dummies at 1%

Figure 1: Kernel density estimates of RTS by two-digit sector

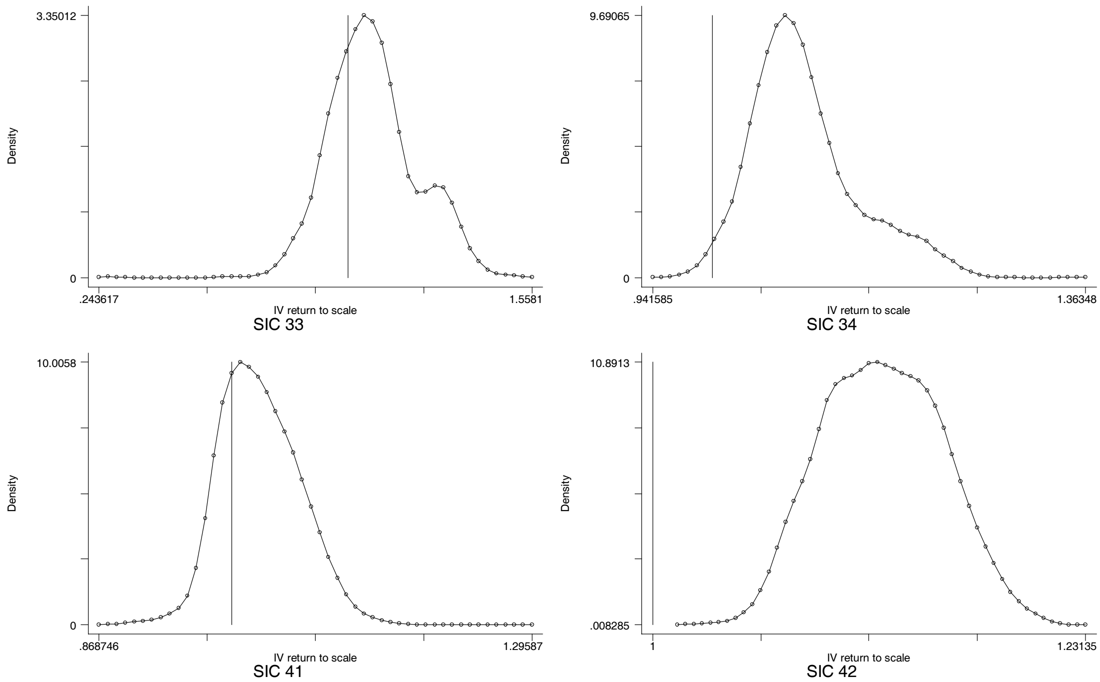
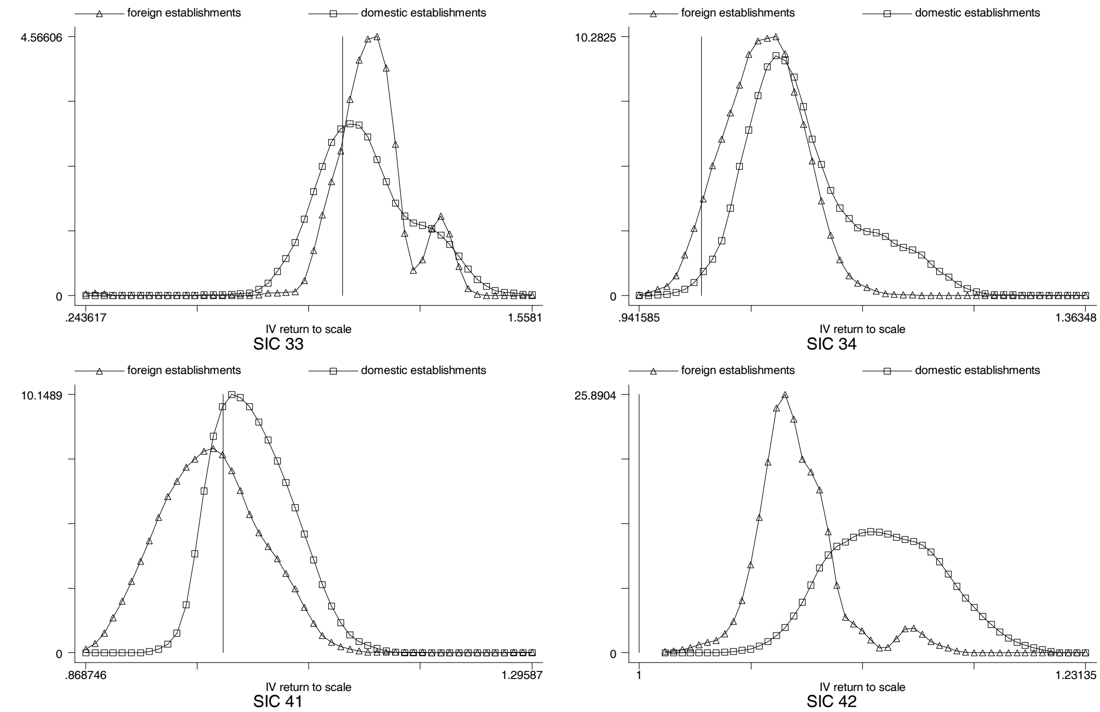


