SERC DISCUSSION PAPER 64

Plant-level Determinants of Total Factor Productivity in Great Britain, 1997-2006

Richard Harris (SERC, CPPR and University of Glasgow)
John Moffat (SERC, CPPR and University of Glasgow)

January 2011

This work is part of the research programme of the independent UK Spatial Economics Research Centre funded by the Economic and Social Research Council (ESRC), Department for Business, Enterprise and Regulatory Reform (BERR), the Department for Communities and Local Government (CLG), and the Welsh Assembly Government. The support of the funders is acknowledged. The views expressed are those of the authors and do not represent the views of the funders.

Plant-level Determinants of Total Factor Productivity in Great Britain, 1997-2006

Richard Harris*
John Moffat*

January 2011

* SERC, CPPR and the University of Glasgow

Acknowledgements
This work contains statistical data from ONS which is Crown copyright and reproduced with the permission of the controller of HMSO and Queen's Printer for Scotland. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

Abstract
This paper examines the determinants of total factor productivity (TFP) using a GB plant-level dataset. Using a systems-GMM approach, it considers the role of the following four plant characteristics: internal and external knowledge; foreign ownership, multi-plant economies of scale and competition; and spatial spillovers and 'place' effects. The sample is disaggregated into manufacturing and services and by technology to show any differences across sectors. In terms of knowledge, undertaking R&D is positively associated with TFP in most sectors. Plant age is generally negatively related to TFP suggesting that the older vintages of technology embodied in the capital of older plants is outweighing any learning-by-doing effect. Foreign ownership is positively related to TFP although there is no obvious TFP ranking in terms of which investing country does better, or in terms of the method by which FDI is undertaken. Manufacturing industries are generally found to operate under conditions of increasing returns-to-scale while service industries generally have decreasing returns. Across most sectors, single plant enterprises have higher TFP than plants belonging to multi-plant enterprises operating in only one region, but lower TFP than plants belonging to multi-plant enterprises with plants in more than one region. Industry concentration (proxying competition) has both positive and negative impacts on TFP across sectors. The agglomeration variable is generally positive and significant for services but less so in manufacturing. A measure of diversification is negatively related to TFP for most sectors although this association is only statistically significant for four out of eight sectors. This may suggest that congestion diseconomies are important. Plants located in cities generally perform better than plants in the same region outside of these cities; but with the exception of London, plants in the South-East have higher TFP levels. This suggests that spatial externalities associated with city location are not as important as the benefits of being situated in the South East region.

Keywords: productivity, plant level TFP, spatial 'place' effects, foreign-owned plants
JEL Classifications: C23; D24; R12

1. Introduction

Productivity (and especially the productivity of both labour and capital inputs into the production process, i.e. total factor productivity, or TFP) is widely recognised as a key driver of long-run economic growth. As Paul Krugman (1997) noted "… Productivity isn't everything, but in the long run it is almost everything"; and William Baumol similarly states that "without exaggeration in the long run probably nothing is as important for economic welfare as the rate of productivity growth" (Baumol, 1984). Using standard growth-accounting methods, large-scale country and industry studies tend to confirm the importance of TFP and its dominance in terms of explaining differences in output growth across different economies (e.g., Figure 1.2, OECD, 2003; Figure 6.3, BERR, 2008; Figure 10, Mourre, 2009; Table 2, O'Mahony and Timmer, 2009).

In this study we use plant level panel data for Great Britain covering 1997-2006 and estimate production functions for eight sub-sectors spanning marketable output in Great Britain. These sectors cover high-tech manufacturing; medium high-tech manufacturing; medium low-tech manufacturing; low tech manufacturing; high-tech knowledge intensive services; knowledge-intensive market services; low knowledge-intensive market services; and other low knowledge intensive services. Our results allow us to consider the relative importance (across these sub-sectors) of a wide range of determinants of TFP grouped under the following headings: (i) internal and external knowledge creation (as represented by technical progress due to undertaking R&D in the plant, and exogenous gains over time) and its obsolescence (as represented by the age of the plant); (ii) access to better technology through belonging to a foreign-owned multinational firm ('greenfield' versus 'brownfield' impacts for different sub-sets of countries are considered); (iii) the impact of multi-plant economies of scale (proxied by whether the plant is a single-plant enterprise and, if not, whether the firm operates in more than one UK region) and external market-based competition effects (as represented by the Herfindahl index of industry concentration); and (iv) the impact of spatial spillover and 'place' effects (as proxied by measures of industrial agglomeration and diversification, as well as the impact on productivity of being located in a particular region and/or city).

This is the most comprehensive and up-to-date study of its kind for Great Britain; and in particular, there are significant policy implications of being able to measure more accurately the determinants of TFP and their relative importance. Moreover, the current UK Government has recently signalled its intent not to provide subsidies to firms and industries but rather to concentrate on improving the overall business environment.[1] The extent to which this may impact on the relative attractiveness of the UK as a whole for inward foreign direct investment (FDI), and/or on maintaining or increasing divergent growth rates across the regions of the UK, is important and we make some comments on this in the conclusions after presenting the results of our analysis.

The next section sets out the modelling approach and data used to obtain estimates of plant level TFP for a majority of market-based sectors in the UK covering 1997-2006. The results are then presented in Section 3, disaggregated under the four sub-headings set out above. We begin each sub-section with a brief overview of the main literature in the area, concentrating on previous empirical results, as a prelude to presenting and discussing our own results. Finally, we summarise our major findings and discuss their policy implications.

2. Data and Model estimated

Plant-level panel data from the Annual Respondents Database (ARD)[2] is used covering 1997-2006 and all market-based sectors for Great Britain (although in this study we have omitted the following industries: those areas of agriculture, fishing and forestry covered in the ARD; mining & quarrying; utilities; construction, sales and motor vehicles repairs, wholesale and retail distribution; and financial services.[3] This data is collected by the UK's Official for National Statistics each year as part of the Annual Business Inquiry, designed to obtain statistics for calculating the national income accounts. It is available for academic use via the Virtual Microdata Laboratory (VML), with stringent conditions attached to it use.[4] In our econometric analysis we weight the data using sample weights to ensure that the distribution of plants for which there is financial data are representative of the population of plants operating in each year in Great Britain. Weighting is necessary both to ensure that population parameters are estimated and because of the fact that one of the endogenous variables in the

[1] On June 28th 2010 (as reported in the *Financial Times*), the UK Secretary for State for Business Mr Cable made it clear he would only give direct grants to individual companies in exceptional circumstances, focusing instead on creating a better climate for business through lower taxes and promoting training.
[2] For a detailed description of the ARD and discussion of several issues concerning its appropriate use, see Oulton (1997), Griffith (1999), and Harris (2002, 2005). Analysis using the database covers a range of areas: cf. Disney *et. al.* (2003a,b), Harris and Drinkwater (2000), Harris (2001, 2004), Collins and Harris (2002, 2005), Harris and Robinson (2002, 2003, 2004a,b), Harris and Hassaszadeh (2002), Harris *et. al.* (2005), and Chapple *et. al.* (2005).
[3] For most of these industries we have no data on capital stocks, or they are only partially covered by the ARD. Others we have deliberately chosen to omit (i.e., sale and repair of motors, and the distribution sectors), mainly because of limitations with computer memory when using the ARD on the VML (the deliberately omitted industries have many hundreds of thousands of observations).
[4] More details on the VML are available at http://www.ons.gov.uk/about/who-we-are/our-services/vml/about-the-vml/index.html.

model (employment) is used by the ONS as part of the stratified sampling approach to collect the ARD data; thus leading to the problem of endogenous sampling or stratification (see the appendix in Harris, 2002).

Information on intra- and extra-mural expenditure on R&D is available in the VML from the Business Enterprise R&D (BERD) database on enterprises that undertake this activity each year. This data have been merged into the ARD using the unique enterprise reference codes available information in both databases, and where this information was missing[5] we have used information on industry SIC codes and geographic postcodes to match respondents in the two databases. In total, based on annual data for 1997-2006 we have been able to successfully match in over 95% of the BERD respondents into the ARD (in terms of both enterprise numbers and the total spending on R&D).

