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# Regional Underdevelopment: Is FDI the Solution? A Semi-parametric analysis

*By S. Girma and K. Wakelin*

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# Regional Underdevelopment: Is FDI the Solution?
# A Semiparametric Analysis

**by**

**S. Girma and K. Wakelin**

**Abstract**

In this paper we aim to examine the regional impact of foreign-owned establishments on the performance of domestic establishments in the electronics sector in the UK. We use establishment-level data taken from the UK Census of Production (the ARD) and introduce a semiparametric approach that deals with selectivity and endogeneity in the production function. The results indicate that positive spillovers exist but are mostly confined to the region in which the MNE locates. A number of characteristics influence their level, they are higher from non-US firms (in particular Japanese firms) and in more-developed regions.

**Outline**

**Non-Technical Summary**

In recent years, industrial policy has been focused at the regional level. In part because at present this is the only avenue through which subsidies can be given under EU competition regulations. The main justification for offering such incentives to foreign firms is the positive impact they can have on lagging regions. Potential benefits include indirect effects such as improvements in domestic firms' performance by proximity to foreign firms. Positive spillovers are anticipated, as multinational enterprises (MNEs) are expected to have firm-specific assets – such as superior technology – to compensate for the higher costs of entering a foreign market. Failure to fully internalise these assets can result in externalities that benefit domestic firms.

In this paper we aim to examine the regional impact of foreign-owned firms on the performance of domestic firms. The paper has a number of features. First, we concentrate on the electronics sector – a sector that has received a great deal of attention, and in which spillovers are expected to be particularly high. Second, we use establishment-level data taken from the UK Census of Production (the ARD). This data set has only recently been made available and has a number of advantages. Third, we apply newly developed econometric techniques to take account of a number of issues that arise when estimating production functions. Briefly, we allow for the time-varying endogeneity of the factors of production function, and correct for the sample-selection bias generated by plants with larger capital stocks surviving in spite of lower productivity realisations. The FDI spillover literature has so far abstracted from the selection problem generated by plant exit. To our knowledge, this is the first paper that simultaneously attempts to correct the production parameter estimates for selectivity induced by plant exit as well as time-varying endogeneity (the "not so fixed" effect), before identifying the impact of foreign direct investment on domestic plant's productivity. Fourth, we take into account the nationality of the multinational firm in particular separating out Japanese firms to which the highest expectations of spillovers are attached. Finally, we separate regions into those with Assisted Area status (i.e. those for which incentives are available) and those without. This allows us to assess if spillovers are particularly high or low in these lagging regions.

We find that positive spillovers from MNEs are limited to the region in which the MNE locates, and are higher for non-US firms, particularly those from Japan. Foreign firms located outside the region of the domestic establishment appear to have no impact on domestic productivity. Within the region both foreign firms in the same closely-defined sector, and those in the broader 2-digit sector (i.e. half of the electronics sector as a whole) have a positive impact on domestic productivity.

This positive effect is significantly smaller in the case of less-developed regions, for instance for Japanese firms, the spillovers are half the size. When we examine which establishments in a region particularly benefit from foreign firms we find that it is relatively small, relatively skill-intensive domestic establishments that experience the most positive spillovers.

Our aim is to complement this analysis by extending it to a less 'high-tech' sector in order to get a representative picture of the impact of MNEs on domestic firms.

## 1. Introduction

In recent years, industrial policy has been focused at the regional level. In part because at present this is the only avenue through which subsidies can be given under EU competition regulations. A significant proportion of Regional Selective Assistance (RSA) – the main form of regional subsidy – goes to foreign-owned firms (over 40% in the early 1990s according to Taylor and Wren, 1997), and foreign-owned firms also gain from other regional subsidies such as expenditure on land and buildings. The main justification for offering such incentives to foreign firms is the positive impact they can have on lagging regions. Potential benefits include both direct positive effects such as increased employment and investment (assuming there are unemployed resources) and indirect effects. The latter encompass both employment effects, through linkages to domestic firms, and improvements in domestic firms' performance by proximity to foreign firms. Positive spillovers are anticipated, as multinational enterprises (MNEs) are expected to have firm-specific assets – such as superior technology – to compensate for the higher costs of entering a foreign market. Failure to fully internalise these assets can result in externalities that benefit domestic firms.

In this paper we aim to examine the regional impact of foreign-owned firms on the performance of domestic firms. The paper has a number of features. First, we concentrate on the electronics sector – a sector that has received a great deal of attention, and in which spillovers are expected to be particularly high. Second, we use establishment-level data taken from the UK Census of Production (the ARD). This data set has only recently been made available and has a number of advantages. Third, we apply newly developed econometric techniques to take account of a number of issues that arise when estimating production functions. Briefly, we allow for the time-varying endogeneity of the factors of production function, and correct for the sample-selection bias generated by plants with larger capital stocks surviving in spite of lower productivity realisations. The FDI spillover literature has so far abstracted from the selection problem generated by plant exit. To our knowledge, this is the first paper that simultaneously attempts to correct the production parameter estimates for selectivity induced by plant exit as well as time-varying endogeneity (the "not so fixed" effect), before identifying the impact of foreign direct investment on domestic plant's productivity. Fourth, we take into account the nationality of the multinational firm – in particular separating out Japanese firms to which the highest expectations of spillovers are attached. Finally, we separate regions into those with Assisted

Area status (i.e. those for which incentives are available) and those without. This allows us to assess if spillovers are particularly high or low in these lagging regions.

The structure of the paper is as follows. Section Two presents theoretical considerations and an outline of the existing empirical evidence concerning spillovers. Section three gives some information on the UK electronics industry. Section 4 covers the modelling framework of the paper while Section 5 gives some data details. Section 6 presents the results of the analysis and Section 7 concludes.

## 2. The Empirical Evidence

The theoretical basis for the expectation of spillovers from foreign affiliates is the level of firm-specific assets that MNEs are assumed to have in order to overcome the higher costs they face in foreign markets (Hymer, 1976; Dunning, 1977). These higher costs arise as the foreign firm is unfamiliar with the market, demand characteristics, supplier links etc. that are known to the domestic firm. These firm-specific assets may be technological – more than 80% of royalty payments for international technology transfers were made by affiliates to their parent companies (UNCTAD, 1997), managerial or based on brand ownership. Given the importance of technology, they may also have public-good characteristics so that excluding other (in this case local) firms from obtaining the knowledge can be difficult.

This theory has led to the empirical investigation of two important questions: are foreign-owned firms more productive than domestic firms? Do domestic firms benefit or lose from the presence of foreign-owned firms in the economy? The empirical evidence for the latter is mixed (Blomström and Kokko, 1996, 1998); the evidence for a productivity differential between foreign and domestic firms in favour of MNEs is more convincing (Girma *et al*., 2001; Djankov and Hoekman, 2000).