Figure 2: Kernel density estimates of RTS by two-digit sector and nationality



Appendix

Table A1: Estimates of the translog cost function (Iterative 3 SLS with instruments)

SIC	33	33	33	33	34	34	34	34	41	41	41	41	42	42	42	42
nationality	for	for	dom	dom	for	for	dom	dom	for	for	dom	dom	for	for	dom	dom
	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat
β_s	--		--		--		--		--		--		--		--	
β_{us}	0.225	0.140	--		--		--		--		--		--		--	
β_y	--		16.718	2.610	8.420	3.380	5.170	4.680	24.363	5.130	12.963	15.030	2.903	0.460	-7.475	-3.450
β_k	14.740	3.150	10.134	2.620	1.367	1.110	1.766	3.600	-6.979	-2.490	-0.993	-1.890	-1.575	-0.330	2.376	1.660
β_t	-0.033	-0.830	-0.121	-2.570	-0.046	-2.210	-0.022	-2.560	-0.134	-3.350	-0.089	-12.520	-0.006	-0.170	0.048	2.890
β_{ss}	0.132	4.860	0.081	4.030	0.051	7.560	0.035	10.470	0.028	6.180	0.029	30.730	0.037	6.580	0.021	8.630
β_{uu}	0.007	0.900	0.069	5.770	0.063	10.420	0.049	14.390	-0.064	-6.180	-0.075	-24.250	-0.028	-2.950	-0.035	-9.490
β_{yy}	-0.026	-1.730	-0.024	-2.340	-0.016	-2.390	0.022	9.620	0.032	1.910	0.020	10.480	0.002	0.120	-0.014	-2.770
β_{kk}	-0.102	-7.780	-0.048	-6.040	-0.011	-3.840	-0.013	-9.810	0.001	0.270	-0.004	-4.540	-0.012	-1.930	-0.020	-8.350
β_{tt}	0.000	0.790	0.000	2.450	0.000	2.050	0.000	2.410	0.000	3.300	0.000	12.150	0.000	0.120	0.000	-2.920
β_{su}	-0.013	-1.390	-0.060	-5.350	-0.018	-4.020	-0.043	-17.790	-0.014	-3.290	-0.019	-20.900	-0.032	-6.450	-0.020	-9.830
β_{sy}	-0.028	-5.140	-0.015	-3.770	-0.020	-13.240	0.010	12.030	-0.004	-2.630	-0.007	-21.430	-0.004	-2.260	-0.003	-5.060
β_{sk}	0.009	2.330	0.002	0.840	0.005	6.460	0.000	-0.910	0.003	3.970	0.001	7.430	0.003	2.290	0.002	5.110
β_{st}	0.000	-2.440	0.000	1.250	0.000	1.700	0.000	2.170	0.000	-1.440	0.000	4.810	0.000	0.750	0.000	3.070
β_{uy}	-0.014	-6.840	-0.026	-7.530	-0.021	-12.740	-0.027	-31.140	-0.014	-3.800	-0.020	-19.550	-0.008	-2.460	-0.005	-4.640
β_{uk}	0.001	0.460	0.002	1.010	0.000	0.400	0.000	-0.820	0.002	0.930	0.003	6.040	0.011	5.540	0.005	7.490
β_{ut}	0.000	0.080	0.000	4.200	0.000	1.960	0.000	20.280	0.000	10.150	0.001	49.310	0.000	8.260	0.000	17.940
β_{yk}	0.056	5.960	0.012	2.140	0.005	1.950	0.003	3.340	-0.002	-0.260	0.000	-0.300	0.001	0.140	0.022	10.640
β_{yt}	0.000	2.620	-0.008	-2.420	-0.004	-2.780	-0.002	-4.110	-0.012	-4.890	-0.006	-14.020	-0.001	-0.310	0.004	3.830
β_{kt}	-0.007	-3.010	-0.005	-2.490	-0.001	-1.070	-0.001	-3.270	0.003	2.440	0.001	1.960	0.001	0.350	-0.001	-1.710
β_0	--		--		--		--		--		--		--		--	