The full set of available variables, and their definitions, is set out in Table 1. Capital stocks were estimated at the plant level, linked to a benchmark estimate based on 1969 for manufacturing and 1996 for services. That is, annual 3-digit SIC real gross investment data dating from 1948 was used to calculate a benchmark capital stock for each industry, and this was then apportioned to each plant existing in the year following the benchmark year. Details on the methods used for manufacturing are set out in Harris and Drinkwater (2000); a similar approach was used for services and based on the length-of-life of plant and machinery in each service sector as estimated by the ONS. We also added (deflated) spending on the hire of plant and machinery to obtain an estimate of the total capital stock available to each plant.

The age of the plant is obtained from whichever was oldest from either the year when the plant was first observed in the ARD or from information contained in the Business Structure Database (BSD) in the ONS. The latter is especially important for services, since the ARD only includes services from 1997 (data for manufacturing is available from 1970); however, the BSD also uses information from various service sector surveys conducted by the ONS (and its predecessor, the CSO) from the 1970's and 1980's and information is available from these dating back to when plants were first included. Harris *et. al*. (2006) discuss these sources; for present purposes it is important to note that for most service sector plants for which there is data, the earliest observation is usually in 1977.

[5] A major problem with the BERD is that the ONS use a different system of enterprise codes for some respondents.

Single-plant status and whether the plant belonged to an enterprise operating in more than one region are obtained from using the enterprise group reference codes contained in the ARD; foreign-ownership is obtained from the ARD, and is aggregated into 3 sub-groups. Attempts have been made to capture two types of spillover: agglomeration economies associated with localisation externalities due to industrial specialisation and thus an intra-industry phenomenon (typically called Marshall (1890), Arrow (1962), and Romer (1986), or MAR, externalities in the literature); and urbanisation economies (typically called Jacobian externalities after Jacobs, 1970 and 1986), representing diversification and therefore inter-industry spillovers. The Herfindahl index of industrial concentration was also computed to take into account entry (and exit) barriers that can impact on competition, with the expectation of a potentially negative influence of higher concentration on productivity. In addition, information is available on whether the plant was located in an Assisted Area, and to which Government Office region, and/or city[6], and industry (2-digit 1992SIC) it belonged.

Table 2 presents the mean (weighted) values for the variables, broken-down by the eight sectors used in this study. The latter were chosen based mostly on Eurostat definitions (although with some minor amendments).[7] High-tech manufacturing plants were largest (in terms of gross output, intermediate inputs and employment), but they were relatively younger (which in part explains why their capital stock was relatively small compared to other manufacturing sectors). In general manufacturing plants were larger than those operating in the service sectors, although the age of the plants in services was generally higher (see footnote 3 for a list of those service industries omitted from this study). Single-plant operations were more prevalent in manufacturing, while in services over 80% of plants belonged to enterprises operating plants in more than one region.

Around 22-25% of plants in manufacturing (excluding low-tech manufacturing) were foreign-owned, with 'brownfield' plants somewhat more likely to be in operation, and overall EU-ownership predominating (except for high-tech manufacturing where US-ownership was a little more likely). Plants owned by firms from other foreign-owned countries were in the minority (generally across all sectors). For low-tech manufacturing and high-tech KI services, around 18-20% of plants were foreign-owned (EU-ownership was more likely in low-tech manufacturing; US-owned in high-tech KI services); 'brownfield' plants were generally more

[6] The major cities we identify were either capitals (i.e., Cardiff and Edinburgh) or they met the criteria of (in 2001) employing over 250,000 with a population density of 20+ persons per hectare; or they had employment over 100,000 and densities of 30+ persons per hectare.

[7] http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/Annexes/htec_esms_an3.pdf.

common than ‘greenfield’ plants. In the remaining service sectors, foreign-owned plants accounted for around 12-14% of all plants (Us-ownership dominating KI services and other low KI services; EU-owned more likely in low KI services), and again ‘brownfield’ plants were generally more in evidence (except for other low KI services were ‘greenfield’ US-owned prevailed).

The average Herfindahl index of industrial concentration was generally very low across all sectors;[8] the highest levels of competition were in KI services, low-tech manufacturing, medium high-tech manufacturing and high-tech manufacturing, while competition was relatively low (on average) in high-tech KI services and other low KI services. Industry agglomeration was highest in the medium low-tech manufacturing sector (covering such industries as metals and shipbuilding), followed by low-tech manufacturing; it was lowest on average in low KI and other low KI services. Diversification was relatively high in KI services (covering higher-level business services), but there was little difference across the other sectors covered. R&D was undertaken in around 24% of high-tech manufacturing plants, falling to 12% in low-tech manufacturing; far fewer service sector plants undertook formal R&D (some 4-5% of those in high-tech KI and KI services, and less than 1% for the other two service sectors included). Lastly, between 16-23% of plants were located in Assisted Areas, where they were eligible for help from such schemes as Regional Selective Assistance, various R&D schemes, and EU assistance (mostly from the ERDF).

There are several approaches to estimating TFP using micro-level panel data. Del Gatto et. al. (2010) and Van Beveren (2010) provide useful surveys on these different approaches to measuring TFP. The former point out that “… an array of methodologies is available, and researchers have to make a choice that, even when the estimation is only propaedeutical to the main analysis, it is likely to represent most of the story of an article” (p. 2). They cover both deterministic methodologies (such as growth accounting and Data Envelope Analysis) and econometric approaches, splitting the latter into frontier and non-frontier models. Del Gatto *et. al.* (*op. cit.*) also discuss the issue of macro versus micro estimation of TFP. The analysis here is more limited (and very similar in scope to Van Beveren, *op. cit.*) as we consider only micro-econometric approaches. This allows us to concentrate on those methodologies that have become the most commonly used in recent years, relying on micro-level (e.g. firm of plant) panel data that is much richer for analysing heterogeneity across enterprises and thus provides a better understanding of the causes of TFP differences. Growth accounting is still mainly confined to the more aggregate analysis of

[8] Dividing these numbers into 1 gives the ‘numbers-equivalent’ of equal-sized firms on average operating in each sector.

TFP at industry or country level (e.g. analysis based on the EU KLEMS database – see O'Mahony and Timmer, 2009)[9].

Here we define TFP using a Cobb-Douglas log-linear production function approach (including fixed-effects, α_i)[10]:

$$y_{it} = \alpha_i + \alpha_E e_{it} + \alpha_M m_{it} + \alpha_K k_{it} + \alpha_X X_{it} + \alpha_T t + \varepsilon_{it} \qquad (1)$$

where endogenous *y*, *e*, *m* and *k* refer to the logarithms of real gross output, employment, intermediate inputs and capital stock in plant *i* in time *t* ($i = 1,\ldots, N$; $t=1,\ldots T$);[11] and X is a vector of observed (proxy) variables determining TFP. In order to calculate TFP, equation (1) is estimated *directly* (e.g., Harris, et. al. 2005) providing values of the elasticities of output with respect to inputs (α_E, α_M, and α_K), and then TFP is measured as the level of output that is not attributable to factor inputs (employment, intermediate inputs and capital) – i.e., TFP is due to efficiency levels and technical progress. Thus, such a measure of TFP is equivalent to:

$$\ln T\hat{F}P_{it} \equiv y_{it} - \hat{\alpha}_E e_{it} - \hat{\alpha}_M m_{it} - \hat{\alpha}_K k_{it} = \hat{\alpha}_i + \hat{\alpha}_X X_{it} + \hat{\alpha}_T t + \hat{\varepsilon}_{it} \qquad (2)$$

An alternative approach, popular in the literature, is to estimate (1) without including X_{it} on the right-hand-side of the equation, and then use (2) to obtain TFP, where X_{it} is now part of the random error term ($\hat{\varepsilon}_{it}$). Typically, $ln\,\mathrm{T\hat{F}P}_{it}$ obtained from equation (2) is then regressed on X_{it} to measure the determinants of TFP as part of a two-stage approach. Clearly, we would expect estimates of the elasticities of output (and thus $ln\,\mathrm{T\hat{F}P}_{it}$) from this two-stage approach to be biased because of an omitted variable(s) problem.