This paper concentrates on whether spillovers have a geographical dimension i.e. whether foreign firms have a larger impact on domestic firms if they locate in the same region. Why would spillovers have a regional dimension? There are a number of possible explanations. First, direct contacts with local suppliers and distributors i.e. upward and downward linkages may be local in nature in order to minimise transport costs and facilitate communication between the supplier/distributor and the MNE. Second, the training of employees by MNEs and subsequent turnover of labour is a major avenue for regional spillovers (Haacker, 1999). As regional labour mobility in the UK is relatively low

(Greenaway *et al*., 2000), many of the benefits in terms of a more skilled workforce with tacit technical knowledge gained from MNEs will be experienced by local employers. Third, demonstration effects may also be local if firms only closely observe and imitate other firms in the same region (Blomström and Kokko, 1996). Fourth, knowledge flows may be regional in character. Jaffe *et al.* (1993) found that knowledge flows in the US have a regional component – the spread of new ideas is most intense in the area close to the innovation. These factors may lead to significant regional benefits from spillovers.

An alternative hypothesis is that if MNEs locate in less-developed regions to take advantage of subsidies (available in regions with Assisted Area status in the UK), spillovers may be reduced, as local firms in these areas do not have the technological capacity to benefit from the MNEs. There is some evidence, that a certain level of technological ability or 'absorptive capacity' is needed in order for domestic firms to benefit from MNEs (Girma *et al*., 2001; Aitken and Harrison, 1999). Spillovers may be maximised by allowing MNEs to choose locations according to location advantages rather than influencing that choice through incentives. This would indicate that spillovers are lower in regions that have been subject to such incentives.

Within the EU, government assistance to industry is limited by the European Commission under competition regulations first set up under the Treaty of Rome. These regulations apply to aid offered to both domestic and foreign firms. One of the main exceptions to these regulations is through aid to promote development in underdeveloped regions. Such regional exceptions explain 50% of aid to manufacturing granted within the European Union in 1996 (UNCTAD, 1996). Even with this form of assistance there are regional ceilings to the level of aid, which vary in the UK between 20% and 30%. For both the UK and the US there is evidence that these incentives influence the choice of location of MNEs (Head *et al*., 1999). In the UK, Taylor (1993) indicates that the Assisted Area status of a county was a significant predictor for the level of Japanese investment. Only 24% of Japanese manufacturing affiliates (up to 1992) had chosen to locate in UK regions without Assisted-Area status. A counter-factual estimation indicated that around two thirds of the location choices were influenced by a region having such status.

At the regional level, Driffield (1999) has examined the role of productivity spillovers from inward investment in the UK using aggregate sector-level data. The data set covers 10 regions, 20 manufacturing sectors for the period 1984-1992. The results indicate that there are positive productivity spillovers from FDI in the same sector and region, and more generally at the regional level, but that these effects are small. FDI in the sector as a whole (but not in the region) actually has a negative impact on productivity. This is assumed to be because of the increased competition at the sector level.

Using company (firm) level data for the U.K., Girma and Wakelin (2001) look at regional productivity spillovers. Their findings indicate that domestic firms' total factor productivity is positively affected by MNEs in the same sector and region and negatively by MNEs in different regions. Less-developed regions generally gained less from spillovers than more developed regions. However, the study has two limitations. First, a company is typically an accounting unit reporting for a number of plants, and the data source used did not allow separation into the individual plants that constitute a company. In the case of multi-plant companies, the constituent plants might be located in different regions and sectors, and as a result the measure of FDI based on accounts data may be misleading. Second, they did not address either the issue of selectivity or that of endogeneity in the production function.

In contrast to the U.K studies, Sjöholm (1998) and Aitken and Harrison (1999) using Indonesian and Venezuelan data respectively, find no significant regional element to spillovers.

The existing literature highlights a number of hypotheses that we investigate in the following analysis:

- Does the level of spillovers from multinationals to domestic firms rely on the region the MNE is located in?
- Does the level of spillovers to domestic firms vary systematically with the nationality of the parent firm?
- Does the level of development of the region influence the level of spillovers?

## 3. Overview of the Electronics Industry

The UK electronics industry is the fifth largest in the world in terms of sales and employs 400,000 people in manufacturing with an additional 100,000 in related services and software[1]. It is an industry with an extremely high level of multinational activity. In 1996, over 25% of the stocks of inward investment from the US, Japan and the rest of the EU was

[1] Unless otherwise stated, the data in this section are from National Statistics.

in electrical engineering including electronics. This proportion has increased from 19% in 1987. Among the three groups of investors Japanese investment is particularly concentrated, with over 50% of inward stocks invested in electrical engineering.

The sector is also characterised by a number of other features. First, there is a high level of innovative activity indicted by the level of expenditure on R&D and the large number of patents granted in the sector. Multinational firms undertake a significant proportion of this innovative activity. Cantwell and Iammarino (2000) indicate that in semiconductors the share of foreign-owned firms in total patents was over 60% for the UK as a whole, and 75% for the South East in particular. Second, high levels of Regional Selective Assistance have gone to firms in this sector. For the period 1991-1994 72% of regional assistance in electrical engineering went to foreign-owned firms in the UK, well above the national average of 40% (Taylor and Wren, 1997). Third, high levels of linkages with local firms have been found internationally (Görg and Ruane, 2001). Together, these characteristics suggest that the potential for spillovers from electronics firms is particularly high.

Nevertheless, a debate has opened up in the UK questioning how ‘embedded’ the electronics industry is in certain regions. This debate considers the proportion of materials that are sourced locally (rather than being imported), and the level of value-added taking place in the UK. The implications are that if local linkages are limited, the scope for spillovers is considerably less than anticipated. Turok (1993, 1997) and McCann (1997) have debated the level of local linkages in ‘silicon glen’ with the former suggesting only a small percentage of material inputs come from Scotland (12%), and that this is declining and the latter suggesting that linkages are actually much higher.

These features of the electronics industry make it a particularly interesting sector to investigate. Many characteristics – high levels of technology, a large presence of multinational firms – indicate that spillovers may be high, yet the actual level of linkages in the sector has been questioned.

We define the electrical and electronic sector as the two two-digit classes 33 and 34 (using the SIC80 revision). The definition of the sub-sectors and their share of foreign ownership are given in Table 1. Foreign presence is measured both as the share of employment. The variation in MNE activity can also be seen on a regional as well as a sectoral level. Table 2 gives the employment share across ten regions for 1980 and 1992. A few points are worth noting:

- In 1992 the regions with the highest share of MNE employment are Wales and the South East with around 30% of employment in foreign firms.
- All regions have experienced a rise in the share of foreign employment, with the share more than doubling in both the East and West Midlands (although the former still has one of the lowest shares at 16%).
- It is clear from the table that while the foreign employment share has fallen slightly in a few sectors, most sectors have experienced a rise in foreign employment. For instance, electronic data processing equipment experienced a large rise in foreign employment from 30% to almost 70% in 1992 making it the second-highest share of foreign employment. Basic electrical equipment also experienced a five-fold increase.
- In 1980 office machinery had the highest proportion of MNE employment, by 1992, this sector was overtaken by electronic consumer goods with over 80% of employment in foreign firms (rising from just over 20% in 1980). Office machinery and active components both have around 50% foreign employment.