Note: -- dropped due to collinearity

Table A2: Estimates of the translog cost function (Iterative 3 SLS without instruments)

SIC	33	33	33	33	34	34	34	34	41	41	41	41	42	42	42	42
nationality	for	for	dom	dom	for	for	dom	dom	for	for	dom	dom	for	for	dom	dom
	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat	Coef.	z-stat
β_s	1.421	0.420	-1.122	-0.570	-1.208	-1.880	-1.910	-5.760	1.562	3.050	-1.500	-12.140	-1.767	-3.120	-3.067	-12.050
β_{us}	-1.634	-0.950	-3.952	-2.180	2.361	3.480	2.110	5.540	1.240	0.920	-8.993	-24.050	2.873	3.070	0.109	0.250
β_y	8.031	1.380	10.543	2.900	9.393	5.950	5.007	7.580	22.996	7.950	12.617	22.650	6.145	1.440	-1.572	-1.330
β_k	-3.584	-0.860	3.566	1.740	1.411	1.780	0.853	2.990	-6.570	-3.400	-1.616	-5.100	-3.643	-1.140	-1.853	-2.430
β_t	0.059	1.410	0.008	0.280	-0.051	-3.800	-0.008	-1.460	-0.125	-5.040	-0.020	-4.340	-0.008	-0.330	0.061	6.780
β_{ss}	0.131	5.560	0.090	6.630	0.053	9.320	0.047	20.070	0.027	7.510	0.031	48.140	0.040	7.870	0.028	16.420
β_{uu}	0.034	3.840	0.085	8.990	0.059	11.870	0.056	21.550	-0.040	-4.650	-0.035	-15.920	-0.020	-2.630	-0.024	-8.290
β_{yy}	-0.002	-0.150	0.049	8.280	-0.003	-0.760	0.028	17.740	0.072	10.160	0.023	17.220	0.012	0.980	0.006	1.860
β_{kk}	-0.038	-7.000	-0.026	-9.560	-0.019	-11.850	-0.012	-21.180	-0.005	-2.100	-0.005	-9.620	-0.005	-1.090	-0.008	-6.400
β_{tt}	0.000	-1.460	0.000	-0.280	0.000	3.640	0.000	1.420	0.000	5.120	0.000	3.940	0.000	0.310	0.000	-6.800
β_{su}	-0.026	-2.630	-0.056	-6.880	-0.014	-3.710	-0.033	-18.620	-0.014	-4.240	-0.016	-24.530	-0.029	-6.990	-0.014	-9.190
β_{sy}	-0.030	-6.590	-0.014	-5.280	-0.018	-15.750	0.005	9.030	-0.003	-2.770	-0.007	-33.530	-0.005	-3.160	-0.004	-9.530
β_{sk}	0.013	4.660	0.002	1.330	0.003	6.270	0.000	-1.340	0.003	5.780	0.001	6.830	0.002	1.790	0.001	5.780
β_{st}	-0.001	-0.570	0.001	0.610	0.001	1.980	0.001	5.670	-0.001	-3.200	0.001	12.350	0.001	3.150	0.002	12.100
β_{uy}	-0.016	-7.410	-0.024	-9.800	-0.020	-16.160	-0.026	-42.140	-0.017	-6.170	-0.022	-32.730	-0.010	-4.110	-0.009	-11.260
β_{uk}	0.001	1.060	0.002	1.810	0.001	0.920	0.001	2.840	0.003	2.250	0.002	6.550	0.011	7.180	0.002	5.930
β_{ut}	0.001	1.140	0.002	2.350	-0.001	-3.390	-0.001	-4.570	0.000	-0.340	0.005	26.620	-0.001	-2.520	0.000	0.970
β_{yk}	0.011	1.590	0.001	0.480	0.009	5.160	0.005	8.370	0.004	1.030	0.000	-0.370	0.000	0.040	0.010	7.660
β_{yt}	-0.003	-1.180	-0.005	-2.810	-0.004	-5.190	-0.002	-6.720	-0.012	-7.950	-0.006	-21.160	-0.003	-1.230	0.001	1.980
β_{kt}	0.002	0.940	-0.002	-1.560	-0.001	-1.590	0.000	-2.560	0.003	3.370	0.001	5.280	0.002	1.130	0.001	2.390
β_0	--		--		--		--		--		--		--		--	

Note: -- dropped due to collinearity

Table A3: Estimates of the translog cost function (OLS without instruments)