The class of models that could be (and indeed have been) used to estimate (1), using micro-level panel data, include: (i) simple OLS models that ignore fixed effects, endogeneity of inputs and outputs in the production function, and selection bias due to firm entry and exit (which is likely to be correlated with productivity); (ii) least squares with dummy variable

[9] If we are mostly interested in micro-panel data analysis, then growth accounting can be problematic as reliable data on factor shares in costs or profits is often not available. It also usually makes certain unrealistic assumptions such as constant returns-to-scale and perfect competition.

[10] The inclusion of fixed effects is necessary as empirical evidence using plant- and firm-level panel data consistently shows that plants are heterogeneous (productivity distributions are significantly 'spread' out with large 'tails' of plants with low TFP) but more importantly that the distribution is persistent – plants typically spend long periods in the same part of the distribution. Evidence using the ARD has been presented in, for example, Haskel (2000) and more recently Martin (2008). Evidence from other countries is presented in Baily et al. (1992), Bartelsman and Dhrymes (1998). Such persistence suggests that plants have 'fixed' characteristics (associated with access to different path dependent (in)tangible resources, managerial and other capabilities) that change little through time, and thus need to be modelled.

[11] In theory the production function should relate the flow of factor services to the flow of goods and services produced; in practice we rarely have data on capital and labour utilization at the micro-level, and this measurement error is included in ε_{it}.

(LSDV) models that allow for fixed-effects;[12] (iii) within-group fixed effects (WG) least squares models that transforms the production function to remove the fixed effects but only controls for endogeneity and selection bias if the unobserved productivity shock is constant throughout time (and is therefore part of the removed fixed effect);[13] (iv) 2SLS within-group fixed effects, allowing for endogeneity and selection bias associated with instrumented right-hand-side variables;[14,15] (v) the increasingly popular Olley and Pakes (1996) and Levinsohn and Petrin (2003) approaches, and associated extensions such as Ackerberg et. al. (2006)[16] which account for both endogeneity of inputs and outputs in the production function and selection bias, through using two-stage procedures where unobserved TFP is 'proxied' by another state variable(s) such as investment or intermediate inputs;[17] (vi) frontier models where the (one-sided) inefficiency term includes fixed effects but do not control for endogeneity and selection bias; [18] and finally our preferred approach of system-GMM, which includes fixed effects and tackles endogeneity of the right-hand-side variables and selection

[12] Note, the LSDV model should be biased because of the incidental parameters problem resulting from the correlation of the fixed effects and the explanatory variables. However, it is possible to use the xtlsdvc routine available for STATA (by Bruno, 2005) which calculates bias-corrected least-squares dummy variable (LSDV) estimators.

[13] However, to be consistent the WG estimator assumes the explanatory variables are strictly exogenous (which is unlikely), or that asymptotic consistency is achieved when $T \to \infty$ (a problem in the typical micro-panel where T is usually short).

[14] Note, this and all other panel estimators are concerned with fixed and not random effects (RE), as it is expected that the cross-sectional intercepts α_i are correlated with the other right-hand-side regressors (x_{it}). Since the RE model is applicable if the panel data comprise N 'individuals' drawn randomly from a large population (e.g. the typical approach in household panel studies), such that the α_i are randomly distributed across cross-sectional units, we expect the fixed effects model is more appropriate when focusing on a specific set of N firms which are not randomly selected from some large population.

[15] Note selection bias is controlled when an instrumental variables (IV) approach is used, because such instruments should remove all the correlation between productivity effects and the error term in the model.

[16] Including extensions by De Loecker (2007a); Van Biesebroeck (2005); Wooldridge (2009) and Katayama *et. al.* (2009).

[17] A thorough description of the approach is provided in Van Beveren (2010) and Del Gatto *et. al.* (2010). In essence, Olley and Pakes (OP) replace equation (1) with

$$y_{it} = \beta_0 + \beta_E e_{it} + \beta_K k_{it} + \beta_M m_{it} + h(i_{it}, k_{it}) + \varepsilon_{it} \tag{1a}$$

where TFP is proxied by h(.) – which itself is approximated by a higher-order polynomial in i_{it} and k_{it} – and i_{it} is investment; Levinsohn and Petrin (LP) replace equation (1) with:

$$y_{it} = \beta_0 + \beta_E e_{it} + \beta_K k_{it} + \beta_M m_{it} + h(m_{it}, k_{it}) + \varepsilon_{it} \tag{1b}$$

Both approaches exclude fixed effects and make some other strong assumptions (as discussed in Ackerberg et. al., 2006) such as: (i) the firm's optimal investment, i_{it} (or optimal level of intermediate inputs, m_{it}) is a strictly increasing function of its current productivity (the latter being assumed to evolve as a first-order Markov-process), so only non-negative values of i_{it} (m_{it}) can be used; (ii) productivity is the only unobservable input entering the investment (intermediate inputs) function, which also rules out measurement error in these variables; (iii) e_{it} is a non-dynamic input (i.e. it has no impact on future profits of the firm, thus ruling out training, hiring and firing costs); and (iv) k_{it} is decided in period $t - 1$ (ruling out the use of hired capital assets, and/or incremental additions to capital, during t). In addition, there are issues over identification of β_E because of collinearity issues (in 1a and 1b) – Wooldridge (2009) proposes a solution to this particular issue using a GMM approach to the OP/LP estimator where both stages of the model are estimated simultaneously.

[18] A major issue with such models is the extent to which X_{it} in equation (1) should be included in the deterministic part of the model (to set the frontier) and to what extent these variables 'explain' inefficiency (and therefore enter the model as a determinant of the one-sided inefficiency term, υ_{it}, where $\varepsilon_{it} = (u_{it} - \upsilon_{it})$ – see Battese and Coelli (1995).

bias by using their lagged values (in first differences and levels) as instruments.[19] Thus equation (1) – in dynamic form with additional lagged values of output and factor inputs – was estimated using the system-GMM approach available in STATA 9.2 (Blundell and Bond, 1998). This is sufficiently flexible to allow for both endogenous regressors[20] and a first-order autoregressive error term. Note, as stated above, all data were also weighted to ensure that the samples are representative of the population of GB plants under consideration.

While the system-GMM has certain advantages over other estimators (such as incorporating fixed effects, allowing for endogeneity and sample selectivity, and generally making fewer assumptions about the role of state variables), there continues to be an issue over which approach leads to least bias in estimating TFP. A number of studies have estimated different models using actual (non-simulated) datasets and compared the results obtained (e.g., Ackerberg et. al., 2006; Blundell and Bond, 1998; De Loecker, 2007b; Olley and Pakes, 1996; Van Beveren, 2010); but without knowing the true data generating processes (and hence model parameter values) underlying any particular dataset, it is not possible to say much more than there are differences obtained when using alternative approaches.[21] It is our contention and experience using system-GMM and other approaches that the former produces results that are sensible and in accord with our *a priori* expectations.

3. Plant-level results

3.1 Internal and external knowledge

Early approaches to understanding the micro-dynamics of productivity and growth were developed for understanding when firms enter markets (both as new firms and/or through expansion into, say, export markets), if and when they expand production, as well as their decision to shutdown some or all of their capacity. All these decisions depend fundamentally on the firm's prospects for profits, and this in turn is dependent on its productivity and on whether this is above various thresholds (e.g., its shutdown threshold, defined as the lowest

[19] The validity of the instruments (i.e., that they are correlated with endogenous regressors but are not correlated with the production function error term – and hence productivity) can be tested, but systems-GMM (which exploits more moments conditions than other GMM approaches) can still face the problem of weak instruments, and it is well-known by those that use the approach that the parameter estimates obtained (and the ability to pass diagnostic tests) is sensitive to the instrument set used.
[20] Output, intermediate inputs, labour, capital, and R&D are treated as endogenous.
[21] Even if there are prior expectations of bias in particular directions associated with particular estimators (and these produce relative parameter values that accord with the direction of expected bias – see Table 1 in Van Beveren, 2010), given the range of potential impacts on parameter estimates (endogeneity, selectivity, technology, demand shocks, measurement error, dynamic misspecification, etc.) it would be difficult to choose one estimator as 'best' or most reliable until more work is undertaken in this area based (optimally) on the use of simulated datasets.

level of productivity that would enable the firm to have positive discounted expected profits greater than its liquidation value over future periods). Such a framework leads to productivity and also sunk costs having a major role in explaining entry, growth and exit decisions, and thus the internal and external factors attached to the firm and the industry in which it operates that impact on productivity and sunk costs.