The debate concerning spillovers has hypothesised that foreign-owned firms may exhibit higher productivity than domestic firms. This higher productivity reflects their superior technology and management skills giving rise to the possibility of spillovers from them to domestic firms[2]. By way of a preliminary analysis, we investigate whether this hypothesis is supported by the data. In Table 3 we present the results for robust OLS regressions using a variety of performance indicators as the dependent variable. We include dummy variables for different groups of establishments – separated by country of ownership as well as into three domestic groups based on the number and distribution of establishments – to see if they are significantly different from the base group. The base group is made up of single-plant domestic establishments and the coefficients on the various dummy variables give the margin with respect to these establishments. The first two groups of domestic firms are domestic multi-plant establishments with the plants in the same region, and domestic multi-plant establishments with plants in different regions. As Table 3 shows, foreign-owned firms have significantly higher labour productivity, capital intensity, input intensity and total factor productivity than domestic single-plant firms (with the exception of ‘other

[2] Other spillovers, for instance those that occur as a result of increased competition, do not rely on the existence of a productivity differential.

foreign' total factor productivity). This differential is particularly large in the case of Japanese affiliates, which have 69% higher labour productivity than domestic establishments. In part this can be explained by considerably higher capital intensity (60% higher, 90% higher investment) and greater use of intermediate inputs (over 80% higher), nevertheless total factor productivity is also 5% higher in Japanese affiliates. Other foreign affiliates – from the US and other countries – are approximately the same. The labour productivity differential with respect to domestic establishments is around 30% with a similar differential in capital intensity and intermediate input use. Total factor productivity is 2% higher in US affiliates and insignificantly different for other foreign affiliates.

Multi-plant domestic establishments also show higher labour productivity than single-plant ones, although this is reflected in only a small differential (1%) in terms of total factor productivity for those multi-plant firms that cross regions.

Overall, the most noteworthy result is that Japanese affiliates appear to have considerably higher total factor productivity, and they also appear to be different from domestic establishments in terms of production. Japanese affiliates are more capital intensive, and have much higher levels of intermediate-input intensity. While a differential is also observed for other foreign-owned affiliates – such as US affiliates – the differential is of much smaller magnitude. This suggests that the potential for technological (or managerial) spillovers is higher from Japanese affiliates than affiliates of other nationalities.

## 4. The Modelling Framework

### *4.1 The Semiparametric Approach*

The estimation of production functions is beset by two well-recognised problems: selection and simultaneity. The selection problem results from the relationship between productivity and the probability of exit. Smaller establishments (which are less capital intensive) are more likely to shut down following a negative productivity shock. In a production function regression framework, this will induce a negative correlation between the stock of capital and productivity among the surviving establishments (Griliches & Mairesse, 1995). Thus unless one deals explicitly with the selection problem generated by liquidating establishments, the estimated capital coefficient will be biased downward, making the measure of establishment productivity unreliable. For example, with downward biased capital and labour coefficients, the mean productivity level will be overestimated and any study relating productivity changes to, say foreign direct investment, will be flawed.

The second problem, that of simultaneity in the production function, arises because a plant's knowledge of its productivity affects its choice of inputs. The problem is expected to be more severe for inputs that are faster to adjust to any productivity shock. As Levinsohn & Petrin (2000) argue, simultaneity may also occur when input decisions are characterised by serially correlated errors and it is costly to make large immediate adjustment to inputs. Since productivity shocks are not observed, simultaneity has the effect of making OLS estimates biased upwards. It is difficult however, to sign the biases when there are many inputs and both selection and simultaneity occur.

Olley and Pakes (1996, OP henceforth) offer a novel and interesting way of correcting for simultaneity and selection bias in production functions. OP suggest conditioning the estimation on establishments probability of survival to deal with the selection issue. The technique of conditioning on survival probability (i.e. staying in the market) is akin to the method of controlling for selection in single index models (Resenbaum and Rubin, 1983). Assuming that future productivity is an increasing function of current productivity, OP sort out the simultaneity problem by using investment as a proxy (instrument) for productivity shocks. The reason why investment is correlated with unobserved (to the econometrician) productivity is simple. An establishment with a larger productivity shock this year will invest more than an otherwise similar establishment with a smaller realised productivity shock, because it expects to do better in the future. Following the line of OP's argument, each establishment begins period *t* with the quasi-fixed input capital, $K_t$. It then observes its current productivity, say, $w_t$, after which it decides whether to stay or exit ($c_t$). Conditional on staying and given output price $p_t$, it then chooses the levels of investment $I_t$ and variables inputs skilled and unskilled labour and intermediate materials ($L_t^s, L_t^u, M_t$). Using lower cases for log values and indexing establishments by *i*, we write the production function as $y_{it} \equiv f(l_{it}^s, l_{it}^u, m_{it}, k_{it}, w_{it}, e_{it})$[3], where y is output, the time-varying productivity shock $\omega_t$ is correlated with inputs and $\varepsilon$ is a random error term. For

[3] OP include the age of the establishment as an additional determinant of the level of production, but report insignificant coefficients under all specifications.

estimation purposes we employ a first-order Taylor approximation and we write the production function as:

$$y_{it} = b_0 + b_s l_{it}^s + b_u l_{it}^u + b_m m_{it} + b_k k_{it} + w_{it} + e_{it} \qquad (1)$$

Olley & Pakes (1996) show that under certain conditions the investment function of a profit-maximising establishment, $i_{it} \equiv i_t(k_{it}, w_{it})$, is strictly increasing in the productivity shock $w_{it}$. Note that the investment function is indexed by time to allow for changing input and output prices over time. It is not indexed by establishment, however, because of the assumption that establishments face identical prices (i.e. perfect competition). Given that the investment function is strictly monotonic, it can be inverted and one can write $w_{it} = w_t(i_{it}, k_{it})$ for some function $w_t$. Equation (1) can then be expressed as

$$y_{it} = b_s l_{it}^s + b_u l_{it}^u + b_m m_{it} + l_t(i_{it}, k_{it}) + e_{it} \qquad (2)$$

with

$$l_t(i_{it}, k_{it}) = b_0 + b_k k_t + q_t(i_{it}.k_{it}). \qquad (3)$$

As $l_t$ is an unknown function, equation (3) is a “partially linear” model: it is linear in the variable inputs, $x_{it} \equiv (l_{it}^s, l_{it}^u, m_{it})'$, only. In the first stage, the parameter vector $b_v = (b_s, b_u, b_m)'$ can be consistently estimated via semiparametric regression (Robinson, 1988) by approximating $l_t$ by a fourth order polynomial series expansion in capital and investment. The reason why the estimator of $b_v$ is consistent is because $l_t$ controls for the unobserved productivity shock (hence the problem of simultaneity), and the remaining error term $\varepsilon$ is uncorrelated with input decisions by assumption. Note that the first stage estimation also yields an estimate of the polynomial, $l_t$. The estimate of $b_v$ is then used to purge the contribution of variable inputs in equation (1) from the variation in output, and we have:

$$y_{it}^* = y_{it} - x_{it}' b_v = b_0 + b_{k\,it} + w_{it} + e_{it} \qquad (4)$$

In order to identify the elasticity of capital $b_k$, it is assumed that productivity follows a first order Markov process[4], in which case $w_t$ can be decomposed as $w_{it} = E[w_{it} \mid w_{it-1}] + u_{it}$, where $u$ is mean zero innovation term. This allows us to write (4) as:

$$y_{it}^{*} = b_k k_{it} + g(w_{it-1}) + e_{it}^{*} \qquad (5)$$

where: $g(w_{it-1}) = b_0 E + [w_{it} \mid w_{it-1}]$ and $e_{it}^{*} = e_{it} + u_{it}$.