SIC	33	33	33	33	34	34	34	34	41	41	41	41	42	42	42	42
nationality	for	for	dom	dom	for	for	dom	dom	for	for	dom	dom	for	for	dom	dom
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
β_s	46.706	1.190	-1.376	-0.060	-16.286	-1.830	2.302	0.680	36.089	2.360	17.122	8.990	55.895	3.340	-14.968	-2.590
β_{us}	-10.616	-0.330	17.791	0.910	-14.127	-1.860	7.079	2.210	24.242	1.670	30.417	14.470	35.020	2.200	16.671	2.750
β_y	6.984	0.640	10.262	2.230	10.047	5.250	0.326	0.450	19.474	5.630	1.755	2.740	1.522	0.310	-3.882	-2.600
β_k	-8.096	-1.230	3.521	1.420	1.663	1.930	0.644	2.180	-4.832	-2.090	-0.939	-3.060	-5.706	-1.760	-3.286	-3.950
β_t	-3.902	-0.710	-1.915	-0.610	-9.632	-8.880	-6.386	-13.520	-16.036	-8.110	-11.924	-31.400	-9.882	-4.680	-12.284	-13.700
β_{ss}	0.090	0.260	0.242	1.450	0.217	2.630	-0.045	-1.860	-0.030	-0.240	-0.036	-2.980	0.329	2.100	0.002	0.040
β_{uu}	-0.170	-1.070	-0.029	-0.380	0.016	0.230	-0.035	-1.320	-0.057	-0.440	-0.155	-11.240	-0.263	-1.430	0.034	0.650
β_{yy}	0.000	0.010	0.047	7.250	-0.010	-2.110	0.013	7.950	0.074	9.320	0.002	1.240	0.029	1.770	-0.004	-1.080
β_{kk}	-0.036	-6.370	-0.021	-7.520	-0.010	-6.060	-0.006	-10.680	0.006	2.160	0.001	2.830	-0.005	-1.020	0.006	4.080
β_{tt}	0.002	0.740	0.001	0.640	0.005	8.890	0.003	13.680	0.008	8.300	0.006	32.050	0.005	4.870	0.006	13.700
β_{su}	0.063	0.340	-0.108	-0.910	-0.005	-0.090	-0.002	-0.090	-0.204	-2.350	-0.010	-1.040	-0.088	-0.650	-0.050	-1.350
β_{sy}	0.008	0.130	-0.104	-3.510	0.031	2.100	0.017	3.050	0.101	3.870	0.004	1.090	-0.102	-2.270	-0.053	-4.940
β_{sk}	0.009	0.190	0.011	0.700	0.006	0.880	-0.001	-0.710	-0.022	-1.450	0.002	1.190	0.149	4.910	0.005	1.210
β_{st}	-0.024	-1.280	0.001	0.070	0.007	1.590	-0.001	-0.620	-0.018	-2.310	-0.008	-8.900	-0.029	-3.470	0.008	2.800
β_{uy}	0.026	0.550	0.022	0.870	-0.026	-1.960	0.040	8.020	-0.075	-2.960	0.034	8.720	-0.025	-0.510	0.009	0.820
β_{uk}	0.059	1.830	-0.008	-0.710	-0.005	-0.940	-0.006	-3.140	-0.004	-0.290	0.001	0.580	0.032	1.030	-0.013	-2.770
β_{ut}	0.005	0.320	-0.008	-0.880	0.007	1.960	-0.004	-2.320	-0.010	-1.420	-0.015	-14.200	-0.016	-2.020	-0.008	-2.760
β_{yk}	0.009	0.980	0.002	0.510	0.004	2.130	0.002	3.530	-0.001	-0.190	-0.004	-6.200	-0.011	-1.600	0.002	1.500
β_{yt}	-0.003	-0.610	-0.005	-2.120	-0.005	-4.830	0.000	-0.130	-0.010	-5.750	-0.001	-1.650	0.000	0.040	0.003	3.560
β_{kt}	0.004	1.240	-0.002	-1.330	-0.001	-1.860	0.000	-1.790	0.002	2.180	0.000	3.110	0.002	1.370	0.002	3.910
β_0	3828.274	0.690	1833.721	0.580	9646.366	8.870	6338.557	13.360	15576.700	7.910	11665.320	30.730	9477.723	4.490	12273.020	13.670

Note: -- dropped due to collinearity

Table A4: Specification tests

Sector	Nationality	Hausman test (p-value)	Sargan test (p-value)
33	foreign	0.97	0.99
33	domestic	0.99	1.00
34	foreign	0.90	1.00
34	domestic	0.00	0.98
41	foreign	0.96	0.99
41	domestic	0.00	0.99
42	foreign	0.12	0.99
42	domestic	0.00	0.05