Early theoretical work was particularly concerned with how productivity was related to size, the learning-by-doing effect associated with the age of the firm, and thus the likelihood of survival (cf. Jovanovic, 1982; Pakes and Ericson, 1998). Learning-by-doing models have been extended to include the investments of individual firms (particularly on intangible assets – cf. Griliches, 1981) to allow for 'active learning', thus relaxing the assumption that firm productivity levels are exogenously determined by a random draw from some stochastic distribution, and are thus constant over time (e.g., Ericson and Pakes, 1992; and Olley and Pakes, 1996). According to resource-based theories[22], firms that invest in intangible assets, such as R&D, and consequently increase their specific internal capabilities and ability to absorb external knowledge, are more likely to increase their competitiveness.[23] Aw *et. al.* (2008) also allow firms to generate (external) knowledge through participating in new (e.g., export) markets, so that the evolution of firm productivity over time is determined by past productivity as well as investments in such knowledge acquiring activities as undertaking R&D (and exporting). Path-dependency is therefore an important theme of this type of approach; competitive advantage is dependent on accumulated firm-specific resources and production capabilities that have been (often slowly) developed over time and which cannot easily be acquired, replicated, diffused, or copied – they therefore cannot easily be transferred or built-up outside the firm (Nelson and Winter, 1982; Pavitt, 1984; David, 1985; Arthur, 1989; Teece and Pisano, 1998; Dosi et. al., 2000).

Thus in estimating equation (1), we take account of internal and external knowledge creation (as represented by both endogenous technical progress due to undertaking R&D in the plant, and by exogenous gains over time) and its obsolescence (as represented by the age of the plant). R&D is expected to have an impact on TFP through two channels. Most obviously, performing R&D may generate process innovations that allow existing products to

---

[22] The resource-based view (RBV) of the firm was initially put forth by Penrose (1959), and subsequently developed by Wernerfelt (1984) and Barney (1991, 2001). The thrust of this viewpoint lies in the established assumption that 'better' firms possess intangible productive assets that they are able to exploit to derive competitive advantages.

[23] The notion of 'absorptive capacity' was initially put forward by Cohen and Levinthal (1990), who argued that the firm's "prior related knowledge confers an ability to recognize the value of new information, assimilate it and apply it to commercial ends" and "these abilities collectively constitute what we call a firm's 'absorptive capacity' ". Thus, in simple terms, absorptive capacity is the firms' ability to internalise external knowledge.

be produced with greater efficiency (through lower costs). It may also generate product innovations which will improve TFP if the new products are produced with greater efficiency or by using better technology than existing products (i.e., an outward shift of the firm's production possibility frontier). The second channel is through the development of absorptive capacity (see Zahra and George, 2002, for a detailed discussion of the concept). Absorptive capacity permits the identification, assimilation and exploitation of innovations made by other firms and R&D actors, such as universities and research institutes, and is therefore also expected to lead to improvements in TFP. The notion of absorptive capacity is based on the observation that some knowledge is tacit and is difficult to acquire unless the firm is directly involved in R&D in the area. These two channels through which R&D may affect TFP reflect the two 'faces' of R&D.

Theoretical models exploring the implications of the two faces of R&D are provided by, for example, Cohen and Levinthal (1989). Empirical evidence in support of their existence is provided by Griffith et al. (2004) using industry panel data for 12 OECD countries. However, Kneller (2005), using a similar dataset, find that while there was a general impact of R&D on productivity through increased innovativeness, he could only find evidence of an impact for R&D through the creation of absorptive capacity for smaller OECD countries. Similarly, Cameron et al. (2005), using a panel of UK manufacturing industries, did not find evidence of a role for the second face of R&D. In contrast, Lokshin et. al. (2008) used panel data for Dutch manufacturing firms finding that "combining internal and external R&D significantly contributes to productivity growth … (but) a positive impact of external R&D is only present in case of sufficient internal R&D in line with the absorptive capacity argument" (p. 400).

Many more authors have looked for a relationship between R&D and productivity without distinguishing the channels through which this relationship arises. This approach is based upon the notion of the 'knowledge production function' (Griliches, 1980). Essentially, knowledge is treated as a factor of production, which is augmented by investment in R&D. A large empirical literature exists in this vein which tests whether R&D has an impact on productivity or productivity growth (see Wieser, 2005 for a review). For example, Wakelin (2001) finds that R&D intensity has a positive impact on labour productivity growth using a sample of 170 UK manufacturing firms. A similar paper by Kafouros (2005) finds that performing R&D has a positive impact on productivity growth using a dataset of 205 UK manufacturing firms. Maté-Garcia and Rodríguez-Fernández (2008) use Spanish firm-level data and find that R&D intensity leads to a statistically significant rise in the growth of labour productivity. They also find that there is a stronger relationship between R&D and labour productivity growth in high-tech than low-tech firms. Tsai and Wang (2005), obtain the same result using firm-level Taiwanese data. They find a positive impact of R&D on labour productivity growth that was larger for high-tech firms than traditional manufacturing industries. Ortega-Argiles (2010), using a dataset of large European R&D investors, find evidence of a positive impact of R&D intensity on labour productivity, the size of which is smallest in low-tech firms and largest in high-tech firms. Finally, Ho et. al. (2009) found that R&D investment had a significant impact on TFP in Singapore, however when compared to OECD countries the impact was not as strong.

The age variable is included to measure whether younger plants produce with greater efficiency and better technology than older plants (a vintage capital effect); or if through learning-by-doing productivity increases as the plant ages (e.g., Jovanovic and Nyarko, 1996). Note, the measure of the capital stock we use here (see Harris and Drinkwater, 2000; Harris, 2005b) is in theory adjusted to take account of vintage effects, that occur through 'wear and tear' (i.e., deterioration of capital through use) and because new capital embodies the latest technology (leading to obsolescence in older vintages). Thus the coefficient obtained on our plant age variable should be an estimate of whether older firms have higher TFP because 'as plants age, managers accumulate experience, gain from learning by doing, undertake new investments, or achieve economies of scale, all of which can improve plant-level productivity' (Jensen et al., 2001). In practice though, it is unlikely that our capital stock estimates are fully adjusted for obsolescence,[24] while additionally new plants have a relative advantage in adopting new technology since existing plants face sunk costs (Campbell, 1993). According to Lambson (1991) the strength of this 'sunk cost effect' is likely to be lower in industries characterised by low sunk costs (where entering plants can choose a mix of new and old technologies).

Jensen et al. (2001) find evidence that both learning and vintage effects are important in determining labour productivity using US firm-level data and that these two effects roughly offset one another so that all cohorts of firms have similar levels of productivity in a given year. In other words, firms that use older vintages of capital tend to have learned enough to offset the disadvantage at which they are placed by their older capital. In contrast, Salvanes and Tveteras (2004) using Norwegian manufacturing data also found that both effects matter, but they found "… the learning effect dominates the early years in the life of a

[24] As Gittleman et. al. (2006) show "… the correction of productivity growth for the vintage effect requires an estimate of the obsolescence and depreciation parameters on the basis of age data…(then) the use of capital stock in efficiency units does cause some smoothing of total factor productivity growth over time" (p. 306).

plant and the capital vintage effect dominates in later years" (p.274). Using Dutch data, Brouwer et al. (2005) find that the productivity of new firms that have recently entered the market is lower than average but that those that survive catch up with other firms in the market. Once plants have survived ten years, there is little relationship between age and productivity. Dunne (1994), based on US manufacturing plant data, found that the use of advanced technology and plant age were relatively uncorrelated (and this was true for both low and high entry/exit industries). Power (1998) used US manufacturing panel data and also found little relationship between vintage effects and productivity. Others have also found mixed effects: a negative relationship is reported in Hill and Kalirajan (1993); positive in Biggs et. al. (1996); and no effect in Lundvall and Battese (2000). Although not the main focus of their paper, using UK data Harris & Robinson (2004a) and Harris (2010) find evidence of a negative relationship between age and TFP.

A time trend is also included in equation (1) to account for (Hicks-neutral) technical change. This is done to capture the impact on TFP of exogenous improvements in technology that are common to all plants.