Now using the first-stage estimate $\hat{l}_t$ and the identity expressed in equation (3), $g(w_{it-1})$ can be rewritten as $g(\hat{l}_{it-1} - b_k k_{t-1})$.[5] The basic assumption that helps identify $b_k$ is the one which states that capital is slow to adjust to the innovations, so that conditional on $w_{it-1}$, $k_{it}$ is independent of $e_{it}^{*}$. To control for selection, the function g(.) can be augmented by the probability of survival function , $p_{it-1}$. In OP this probability depends on the productivity shock $w_{it-1}$ and a threshold productivity level $w_{it}^{*}$. If the establishment's actual productivity is below $w_{it}^{*}$, its future profitability is less than its liquidation value, and this triggers its exit from the market. In this paper we generate the survival probabilities via a probit model using a polynomial series expansion in capital and investment to proxy for productivity. The final estimating equation is then:

$$y_{it}^{*} = b_k k_{it} + g(\hat{l}_{it-1} - b_k k_{it-1}; p_{it-1}) + e_{it}^{*} \qquad (6)$$

Following Pavenick (2000), we approximate g(.) by the following third order polynomial[6] in $\hat{l}_{it-1} - b_k k_{it-1}$ and $p_{it-1}$ :

$$g(.) = \sum_{j=0}^{3-l} \sum_{l=0}^{3} g_{lj} \left(\hat{l}_{it-1} - b_k k_{tt-1}\right)^{l} p_{it-1}{}^{j} \qquad (7)$$

and estimate $b_k$ in equation (6) by employing a non-linear technique. Since the limiting properties of the series expansion estimators with functions like g(.) are not yet worked out

[4] The method easily handles extensions to higher order Markov processes.
[5] The intercept term $\beta_0$ is subsumed into the unknown function g(.)
[6] Olley and Pakes (1996) use a kernel approximation for g(.) , which is equivalent to polynomial approximations but much more difficult and slow to implement.

in the econometric literature[7], we compute a bootstrapped standard error of the estimate of $b_k$. Our approach is based on block bootstrapping, where all establishment-specific observations are considered as one i.i.d observation. The estimated capital elasticity and the variable input coefficients are finally used to generate the endogeneity and selectivity-corrected plant level productivity as $\exp\left(y_{it} - \hat{b}_k k_{it} - \hat{b}_v x_{it}\right)$.

The OP-inspired semiparametric strategy of production function estimation has, however, some practical complications and theoretical limitations. First, because of the assumption of the strictly increasing production function in investment, data on establishments with zero investment cannot be used. This may or may not be a serious impediment depending on the nature of the actual data set. In the sample used in this paper, about 6% of observations have zero investment and are therefore discarded. Once the input coefficients are identified however, productivity can be estimated for these establishments too. Second, and perhaps more crucially, the Olley and Pakes capital accumulation rule with δ% depreciation rate is $k_{it} = (1-d)k_{it-1} + i_{it-1}$ (referred to as Version A hereafter), whereas the more usual perpetual inventory formula is $k_{it} = (1-d)k_{it-1} + i_{it}$ (version B). In the OP framework current investment does not affect current output (i.e. investment becomes productive with some lag), hence it's validity as a proxy for unobserved productivity shocks. To the extent that $i_{it}$ responds to current productivity without a lag, the use of Version A is likely to impart some bias in the estimators. On the other hand, if one is constrained to use the Version B capital accumulation rule, future investment $i_{t+1}$ can be used as a proxy for the transmitted productivity shock, provided that one is willing to make a small change to the original OP assumption on the timing of investment (see Levinshon and Petrin, 1999, p.17). In this paper we use both methods of capital accumulation, although our preference is for the theoretically more consistent Version A.  Some of the theoretical shortcomings of the OP approach are discussed in Griliches and Mairesse (1995) and Levishon and Petrin (2000). The main worry seems to be that due to the adjustment cost of inputs, investment might not respond fully to productivity shocks. This implies that the basic monotonicity condition of the investment function might be violated. The fact that productivity shock is proxied by investment only is also a cause for concern, although the effect of macro variables is implicitly accounted for by allowing the investment function to vary over time.

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[7] See Andrew(1991) for a discussion of the asymptotic properties of polynomial series estimator.

In spite of these reservations, the OP approach offers some major advantages over the more traditional parametric estimators[8]. First, it allows for plant-specific time-varying heterogeneity. In sharp contrast, “within” and GMM panel-data estimators rely on the *fixed effect* formulation to control for the simultaneity between productivity shocks and inputs. In these methods, the correlation between productivity and inputs is assumed to be constant over time. This is a very restrictive assumption, as it does not allow for any dynamics in the relationship between productivity and inputs. A second notable advantage of the OP method is that it makes use of all the identifying variation in the data. In traditional panel models, the “within” approach dispenses with all between-plant variation, while GMM estimators are typically based on first–differences. As Griliches and Mairesse (1995) numerically demonstrate, this is bound to exacerbate other flaws in the data, most notably measurement error problems.

### *4.2 Modelling Spillovers from the Regional FDI*

Now we turn to the issue of identifying the influence of regional FDI on the productivity dynamics of domestic establishments. To do so we first obtain the selectivity and endogeneity corrected measure of total factor productivity using the method outlined in the previous section. We then employ the following heteroscedasticity-robust regression framework:

$$w_{it} = a_1 w_{it-1} + \sum_{j=1}^{3} a_{2j} FDIJ_{rst-1} + a_3 D_{it} + u_{it} \qquad (8)$$

where $w$ is the log of productivity of establishment $i$ at time $t$, D represents a vector of dummy variables consisting of year dummies to account for macro productivity shocks, four-digit industry affiliation, and the region the establishment is located in. If the regressions were run without industry and regional dummies, the estimated coefficient on the FDI variables could simply reflect the fact that foreign firms invest in industries that enjoy higher productivity or in regions that give the largest subsidy. *FDIJ* in equation (8) denotes the type of foreign direct investment indicator. *FDI*1 is the share of employment of foreign firms located in the establishments region and four-digit industry. It is designed to capture the local intra-industry spillover from FDI. As all FDI variables in this study, it is interacted with an Assisted Area status dummy to see if the presence of government

[8] We have also carried out a parametric analysis for comparison. A discussion of the method and the results are given in Appendix B.

incentives to locate in the region influences the magnitude of the potential spillover.

In order to test for the importance of the country of origin of FDI in the electronics industry, *FDI1* is divided into that originating from the US, Japan and others[9]. *FDI2* is a distance-weighted measure of foreign presence outside the region but within the same sector. Following the literature on neighbourhood agglomeration (Adsera, 2000), *FDI2* for an establishment in region *r* and industry *s* is defined as $FDI2_{rs} = \sum_{k \neq r} \frac{FDI1_{ks}}{d_{kr}^2}$, where $d_{kr}$ is the distance (in miles) between the largest cities in regions *k* and *r*. If the productivity impact of FDI is only local, we would not expect *FDI2* to be important. Finally, *FDI3* measures FDI in the wider 2-digit sector (excluding the establishment's four-digit industry) in the region, and is meant to identify the variation in productivity due to regional intra-industry spillovers.

The FDI variables in this study are all lagged by one period to allow for some time in the realisation of potential spillover. Finally, the inclusion of a lagged productivity term allows for persistence in the productivity trajectory. It is also in line with the assumption of the theoretical model that productivity follows a first-order Markov process.

## 5. Data Details

This paper draws on the Annul Business Inquiry Respondents Database (ARD) provided by the Office for National Statistics in the U.K. The ARD consists of individual establishments' records that underlies the Annual Census of Production. As Oulton (1997) and Griffith (1999) 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 establishments with more 100 employees are always sampled. In the electronics industry, selected establishments account for less than one eight of the total number of establishments, but for more than 80% of output and employment.

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 (1980-92), 95% of the establishment that are present in the electronics industry are single-plant firms[10]. In the actual sample we used for the econometric estimation this figure is around 80%. Thus most of the data we used is actually plant level data.

Like the majority of researchers who worked with the ARD (e.g. Disney *et al.* 2000; Griffith, 1999), we use data on multi-plant establishments at they are. Harris (2000) uses a different approach imputed plant-level data for multi-plant establishments. He argues that establishment data is not suitable for economic analysis; the most compelling reason he offers being that the composition of establishments might not be stable over time as it depends on the way the company choose to collect financial information. Since (imputed) employment data is available for plants in the ‘non-selected file’, he suggests that information collected from the parent establishment be allocated *pro rata* to each local unit.

Although we have not followed this approach, there are two important ways in which we have made use of the local unit information in the non-selected file. The first is in the construction of measures of regional FDI. Foreign presence in a region and sector is defined in this paper as the proportion of employment accounted for by foreign multinationals. Simply relying on establishment data could be misleading, as they could report for plants across different regions or sectors. However, by extracting the employment, ownership and industrial affiliation data of the ‘children’ in the ‘non-selected’ file, it was possible to correctly calculate the regional FDI variables. The second way information in the non-selected file was used is in the identification of single location (region) and multiple location establishments. We excluded some 189 domestic establishments that had plants in more than one region for the full period, as we do not believe that the concept of regional spillovers can be meaningfully applied to such establishments[11]. We also excluded from our

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[9] This group is mostly made up of affiliates with European parent companies.
[10] As a result we tend to use the terms plant and establishment interchangeably for what are termed establishments in the ARD.
[11] Initially we performed separate regression analyses for these firms. The coefficients on the regional variables were difficult to interpret.

regression analyses domestic establishments with zero output[12], negative capital stock and with no regional information. Also ruled out are establishments with observations at the top and bottom one percentile in terms of the capital/labour ratio, out of concern for the size of the measurement errors. Table 4 gives the panel structure of the resulting sample of establishments used in this study. There are almost twice as many establishments in non-assisted regions as those located in assisted ones. The majority of establishments are observed for less than five years and a sizeable proportion of establishments are only observed once or twice. The parametric IV selection model, because of the need to use twice-lagged variables as instruments, cannot use these establishments. The averages of the main variables for the production analysis are presented in Table 5. The raw data show that establishments in non-assisted regions have a higher average percentage of skilled workers, intermediate material input usage, and investment and capital intensities. In the next section we report the results from the econometric investigations.

## 6. Estimation Results

### *6.1 Alternative Estimates of the Production Function Coefficients*

Whatever the object of the productivity analysis, it is very important to obtain consistent estimates of the parameters of the production function. Table 6 presents alternative estimates of the input coefficients from the production function specified in equation 1. We employed the fixed effects (within), first-difference (growth) and semiparametric strategies, using both types of capital accumulation rules. The first two approaches basically employ OLS on suitably transformed data. Econometric theory predicts that the negative correlation between capital stock and lower productivity in the sample of surviving plants induces a negative bias on the OLS estimators of the capital coefficients, $b_k$. In line with this expectation, the two OLS-based approaches underestimate $b_k$ by three to four-fold. Of all variables used in the production function, capital stock is arguably the most susceptible to the problem of measurement errors. The significant downward bias in the within and first-difference estimators of $b_k$ is also consistent with the theoretical expectation that demeaning or differencing magnifies measurement errors, thereby exerting further downward bias.

It is obvious that establishments hire (fire) workers in good (bad) times. As discussed

[12] The definition of the variables used in this study is given in the data appendix.

earlier in this paper, this simultaneity between productivity and the level of inputs generates an upward bias in the estimated coefficients. The bias is more severe for variable factors of production such as unskilled labour that are more easier to adjust to realised productivity. The coefficients reported in Table 6 appear to confirm this. Fixed and first-difference estimates of $b_u$ are typically overestimated by more than 100%, assuming the semiparametric estimator is consistent. By contrast, the skilled labour and intermediate-input coefficients are moderately underestimated. Due to the higher cost of hiring and firing skilled worker, the correlation between $L^s$ and ω is probably not strong enough in the data to counteract the negative bias resulting from selectivity/measurement error. Overall, we find it reassuring that the semiparametric estimator differs in some theoretically predictable ways from the estimators that ignore simultaneity and selectivity.

*6.2 Identifying Productivity Spillovers from Regional FDI*

Has the presence of multinational affiliates made domestic establishments more productive? A reading of Table 7 suggests that the answer to this question may depend on the type and source of FDI. Japanese FDI has a positive effect on the productivity of domestic establishments in the same region and four-digit sector. A 10% increase in Japanese production will, in the short run, improve productivity by about 2.5%[13]. Since productivity is found to be highly persistent, the long run impact is bound to be much larger. There is weak evidence that the magnitude of the spillover from Japanese FDI is lower for plants located in government assisted areas (AA), as the AA interaction term attracts a negative coefficient which is significant at the 10% level. It appears that AA regions have to attract twice as much Japanese FDI as non-AA regions to experience the same productivity spillover. This may be due to the higher absorptive capacity of plants in non-AA regions, as shown by their higher investment intensity and the proportion of skilled workers in the total workforce (see Table 5).

FDI in the same sector and region coming from ‘other countries’, mainly European, also benefits plants in non-AA regions in the form of higher productivity. However, the size of the spillover parameter is less than half of that resulting from Japanese FDI. In sharp contrast, US firms did not exert any influence on the productivity dynamics of indigenous plants. MNEs from the US are generally of older vintage, and it seems that domestic plants

[13] As is evident from Table 7, the pattern and extent of spillover is insensitive to the type of capital accumulation rule. Our discussion will be confined to results employing Variant A.

in the sample period have nothing new to learn from them.

We also fail to find any evidence of an impact on productivity from FDI in the same four-digit sector but outside the region. This supports the notion that spillovers from FDI in the U.K have a strong regional dimension. However, this new plant-level result qualifies the conclusion of Driffield (1999) and Girma and Wakelin (2001) that FDI outside the region has detrimental effects on productivity.

On the other hand, the productivity effects of upward and downward linkages resulting from the presence of MNEs in the region appear to be quite significant. The semiparametric estimator suggests that an increase in *FDI3* (FDI in the 2-digit sector in the region) of 10%, generates a 2.7% improvement in the productivity of the average UK-owned plant, irrespective of the AA status of the region it is located in. This positive externality from *FDI3* further reinforces the message that spillovers are confined to the region the foreign investment takes place, but not necessarily the sector.