A priori expectations are that the importance of all three variables will vary across industry categories. In particular, these variables might be expected to be more important in high-tech industries as these tend to be more dynamic and competitive, and will therefore depend to a greater extent on operating close(r) to the technological frontier.

The results obtained for the knowledge-based variables in equation (1) are reported in Table 3. The impact on TFP of a plant having a non-zero R&D stock is generally positive and significant, except for medium low- and low-tech manufacturing where there was little impact. Plants in medium high-tech manufacturing benefited the most vis-à-vis other manufacturing plants (plants in this sector with R&D had on average 11.4% higher TFP); but perhaps more surprisingly, plants in services that had positive R&D stocks had the highest TFP gains, especially in high-tech knowledge-intensive (KI) services and other low KI services. However, as was shown in Table 2, relatively few plants in the service sectors had non-zero R&D stocks (e.g., in other low KI services only 0.2% of plants engaged in R&D); this suggests that the results for services in Table 3 are identifying gains achieved in relatively specialised plants.

As well as considering the conditional impact of R&D on TFP (i.e., the parameter results reported in Table 3), Figure 1 also shows the unconditional (i.e., allowing for size, ownership, age, etc. to vary) cumulative distributions of TFP for each sector, divided into those that had non-zero R&D stocks and those that did not; TFP was obtained from estimating equation (1) and then applying equation (2). A sub-group (e.g. plants with non-zero R&D stocks in the high-tech manufacturing sector) with a productivity distribution always to the right of the contra sub-group (e.g. plants with zero R&D stocks in the high-tech manufacturing sector) is said to dominate the other sub-group. We can formally test if the rank ordering of productivity distribution of one sub-group of plants lies to the right of another sub-group using a two-sided Kolmogorov-Smirnov (KS) statistic (see Stevens, 1974); if so, there is shown to be first-order stochastic dominance between such (random) variables, which is a stricter test than simply comparing average productivity levels across sub-groups. Figure 1 shows that in all sectors (both in manufacturing and services) plants involved in R&D had higher TFP when compared to those who did not; the (KS) statistics are also reported for each sector and all are significant at the 1% level. The value of each KS statistic indicates the maximum distance between each distribution; this was greatest for high-tech manufacturing (with a KS statistic of 0.41), high-tech KI services (test statistic of 0.53), and other low KI services (0.50).

Figure 1 also shows that for those plants undertaking R&D (which dominated those without R&D) TFP distributions can be ranked from highest-to-lowest as follows: KI market services, medium low-tech manufacturing, high-tech KI services, high-tech manufacturing, low-tech manufacturing, other low KI services, medium high-tech manufacturing, and low KI market services. A priori it might be expected that TFP distributions would be ordered right-to-left starting with high-tech manufacturing and high-tech KI services, and then working down the sectors in terms of their presumed technological/knowledge intensity. However, Figure 1 shows that medium low-tech dominates in manufacturing, above high-tech manufacturing, while medium high-tech manufacturing is ranked lowest in manufacturing; the rank ordering in services matches expectations more closely although KI market services dominates high-tech KI services.

Table 3 shows that exogenous technical change was highest in high-tech manufacturing (at around a 4.8% p.a. increase in TFP), while other manufacturing sectors also experienced significant boosts from the use of new technology (on average around 2-3% p.a.). Gains in the service sectors were very low, and in the case of low KI services (such as hotels & restaurants, real estate and various labour intensive business services) technological progress was negative. There are few studies against which to make any comparisons; however, using the EU KLEMS database (O'Mahony and Timmer, 2009), average TFP over

1997-2006 (which might be expected to be dominated by gains from new technology rather than a catch-up in efficiency levels[25]) was 5.1%, 1.4%, 2.3%, 0.5%, and 0.7% in high-tech manufacturing, medium high-tech manufacturing, medium low-tech manufacturing, and market services respectively.[26] These results, despite being based on a growth-accounting approach and industry-level data, are broadly in line with those reported in Table 3. The major exceptions are that our results (having controlled for various other impacts on TFP) are higher for low-tech manufacturing, and lower for the service sector.

Lastly, we find that higher plant age is significantly related to lower TFP, especially in manufacturing and high-tech KI services (doubling plant age would decrease TFP by between 14-19%); in other service sectors the elasticity of output with respect to the age of the plant is less than half of the impact in manufacturing. There is some evidence that suggests that the strength of the relationship is indeed lower in industries where we might expect sunk costs to be lower, thereby lending some support to the approach put forward by Lambson (1991).

When the relationship between productivity and plant age is considered using unconditional cumulative distributions of TFP, Figure 2 shows that older plants have higher TFP in every sector (although the KS statistics – all of which are significant at the 1% level – indicate that the difference is small for low-tech manufacturing and low KI market services). The difference between the conditional and unconditional results for the impact of age on TFP show that older plants also tend to be larger and more likely foreign-owned, and belong to enterprises that operate plants in more than one region (all factors that are shown below to be positively related to higher levels of TFP).

3.2 Impact of foreign-ownership

Foreign ownership dummies were also included in the model. This is justified by the observation that, to make it worthwhile for a foreign firm to incur the costs of setting up or acquiring a plant in the domestic market, foreign firms must possess characteristics that give them a cost advantage over domestic firms (Hymer, 1976). These characteristics may include specialised knowledge about production and better management or marketing capabilities,

[25] That is, given the persistence of heterogeneity (such that plants are expected to occupy similar positions in the distribution of TFP for long periods of time), it might be expected that relative inefficiency levels change slowly and changes in the productivity distribution are more likely in short periods to be dominated by rightward shifts caused by technical change.

[26] The sectors were not exactly the same as that used in our study (high-tech in EU KLEMS is SIC30-33; medium high-tech is SIC29, 35-35; medium low-tech is SIC23-28; low-tech is SIC15-22, 36-37; and services comprised sectors G, H, I, SIC60-64, K and O). Note we weighted individual industry results by their share in GVA for each year 1997-2006 to obtain the overall TFP figures reported here.

both of which would lead to relatively high levels of TFP. It should be noted that, in the long-run, some of these advantages may dissipate as domestically owned firms learn to imitate the foreign firms as a result of knowledge spillovers (Harris and Robinson, 2003). The speed at which this process occurs will be dependent upon levels of absorptive capacity in the domestic firms. Conversely, cultural differences between the owners of the plant and the workforce may act to lower levels of TFP in foreign owned plants, especially in the immediate period after the establishment of new 'greenfield' operations, or the acquisition of an existing plant. Dunning (1988) suggests a lack of understanding of management and labour attitudes as one such disadvantage possessed by foreign owned firms. It is likely that, in the long-run, this problem can be overcome as the owners of the plant become more familiar with domestic working practices.

Furthermore, firms may undertake FDI to source technology from the host economy rather than to exploit superior technology from the home country (Driffield and Love, 2007). Plants owned by foreign owned firms that are motivated by technology sourcing rather than technology exploiting are likely to have lower TFP than plants owned by foreign owned that are technology exploiting (Fosfuri and Motta, 1999; Cantwell et al., 2004; Driffield and Love, 2007). However, Love (2003) was unable to find strong evidence of technology sourcing but does obtain strong evidence in favour of the technology exploitation hypothesis using data on flows of FDI into and out of the US. Similarly, Kogut and Chang (1991) use data on the entry of Japanese firms into the US to show that R&D intensity and the frequency of innovation were not statistically significant determinants of Japanese entry. This suggests that technology sourcing is not a strong motivation for FDI. However, Neven and Siotis (1996) employ a similar methodology to examine FDI inflows into the EC and do find some evidence that technology sourcing is a motivation for FDI.

Foreign-owned plants may also be expected to have lower levels of TFP if foreign-owned firms tend to keep their high value production at home and leave lower value added assembly operation to their foreign subsidiaries (Doms and Jensen, 1998). The latter will tend to employ lower-skilled workers and older technologies. This phenomenon may be especially problematic in peripheral regions as this is where multinationals often place low value added 'branch plant' activities (Harris, 1991).