But are the average figures reported in Table 7 truly representative of the sector? Answering this question might be relevant for policy purposes, as it helps to identify the characteristic of domestic firms that are most likely to benefit/lose from FDI. To shed some light on this issue, we classified the sample of domestic plants by size and skill level. Size and skill are measured relative to the minimum efficiency scale and average proportion of non-operative workers in the establishment's industry, respectively. The rationale for dividing plants by skill and size is to discover whether plants with a better skilled workforce benefit more from the presence of MNE and what role, if any, the size of the plant plays in this. We note that re-estimating equation (8) based on these relatively homogenous sub-samples will also help mitigate the problem of heterogeneity inherent in large cross sectional data sets.

The semiparametric estimates based on Version A of capital accumulation are given in Table 8. A notable result is that the productivity dynamics of large and highly skilled establishments are not affected by FDI. These establishments are probably the nearest to foreign multinationals in terms of technology and market share, and may already operate at the technological frontier. We also observe that the benefits accrued by larger but lower-skill plants are confined to inter-industry spillovers. Overall, smaller plants seems have the most scope for gaining from FDI, especially those with a relatively high proportion of skilled employees. In none of the sub-samples were we able to discover any externality generated by FDI occurring outside the region of the establishment.

### *6.3 The Policy Significance of the Econometric Results*

In assessing the results in terms of welfare two different perspectives can be taken. One – probably taken by national policy makers – is to maximise welfare in the country as a whole, while the other – perhaps found more frequently in regional policy makers – is to maximise the return to the region, without regard to the impact on other regions. As usual, the basis for government intervention is that the social returns to foreign investment exceeds the private returns i.e. that positive externalities exist from FDI. First, the results indicate that this is the case: positive spillovers do occur from foreign to domestic establishments. Second, the results have different policy implications depending on whether the unit of analysis is the country or the region. From the perspective of national welfare, the results confirm that spillovers from foreign affiliates are lower in less developed regions. One implication of this result is that regional policy aimed at attracting FDI to such regions under EU policy guidelines may be misguided from a national perspective. If, in the absence of incentives, multinational firms were still to choose a location in the UK, but not in a less-developed region, then positive spillovers to domestic plants could be doubled, raising the social return to the country. However, a risk in unilaterally reducing or abolishing incentives is that MNEs would no longer chose to locate in the UK at all, thus forgoing any positive spillovers to domestic firms. Nevertheless, by influencing the regional distribution of FDI within the country through government incentives, government policy does run the risk of reducing the possible benefits for domestic firms.

However, the perspective of the regional policy maker may be different. While positive spillovers appear to be lower in less-developed regions they nevertheless exist. If the regional policy maker is only concerned with the welfare of individuals in that region they may wish to attract MNEs in order to benefit from the positive regional spillovers to domestic establishments. That other regions could benefit even more (in the Japanese case double) is unlikely to be a consideration at the regional level.

While this paper has not considered a cost-benefit analysis of the return to incentives (no data are available on the latter) the results do indicate that positive spillovers occur from foreign firms. The results also highlight a policy dilemma: that policy makers aiming at maximising regional welfare may reduce the possible benefits to the economy as a whole by changing the location of MNE affiliates to less-developed regions. There appears to be a trade off between maximising spillovers on the one hand – which would imply no regional 'distortions' in location – and the objectives of regional development policies.

## 7. Conclusions

The results presented have a number of original characteristics. First, they use semiparametric techniques in estimating production functions taking account of both time-variant endogeneity and selectivity. Second, they make use of a recently available establishment-level data set allowing a more precise measurement of FDI at the regional level. Third, we have concentrated on a high-technology sector, dominated by multinational firms, from which significant spillovers to domestic firms are expected. We find that positive spillovers from MNEs are limited to the region in which the MNE locates, and are higher for non-US firms, particularly those from Japan.

Single-sector studies overcome many of the limitations of more aggregate studies by reducing the problems of FDI locating in more productive sectors and the heterogeneity associated with large cross-section data. But how much can the findings of this paper be generalised to other sectors? Because of the particular features of the electronics sector, we expect our results to represent an upper bound for the level of spillovers to domestic firms. Other high-technology sectors may mirror the case of electronics, where positive technological spillovers appear to outweigh any negative competition effects from FDI. Our aim is to complement this analysis by extending it to a less 'high-tech' sector in order to get a representative picture of the impact of MNEs on domestic firms.

**Table 1:**

**Employment share of MNE activity in the Electronics Industry**

| Standard Industrial Classification | 1980 | 1992 |
|---|---|---|
| Office Machinery and Electronic data processing equipment (330) | 0.345 | .684 |
| Insulate wires and cables (341) | 0.205 | .198 |
| Basic electrical equipment (342) | .073 | .345 |
| Electrical equipment for industrial use , and batteries and accumulators (343) | .124 | .175 |
| Telecommunication equipment, electrical measuring equipment, electronics capital goods, passive electronic components (344) | .231 | .266 |
| Other electrical and electronic engineering (345, 346,347) | .311 | .442 |

Note: The econometric analysis is conducted at four-digit industry level , encompassing 17 sub-sectors. The summary statistics reported in this table are at a much aggregate level lest we violate the disclosure criteria set by the ONS.

**Table 2:**
**Pattern of Regional FDI (Employment Share)**

| Region | 1980 | 1992 |
|---|---|---|
| East Anglia | 0.215 | 0.262 |
| East Midlands | 0.076 | 0.156 |
| North West* | 0.146 | 0.228 |
| Northern England* | 0.125 | 0.236 |
| Scotland* | 0.163 | 0.277 |
| South East | 0.204 | 0.298 |
| South West | 0.103 | 0.170 |
| Wales* | 0.192 | 0.297 |
| West Midlands* | 0.090 | 0.213 |
| Yorks. & Humber. | 0.089 | 0.155 |

Note: Regions denoted by * contain Assisted Areas

**Table 3:**
**Differentials Between Foreign and Domestic Establishments**

| | Output per employee | Capital per employee | Investment per employee | Inputs per employee | Total factor productivity |
|---|---|---|---|---|---|
| Domestic | 0.030 | -0.001 | 0.069 | 0.000 | 0.008 |
| Multi-plant | (2.69)** | (0.09) | (2.32)* | (0.01) | (1.43) |
| Domestic | 0.036 | -0.017 | -0.045 | -0.044 | 0.014 |
| Multi-region | (2.91)** | (1.30) | (1.43) | (2.57)* | (2.16)* |
| USA | 0.330 | 0.288 | 0.316 | 0.366 | 0.019 |
| | (21.81)** | (18.97)** | (9.24)** | (19.05)** | (2.57)* |
| Japan | 0.652 | 0.590 | 0.943 | 0.827 | 0.054 |
| | (14.59)** | (13.21)** | (10.72)** | (16.38)** | (2.04)* |
| Other Foreign | 0.289 | 0.257 | 0.268 | 0.346 | 0.002 |
| | (17.57)** | (15.34)** | (6.45)** | (16.24)** | (0.28) |
| N | 14,918 | 14,918 | 14,024 | 14,918 | 14,645 |
| R-squared | 0.38 | 0.38 | 0.12 | 0.30 | 0.97 |

Note: All regressions contains time, region and industry dummies

**Table 4:**
**Number of Establishments**
**by Number of Years Observed**

| Years | Establishments | |
|---|---|---|
| | Unassisted | Assisted |
| 1 | 514 | 266 |
| 2 | 341 | 153 |
| 3 | 187 | 95 |
| 4 | 139 | 80 |
| 5 | 122 | 64 |
| 6 | 92 | 44 |
| 7 | 66 | 47 |
| 8 | 50 | 31 |
| 9 | 49 | 32 |
| 10 | 31 | 23 |
| 11 | 32 | 24 |
| 12 | 43 | 21 |
| 13 | 72 | 55 |
| **Total** | **1738** | **935** |

**Table 5: Summary Statistics**

| Variables | N | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| | | **Assisted regions** | | | |
| **Employment** | 3690 | 197.44 | 400.25 | 7 | 7,375 |
| **% ATC workers** | 3690 | 0.33 | 0.18 | 0 | 1 |
| **Output** | 3690 | 24.87 | 19.34 | 1 | 280 |
| **Inputs** | 3690 | 15.08 | 14.4 | 0.46 | 200 |
| **Capital stock** | 3690 | 14.49 | 20.29 | 0.63 | 272 |
| **Investment** | 3690 | 1.28 | 4.86 | -12 | 119 |
| | | **Unassisted regions** | | | |
| **Employment** | 7289 | 175.12 | 430.98 | 7 | 8,146 |
| **% ATC workers** | 7289 | 0.39 | 0.21 | 0 | 1 |
| **Output** | 7289 | 27.57 | 21.43 | 1 | 805 |
| **Inputs** | 7289 | 14.99 | 12.17 | 0.39 | 253 |
| **Capital stock** | 7289 | 13.2 | 16.91 | 0.59 | 267 |
| **Investment** | 1.11 | 2.64 | 2.64 | -28 | 89 |

Note: Output capital stock, investment and intermediate material inputs are in real £ ‘000 and normalised on employment.

**Table 6: Alternative Estimates of Production Functions**

| | **Fixed effects** | | **First-difference** | | **Semiparametric** | |
|---|---|---|---|---|---|---|
| | **Variant A** | **Variant B** | **Variant A** | **Variant B** | **Variant A** | **Variant B** |
| **Skilled** | 0.177 | 0.172 | 0.143 | 0.135 | 0.213 | 0.209 |
| | (30.14)** | (29.26)** | (12.94)** | (12.15)** | (54.98)** | (53.42)** |
| **Unskilled** | 0.101 | 0.098 | 0.090 | 0.085 | 0.038 | 0.035 |
| | (23.40)** | (22.85)** | (6.57)** | (6.37)** | (13.71)** | (12.61)** |
| **Capital** | 0.040 | 0.070 | 0.032 | 0.091 | 0.173 | 0.237 |
| | (7.31)** | (11.30)** | (3.00)** | (5.43)** | (59.18)** | (64.66)** |
| **Inter.Inputs** | 0.621 | 0.613 | 0.547 | 0.541 | 0.739 | 0.737 |
| | (96.62)** | (95.55)** | (30.64)** | (30.79)** | (180.65)** | (179.96)** |
| **N** | 10906 | 10979 | 6935 | 6978 | 10228 | 10296 |
| **R-squared** | .76 | .76 | .61 | .61 | .96 | .96 |

Notes:

(i) Variant A and B construct capital as $K_t = (1-d)K_{t-1} + I_{t-1}$, and $K_t = (1-d)K_{t-1} + \ .I_t$. In Variant A current investment does not have an impact on current output.

(ii) The t-statistics on the capital coefficients for the Semiparametric estimators are based on bootstrap estimates of the standard errors using 1000 replications.

(iii) The number of observations used in the semiparametric regressions varies form one stage of estimation to another. Here we only report the ones at the first stage of estimation. About 6% observation is dropped in this estimation due to zero investment.

(iv) R-squared value for the semiparametric estimation refers to the first-stage partially linear estimation.

(v) Parametric regressions include time effects.

**Table 7: Productivity and Regional FDI**
**(Semiparametric Approach)**

| | Variant A | Variant B |
|---|---|---|
| **Productivity(t-1)** | 0.809 | 0.852 |
| | (77.61)** | (100.39)** |
| **FDI1 USA** | 0.004 | 0.002 |
| | (0.22) | (0.08) |
| **FDI1 USA * Assisted** | 0.032 | 0.032 |
| | (1.16) | (1.12) |
| **FDI1 Japan** | 0.243 | 0.217 |
| | (5.48)** | (4.92)** |
| **FDI1 Japan * Assisted** | -0.130 | -0.119 |
| | (1.89) | (1.70) |
| **FDI1 Others** | 0.091 | 0.091 |
| | (3.29)** | (3.30)** |
| **FDI1 Others * Assisted** | -0.107 | -0.104 |
| | (2.45)* | (2.39)* |
| **FDI2** | 0.001 | -0.001 |
| | (0.03) | (0.02) |
| **FDI2 * Assisted** | -0.014 | -0.017 |
| | (0.37) | (0.44) |
| **FDI3** | 0.265 | 0.226 |
| | (6.96)** | (5.95)** |
| **FDI3 * Assisted** | 0.005 | 0.013 |
| | (0.17) | (0.42) |
| **N** | 6978 | 6978 |
| **R-squared** | 0.69 | 0.76 |

Notes:
(i) Productivity measures are computed using the factor elasticities reported in Table 6.
(ii) Time dummies are included in the regressions.

**Table 8: Productivity level and regional FDI by establishment skill and size**

| | Higher skill | | Lower skill | |
|---|---|---|---|---|
| | **Larger** | **Smaller** | **Larger** | **Smaller** |
| **Productivity(t-1)** | 0.702 | 0.815 | 0.756 | 0.781 |
| | (16.94)** | (39.70)** | (25.21)** | (52.96)** |
| **FDI1 USA** | 0.165 | -0.004 | -0.036 | -0.001 |
| | (1.36) | (0.10) | (0.67) | (0.03) |
| **FDI1 USA*Assisted** | -0.128 | 0.199 | -0.026 | 0.005 |
| | (0.85) | (2.23)* | (0.34) | (0.14) |
| **FDI1 Japan** | -0.190 | 0.187 | 0.083 | 0.259 |
| | (0.69) | (1.97)* | (0.29) | (5.26)** |
| **FDI1 Japan*Assisted** | 0.471 | 0.056 | 0.349 | -0.212 |
| | (1.10) | (0.32) | (0.75) | (3.23)** |
| **FDI1 Others** | -0.212 | 0.135 | -0.021 | 0.094 |
| | (1.13) | (2.61)** | (0.26) | (2.98)** |
| **FDI1 Others*Assisted** | 0.086 | -0.147 | 0.021 | -0.112 |
| | (0.41) | (1.91) | (0.14) | (1.93) |
| **FDI2** | -0.025 | 0.068 | -0.003 | 0.002 |
| | (0.43) | (1.79) | (0.05) | (0.07) |
| **FDI2 * Assisted** | -0.275 | -0.046 | -0.059 | 0.002 |
| | (1.35) | (0.48) | (0.88) | (0.05) |
| **FDI3** | 0.278 | 0.234 | 0.526 | 0.274 |
| | (1.53) | (2.81)** | (4.56)** | (6.21)** |
| **FDI3 * Assisted** | 0.275 | -0.076 | -0.085 | 0.010 |
| | (1.46) | (0.68) | (0.92) | (0.27) |
| **Observations** | 500 | 1515 | 753 | 4210 |
| **R-squared** | 0.53 | 0.71 | 0.64 | 0.66 |

**Notes:**

(i) An establishment is defined to be large its level of employment is at least two third of he minimum efficiency scale in its sector.