It is therefore not clear from the literature whether foreign owned plants should be expected to have higher or lower TFP than domestically owned plants. The empirical evidence is also inconclusive. Aitken and Harrison (1999) found a 10.5% productivity advantage for foreign owned plants in Venezuela, and Doms and Jensen (1998) also showed, using two measures of TFP, that foreign-owned plants had higher levels of TFP in the US. Similarly, Matthias Arnold and Javorcik (2009) found that being acquired by a foreign owned firm leads to a boost of 13.5% to TFP levels using Indonesian data. By contrast, Okamato (1999) reported that Japanese owned plants had lower TFP than domestically owned plants in the US automotive parts industry. For the UK, Griffith and Simpson (2003) showed that foreign owned manufacturing plants had much lower levels of TFP using the ARD. However, Harris and Robinson (2003), also using the ARD, found that foreign owned (and especially US-owned) plants were more productive. Criscuolo and Martin (2005) combined data from the Annual Inquiry into Foreign Direct Investment (UKFDI) with the ARD to allow them to identify plants owned by UK multinationals. They show that plants owned by US multinationals had a TFP advantage over plants owned by UK multinationals which had similar levels of TFP to plants owned by non-US multinationals (all groups of multinational owned plants had higher TFP than domestically owned plants). Although the weight of the empirical evidence is on the side of a TFP advantage for foreign owned plants, there remains some doubt as to whether we should expect a positive or negative coefficient on the FDI variables.

To make predictions about the relative TFP levels of 'greenfield' and 'brownfield' plants, it is helpful to consider the motives of the foreign firm when undertaking such investment. Greenfield investment involves the opening of a new plant while 'brownfield' investment involves the merger/acquisition of an existing plant. For firms which undertake FDI in order to secure access to and thereby to internalise complimentary local assets, 'brownfield' investment would be the preferred form of investment. This idea is supported by the model of Buckley and Casson (1998) which shows that 'brownfield' investment will be preferred when the costs of learning about the domestic market are high and these costs can be avoided through acquisition. This implies that 'brownfield' plants may well have higher TFP than 'greenfield' plants which will not have access to these assets. An extension of this argument is that plants with better assets will be a more attractive target for foreign-owned firms seeking to acquire plants. If so, plants acquired through 'brownfield' investment will be a self-selected group of the population of plants. Assuming that these assets manifest themselves in the form of higher productivity, it is expected that multinationals tend to acquire plants that have high levels of TFP. Empirical evidence in support of this proposition is provided by Harris and Robinson (2003) and McGuckin and Nguyen (1995).

However, there may be problems associated with 'brownfield' investment. For instance, there may be difficulties with integration of the plant into the firm and the establishment of trust between owners and employees (Harris, 2009). New 'greenfield' investments may also allow foreign-owned firms to introduce modern technology and modern management practices, and establish their own forward and backward supply-chains with plants that are a closer match with their own needs and requirements. Such arguments suggest that 'greenfield' plants may have higher TFP. The limited empirical on this question appears to suggest that foreign-owned 'greenfield' plants do indeed have higher TFP than 'brownfield' plants (Harris, 2009; Harris, 2010).

In estimating equation (1), we allow for different TFP effects for plants belonging to US-owned, EU-owned and other foreign-owned plants, as well as whether these plants were 'brownfield' or 'greenfield' investments. Our results are presented in Table 4. Firstly, we find that plants that are foreign-owned have generally higher TFP in all sectors with the exception of low KI market services (covering industries such as hotels & restaurants, real estate, and lower level and more labour intensive business services); thus only in the latter sector is there any evidence that multinational enterprises operating in GB were engaged in any systematic technology sourcing activities. For those involved in technology exploitation, (cet. par.) US-owned plants had relatively strong TFP advantages in both high-tech manufacturing and high-tech KI services; while EU-owned plants had higher TFP in low-tech manufacturing, high-tech KI services and other low KI market services. Plants belonging to companies based in other foreign countries did relatively well in medium high-tech manufacturing (and 'greenfield' medium low-tech manufacturing), KI market services and 'brownfield' other low KI services. Thus there is no strong evidence that US-owned plants were overall better, except that they tended to operate in high-tech sectors.

As to whether 'greenfield' or 'brownfield' investment by foreign-owned companies resulted in higher TFP, Table 4 shows that in high-tech manufacturing 'greenfield' plants did better within the different ownership sub-groups; the opposite is largely the case for medium high-tech manufacturing where current technology is generally more 'mature' (but note the evidence is less clear-cut in favour of 'brownfield' sites); 'brownfield' plants that are US- or EU-owned do better in high-tech KI services; 'greenfield' sites do on average better in KI market services; while in the other sectors no clear pattern emerges. Overall while we find evidence that foreign-owned plants operate with superior technology, it is less clear whether plants that were set-up as new or whether more established plants had any (cet. par.) productivity advantages.

Figures 3-5 show the unconditional cumulative distribution of TFP for various foreign-ownership sub-groups, compared to the TFP distributions of UK-owned plants. US-owned plants had higher TFP for all sectors except low KI market services (thus generally mirroring the conditional results presented in Table 4). The largest gap between US- and UK-owned plants was in other low KI market services (note, there were fewer US-owned plants in this sub-group, and Table 4 shows that when age, size and other characteristics are controlled for, US-owned plants had lower TFP); this was followed by high-tech KI services and hi- and medium low-tech manufacturing. The results for EU- and UK-owned plants (Figure 4) are broadly similar to the US results. However, there were some major differences when other foreign-owned plants are compared to UK-owned; while other FO plants in high-tech manufacturing and high-tech KI services both dominate their UK-owned counterparts, the latter have TFP distributions that are generally to the right of the other FO plants in medium hi- and medium low-tech manufacturing, and KI market services and low KI market services (the effect is stronger in services vis-à-vis manufacturing).

3.3 Multi-plant economies of scale and competition effects

A single-plant firm dummy, equal to one if that plant is the only plant owned by the firm, is also included in X_{it} in equation (1), together with a multi-plant dummy equal to one if the plant belongs to an enterprise that operated in more than one region. The benchmark sub-group is therefore multi-plant firms that operate in only a single Government Office region. Harris (1989) summarised the literature developed in the 1970s and 1980s on why plants belonging to multi-plant enterprises may have higher productivity (e.g., Scherer et. al., 1975, 1980; Pratten, 1971; Silberston, 1972; Townroe and Roberts, 1980; Wibe, 1984). Firstly, multi-plant enterprises may benefit from any economies of scale (or scope) to a greater extent when compared to single-plant firms, especially in industries which serve a large geographic market and where transport costs are relatively high, since they are able to locate plants close to their markets. They also benefit from centralised services involving spreading risks, raising capital, procuring materials, supporting R&D, and engaging in sales promotion activities. In industries where transport costs are low but where product lines are more complex, multi-plant enterprises may benefit from specialisation by dividing production between plants. Plants belonging to multi-plant enterprises will also benefit from economies of scale associated with the costs of carrying excess capacity if there are indivisibilities in storage facilities. Such plants may also benefit from marketing benefits if advertising expenditures need to meet a minimum threshold to be effective; this also applies to the centralisation of R&D facilities. Plant belonging to multi-plant enterprises may also be able to gain access to cheaper sources of external funding than single-plant enterprises and lower prices for intermediate inputs because of bulk buying. Finally, because the ability to adopt the most modern technologies will be, in part, dependent upon access to information sources, single-plant firms will be at a disadvantage compared to multi-plant firms if technology is shared within multi-plant enterprises (Jarmin, 1999).