(ii) A high skill establishment is defined to have at least ten percentage points more of skilled worker proportion than the average sic4 industry value.

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## Appendix A: Data

In this appendix, we give the definition of the main variables used in the econometric analyses. Unless otherwise mentioned the ARD is the source.

**Output:** We use gross output. This is defined as value of sales plus the increase in the value of stocks of works in progress and goods on hand for sales. Gross output was deflated by 4-digit annual output price deflator from the ONS; this was kindly provided to us by Rachel Griffith.

**Capital stock:** Capital stock is estimated from establishment level investment in plant and machinery, vehicles and buildings, using perpetual inventory methods with the starting values and depreciation rates taken from O'Mahony and Oulton (1990) using the selected sample only. Depreciation rates: buildings 2.91%, plant and machinery 11.097%, and vehicles 28.1%. Buildings and plant and machinery are deflated by two digit industry deflators; vehicles by annual deflators. Benchmark capital stock is proxied by the establishment's share of employment in its three-digit industry times an estimate of industry level capital stock. We thank Mary O'Mahony for supplying us with the latter.

**Skilled labour** Average number of administrative, technical and clerical employees.

**Unskilled labour** Average number of operative employees.

**Material Inputs** It is defined as the sum of the cost of materials and fuel used, cost of goods purchased for resale without processing and all non-industrial services received

## Appendix B: The Parametric Approach

We also report estimates from the now classic parametric sample-selection model (Heckman, 1978). The object of the statistical analysis is the estimation of the input elasticities β and the FDI spillover parameters $\alpha_j$ in the following augmented production function equation:

$$y_{it} = d_{it}\,(x'_{it} b + f_i + \sum_{j=1}^{3} a_j FDIj_{rst-1} + dD_{it} + e_{it}) \qquad (9)$$

where $f$ represents fixed effects and δ is an indicator variable that denotes whether the establishment is selected or not. To integrate the fixed effects out of the model, we estimate equation (9) in first-differences. In our sample of domestic establishments, non-selection occurs if (i) the establishment liquidates, (ii) it is taken over by a foreign firm, or (iii) it is not considered in the econometric analysis because of missing values[14]. We were careful to distinguish between these possibilities and assign the non-selection value to the indicator variable only if the establishment t genuinely exits the market. The indicator is assumed to depend on a vector of conditioning variables Z through a standard binary response model:

$$d = 1(Z'g + v > 0) \qquad (10)$$

where 1(A) denote an indicator function of the event A. In this paper, the vector Z consists of age, age squared, size (employment), efficiency[15]. The dependence between the error terms in the outcome equation (9) and the selection equation (10) introduces a non-linear selection term in the model estimated using observations with d = 1. The final estimating equation has the form:

$$\Delta y_{it} = \Delta x'_{it} b + l\left(Z'_{it} g\right) + \Delta u_{it} \qquad (11)$$

where $l\left(Z'g\right) = E\left(\Delta e \mid v > -Z'g\right)$. To identify β and γ, we postulate that the joint distribution of v and ε is bivariate normal, in which case λ(.) can be shown to be proportional to the inverse Mill's ratio.

[14] For example models in first-difference require data for at least two consecutive years
[15] Efficiency is measured by the deviation from the optimal production frontier (Battese and Coelli, 1988).

The assumptions of the parametric approach of correcting for selection bias can be restrictive in practice[16]. First, one is forced to assume that the productivity shocks that are transmitted to the input decisions are fixed over the length of the sample. Second, while some regressors in equation (9) can be endogenous, they are not allowed to appear in the selection equation. Third, the problem of GMM/IV estimation within parametric selection models is not trivial. For example, if Heckman's (1979) two-step procedure is adopted, the asymptotic covariance matrix of the GMM/IV estimator should be adjusted for the first step estimation of $\gamma$ in the selection equation. To our knowledge, this econometric problem is yet to be solved. For this reason, we bootstrapped the standard errors of the estimated coefficients in the IV regression.

**Results**

In Table 9 we report parametric estimates of the selectivity corrected, augmented production function. The selection term in both the first-differenced OLS and IV frameworks is significant, confirming the importance of conditioning on survival. Regional Japanese FDI attracts a significant positive coefficient, the size of which is remarkably similar to the one produced by the semiparametric approach. But apart from that, the impact of FDI is generally insignificant.

What do we make of this set of results from the parametric model? We certainly take them with a pinch of salt, given that the underlying production function parameters are probably inconsistent. At the same time, we like to think that they lend strength to two of the major conclusions we have made from the semiparametric estimates. Namely, regional Japanese FDI in the electronics sector has had a significant aggregate effect on the productivity of domestic establishments; and the impact of FDI outside the establishment's region is insignificant.

[16] To our knowledge, the paper by Disney *et al.* (2000) is the only one that used the ARD to estimate a production function with selection (though not with endogeneity).

**Table 9: Productivity and Regional FDI Parametric Approach with Selectivity**

| | OLS | IV |
|---|---|---|
| **Skilled Employment** | 0.139 | 0.191 |
| | (12.56)** | (5.90)** |
| **Unskilled Employment** | 0.081 | 0.148 |
| | (5.54)** | (3.27)** |
| **Capital** | 0.091 | 0.067 |
| | (5.26)** | (2.96)** |
| **Intermediate inputs** | 0.546 | 0.463 |
| | (30.45)** | (9.32)** |
| **FDI1 USA** | 0.011 | -0.038 |
| | (0.26) | (0.83) |
| **FDI1 USA * Assisted** | -0.078 | 0.083 |
| | (1.20) | (1.10) |
| **FDI1 Japan** | 0.221 | 0.241 |
| | (2.32)* | (1.99)* |
| **FDI1 Japan* Assisted** | 0.296 | 0.134 |
| | (1.92) | (0.73) |
| **FDI1 Others** | 0.030 | 0.055 |
| | (0.84) | (1.30) |
| **FDI1 Others * Assisted** | -0.066 | -0.089 |
| | (0.98) | (1.09) |
| **FDI2** | 0.026 | 0.025 |
| | (0.87) | (0.80) |
| **FDI2 * Assisted** | 0.001 | -0.004 |
| | (0.02) | (0.08) |
| **FDI3** | 0.085 | 0.134 |
| | (0.99) | (0.74) |
| **FDI3 * Assisted** | 0.027 | -0.137 |
| | (0.21) | (0.78) |
| **Selection term** | .069 | 0.160 |
| | (4.72**) | (5.46)** |
| **N** | 6505 | 5077 |
| **R-squared** | 0.62 | 0.60 |

**Notes:**
i) Capital is constructed according to variant B.
ii) Data are first-differenced before estimation.
iii) Regressions contain time dummies and HAC t-statistics given in parenthesis.
iv) The IV estimator uses twice lagged input and FDI variables as instruments. We also used a Sargan test to confirm the global validity of these instruments.
v) Standard errors in the IV regression are bootstrapped to correct for the stochastic nature of the selection term.
vi) The regressors in the selection equation are signed as follows: age(+),age-squared(-), FDI(-), efficiency(+), size(+). More detail is available from the authors.