Conversely, multi-plant firms may be less efficient if they suffer from X-inefficiency (Leibenstein, 1966). This may be expected if principal-agent problems are more severe in multi-plant than single-plant enterprises. Thus the bureaucratic costs of large multi-plant firms (Chandler, 1962) as well as problems with incentives and information processing costs (Aoki, 1988) suggest that scale economies external to the plant but internal to the firm can be small or even negative. Furthermore, single-plant firms may be more innovative because they have access to a higher level of localised technical skill and knowledge than multi-plant firms. They are therefore more flexible in response to changes in demand (Kelley and Harrison, 1990). Indeed, recent literature has moved away from placing traditional economies of scale at the centre of whether single- or multi-plant firms should benefit most in terms of their productivity levels; instead more emphasis has been placed on the wider advantages of small versus large firms (especially as in recent decades products have become increasingly differentiated with shorter product cycles, implying that all firms benefit from operating smaller plants and thus concentrating on core competencies while outsourcing to other firms the production of semi-finished parts, or distribution networks, which in the 1970s and early 1980s would have traditionally been undertaken 'in-house' in larger plants – Carlsson et. al., 1994).[27]

This newer literature comparing single-plant firms with larger multi-plant firms[28] is concerned with the attributes of firms which are 'smaller' in terms of their organisation and managerial structures. Thus it is argued by Dhawan (2001) that the "… higher productivity or efficiency of smaller firms is the result of their leaner organizational structure that allows them to take strategic actions to exploit emerging market opportunities and to create a market niche position for themselves" (p.271). These themes of structure and niche markets are at the

[27] Discussion of the benefits to TFP of outsourcing, as well as empirical evidence, is presented in, for example, Aoki (1988), Coriat (1995) and Innocenti and Labory (2004). Evidence for the UK is presented in Criscuolo and Leaver (2006). Olsen (2006) provides a review of this area.

[28] Note, the size of the *plants* operated by single- and multi-plant enterprises may be similar (due to internal – technical – economies of scale in production); but the size of the firm is usually larger in multi-plant enterprises. Plant size is taken into account when estimating equation (1) by the inclusion of factor inputs; firm size could have been entered directly as an additional variable but for single-plant enterprises this would have resulted in enterprise and plant employment being the same (and entered twice with associated potential multicollinearity problems). Hence we chose to include dummy variables representing whether the plant belonged to a single-plant firm, and whether it belonged to a multi-plant firm operating in more than one region.

forefront of the reasons put forward in this literature as to the greater flexibility and hence TFP of smaller firms. Larger firms can suffer from diseconomies in managerial efficiency due to coordination costs and incentive difficulties (Williamson, 1967) while smaller firms are more responsive to change and are less risk-adverse (Utterback, 1994; Scherer, 1991; Audretsch, 1995). They tend to carve out niches by operating in specialised product markets, where quality is especially important, where they are not in direct competition with (and which do not require the scale of production undertaken in) large firms. Consequently small firms are riskier and tend to have a higher probability of closure.

In terms of the empirical evidence, many papers have analysed whether single-plant enterprises have a higher or lower probability of survival. To the extent that exit is determined by productivity, this offers some evidence as to the productivities of single-plant enterprises compared to multi-plant enterprises. For example, using US data, Bernard and Jensen (2007), Dunne et al. (1989) and Lieberman (1990), find that plants owned by multi-plant enterprises are more likely to close. Using UK data, Disney et al. (2003) and Harris and Hassaszadeh (2002) obtain similar results. However, these results are all based on controlling for the characteristics of the plants (especially size and age) which reduce the probability of shutdown; the unconditional probability of closure for single-plant firms is considerably higher than for plants belonging to a multi-plant enterprise. Similarly, when comparing the technical efficiency of SMEs and large firms in the electronics sector in Taiwan, Yang and Chen (2009) found that "… average technical efficiency for LEs (large enterprises) is larger than that of SMEs without correcting the size effect, whereas the SMEs have a higher technical efficiency when controlling for the endogenous choice on firm size or assuming them to have different production technologies" (p.377). Harris (2010) provides empirical evidence showing that plants owned by multi-region enterprises plants have higher levels of TFP than plants owned by enterprises that operate in only one region.

The Herfindahl index is also included in equation (1), as a measure of the concentration of output across firms and therefore of market power (Herfindahl, 1950). Under the assumption that the elasticity of demand does not vary too greatly across firms in an industry, it is also a measure of competition within that industry (see, for example, Cabral, 2000). Intuitively, one would expect that greater competition (which implies a lower Herfindahl index) will pressure firms into adopting new technologies and operating more efficiently. The theoretical premise of Nickell (1996) was that greater market competition provided firms with an incentive to reduce internal (X-) inefficiencies with a related increase in productivity (more intense competition brings product prices closer to marginal costs, lowering rents, and this process results in higher productivity as resources and output are allocated to their most productive use).[29] Meyer and Vickers (1997) provide a model in which competition allows the performance of firms to be compared with each other. Investors ‘reward’ firms that are performing well by providing capital at lower cost. This generates pressure for firms to perform better than their rivals which will lead to efforts to improve efficiency. Greater competition also raises the elasticity of demand. This provides greater incentives for management to improve efficiency in order to reduce prices and realise larger profits. Conversely higher elasticity of demand will reduce demand from poorly performing firms which charge higher prices and raise the probability of bankruptcy. Again, this provides an incentive to use improved technology and improve their efficiency. Others have shown that competition is good for innovation (Arrow, 1962; Scherer, 1980; and Aghion and Howitt, 1999). For example, Aghion and Howitt developed a theoretical model that shows that greater competition reduces incumbent’s pre-innovation profits more than it lowers its post innovation profits, thus raising innovation activities.

However, it can also be argued – following Schumpeter (1943) and more recent endogenous growth theory models – that the level of competition may be inversely related to productivity if monopoly rents are required for management to invest in R&D which in turn leads to innovation and improvements in TFP (Dixit and Stiglitz, 1977; Aghion et al., 2001; Aghion and Howitt, 1992 and 1999; Romer, 1990; Grossman and Helpman, 1991). It has also been shown that, under some conditions, increased competition can lower the expected income of managers and therefore their effort (Hermalin, 1992). This reduced effort may be reflected in reductions in plant efficiency levels. However while the theoretical evidence is rather ambiguous, the recent empirical evidence available is less so.[30] Nickell (1996), using UK data, finds that market power is negatively related to TFP levels and that competition, as measured by the number of competitors or the level of rents, is positively associated with TFP growth (see also Nickell et. al, 1997). Disney et al. (2003b), using the ARD, find that competition, measured as industry concentration and rents, raises the level and growth rate of TFP. Tang and Wang (2005) found that a firm’s perception of the level of competition it

[29] Martin (1993) develops a model that shows the opposite; greater competition results in a smaller payoff from increasing marginal efficiency and therefore the less it is in the interest of the owner to put in place an incentive structure that induces the manager to reduce marginal cost. Spence (1984) similarly shows that as the number of firms in the market increases (and the expected sales of each firm decreases) then the incentive to invest in cost reduction falls.

[30] Studies that have supported a negative correlation between competition and productivity included Hamberg (1964), Mansfield (1969), Kraft (1989), Hay and Liu (1997), Porter (1998) and Symeonidis (2001). Other studies detect no significant relationsip – e.g., Geroski and Gugler (2004) considered the impact of the growth of rival firms on a firm’s employment growth using data for 14 Europan countries; while Sutton (2007) shows that the market shares of the first and second largest firms in Japanese industries was generally statistically independent of changes in the shares of other firms in the same industry.

faces had a positive impact on labour productivity in a sample of Canadian firms. Others that have found a positive relationship between competition and innovation and/or productivity include: Geroski (1990), Blundell et. al. (1995 and 1999), Carlin et. al. (2004), and Funakoshi and Motohashi (2009). Additionally, Ospina and Schiffbauer (2010) have confirmed that countries undergoing substantial product-market reforms designed to increase competition also experienced increases in productivity. More recent research has also considered the idea that competition-productivity affects may have an inverted U-shape. Aghion et. al. (2005) present a model that shows how thus might occur; Brouwer and van der Wiel (2010) confirmed that while greater competition in Dutch manufacturing produced higher TFP, at very high levels of competition this leads to a reduction in innovation expenditures and a lower level of TFP.

Table 5 presents the results from estimating equation (1). Firstly, we generally find that manufacturing benefited from increasing returns-to-scale (the exception being medium high-tech manufacturing), while services generally experienced decreasing returns (except low KI market services).[31] Oulton (1996), using a modified growth-accounting approach and industry-level data, was not able to reject constant returns-to-scale in UK manufacturing industries. Using an approach based on estimating Verdoorn's Law, Angeritz et. al. (2008, 2009) have found increasing returns to be the norm in EU manufacturing industries. Moreover, others using the UK data from the ARD generally confirm that manufacturing enterprises operated under increasing returns (Harris, 2002; Harris and Robinson, 2004a,b; Harris et. al., 2005).[32]

As to the impact on TFP of single-plant operations and those plants that belonged to enterprises that operated plants in more than one GB Government Office region (vis-à-vis the benchmark sub-group of multi-plant firms only operating in one region), Table 5 confirms that (cet. par.) both single-plant and multi-region plants had higher TFP. Generally multi-region plants had higher levels of TFP across all sectors (from 7% higher in medium high-tech manufacturing to 46% higher in other low KI market services), compared to single-plant firms (1-53% higher in the same sectors). This suggests that although there may be 'organisation inefficiencies' associated with multi-plant firms, while single-plant firms are

[31] The tests of significance reported in the table are one-sided tests against the null of constant returns-to-scale. Thus, strictly based on the significant results we obtained, we can still conclude that increasing returns is more prevalent in manufacturing vis-à-vis services.
[32] Recent estimates for US manufacturing are reported in, for example, Diewert and Fox (2008); using a cost-function approach they find significant increasing returns in nearly all the US sectors considered.

able to exploit higher efficiency due to greater flexibility and operating in market niches, there are significant benefits in most sectors from locating plants presumably closer to major customers and/or suppliers. This provides support for New Economic Geography and New Trade Theory models where spatial productivity effects arise from plant/firm level increasing returns to scale and indivisibilities in production, which interact with transport costs to provide benefits from proximity to markets and suppliers (Fujita et. al., 1999).

Comparing the unconditional TFP distributions of single-plant firms and multi-plant enterprises (Figure 6)[33], the former have higher TFP throughout in all sectors except high-tech and medium high-tech manufacturing. Part of the reason for this different result for these sectors (cf. Table 5) is very likely to be explained by the significantly smaller size of single-plant high-tech and medium high-tech manufacturing plants when compared to plants belonging to multi-plant firms.[34] Figure 7 compares the unconditional TFP distributions of plants belonging to multi-region firms with plants that did not belong to multi-plant firms (i.e. single- and multi-plant firms operating in only one region); the results for manufacturing are largely the opposite of those provided in Figure 6. For services, plants belonging to multi-region firms dominated in terms of TFP in only KI market services, and again these results are to a large extent likely to be explained by differences in plant sizes.[35]

In terms of competition effects,[36] Table 5 shows that we obtain the expected negative relationships in medium high-tech manufacturing and low KI market services; but in low-tech manufacturing, high-tech KI services, and other low KI market services the more output is concentrated in larger firms, the lower is TFP in the sector. Given that there are several issues with how competition is measured (see, for example the last footnote), this is an area that requires further research in order to provide clearer results.

[33] Note, Figure 6 does not compare single-plant enterprises with multi-plant firms operation in just one region, as in Table 5. Similarly, Figure 7 does not use the same benchmark as in Table 5.

[34] The average employment size of single-plant high-tech and medium high-tech manufacturing plants was 72 and 60, respectively; the average size of multi-plants in these two sectors was 166 and 144, respectively.

[35] The average employment size of multi-region plants in high-tech KI services, KI services, low KI services and other low KI services was 61, 107, 29 and 18, respectively; the average size of non multi-region plants was 102, 75, 52 and 60, respectively.

[36] Note, using competition measures such as firm-level market shares and/or price-cost margins is problematic; as Brouwer and van der Wiel (2010) argue increases in competition intensity can result in the reallocation of market shares from inefficient firms (with low mark ups) to efficient firms (with high mark ups), and thus increasing mark-ups are associated with more (not less) competition. Thus our preference for the Herfindahl index, that includes the entire distribution of market share across firms, in the expectation that this should mitigate against (although perhaps not entirely alleviate) this problem. It is also interesting to note that Martin (2010) found a significant positive correlation between TFP and firm mark-ups (firms with higher TFP charge higher mark-ups), although he also found that over time that when competition increased in Chile mark-ups declined as productivity distributions moved to the right.

3.4 Spatial spillover and 'place' effects

Spatial spillovers or agglomeration externalities are benefits that accrue to plants from being located in the vicinity of large concentrations of other plants. Agglomeration externalities take two main forms: localisation (or Marshallian) externalities, and urbanisation (or Jacobian) externalities. The former arise due to the concentration of plants from the same industry in a given area (Marshall, 1890; Arrow, 1962; Romer, 1986). These externalities may take the form of reductions in cost from being in close proximity to upstream suppliers of inputs and downstream purchasers of outputs due to reductions in transports costs. Cost reductions may also arise due to their being a large pool of labour, common pool of labour that has experience of working within the industry as this will reduce the costs of training. Finally, it may be hypothesised that knowledge spillovers may arise when firms jointly engage in R&D to solve common problems or as employees move between firms. This reflects an acknowledgement that a significant part of knowledge is tacit so that it does not move easily across locations due to its being embedded in individuals, firms and organisational systems (Gertler, 2003). This is a clear channel through which localisation externalities may have an impact on the technology employed in the production process and therefore TFP.

By contrast, urbanisation or Jacobian externalities are benefits that accrue to plants from diversity in the activities of plants in a particular area (Jacobs, 1970). These benefits arise due to economies of scope rather than economies of scale. One explanation for the existence of such externalities is that a more diversified industrial base will provide access to a wider array of business services. This will be especially beneficial to smaller firms in particular, which are unable to provide these services internally (Chinitz, 1961). Urbanisation externalities may also take the form of knowledge spillovers which arise across industries because 'the exchange of complementary knowledge across diverse firms and economic agents facilitates search and experimentation in innovation' (Van Der Panne, 2004). Assuming this innovation leads to improvements in products or processes, it should be expected that such spillovers will have an impact upon TFP. Note that this conception of knowledge spillovers contrasts with the Marshallian view that knowledge spillovers are primarily an intra- rather than an inter-industry phenomenon.

There are therefore reasons to expect both types of externalities to have an impact on TFP. The empirical evidence generally suggests that localisation externalities are, in terms of their effect on productivity, more important. Vernon Henderson (2003), using the US Longitudinal Research Database, finds evidence that localisation externalities have a strong impact on TFP in high-tech industries but not in machinery industries. He is unable to find any evidence of productivity enhancing effects of urbanisation externalities. Capello (2002) also find evidence that localisation externalities have a positive impact on TFP using data on high-tech firms in the metropolitan area of Milan. The evidence for urbanisation externalities is far weaker. . Baldwin et. al. (2010), using Canadian plant-level data, find that productivity growth is positively and significantly associated with the change in variables designed to capture Marshallian externalities (these are the degree of labour market specialisation, the local density of upstream suppliers and the number of plants from the same industry within 5km). They find a negative relationship between productivity growth and the growth in local population which is included as a proxy for Jacobian externalities. They suggest this latter result may reflect congestion diseconomies. Van Der Panne (2004), using Dutch data, investigates the impacts of localisation and urbanisation externalities on innovation and finds that the former has a positive impact on innovativeness but that the latter has no significant explanatory power. Assuming a link between innovation and productivity (see, for example, Crepon et al., 1998 for evidence in support of this assumption), this is further evidence in favour of the idea that Marshallian externalities have a stronger impact on productivity than Jacobian externalities. Graham (2009) finds evidence that both types of externality have a positive impact on productivity using UK data on 27 industries. A positive and statistically significant impact of localisation externalities is found for 13 industries while the corresponding figure for urbanisation externalities is 14 industries.

In the empirical analysis below, Marshallian externalities are proxied by a variable measuring the proportion of industry output located within the local authority area. Jacobian externalities are measured by a variable calculated as the number of different SIC codes within the local authority area. Regional and city dummies are also included in equation (1) to capture the impact of being located in different regions and cities. Note this measures the impact of being situated in a specific region/city, having controlled for the spatial spillovers from which plants benefit as a result of being located in that region/city; i.e., location dummies do not capture the full impact of being situated in a particular region/city, just the TFP advantages and disadvantages over and above any benefits from spatial spillovers.

The results are presented in Table 6; for agglomeration and diversification impacts we generally find that agglomeration externalities are positive in the service sectors and plants located in 'clusters' benefit from higher TFP (doubling MAR-spillovers would cet. par. increase TFP by around 6%). With respect to the Jacobian diversification measure, urbanization economies are mostly negative, and a doubling of the proportion of industries present would lower TFP by 9-19% (depending on the sector). In high-tech manufacturing we get the opposite effect; doubling MAR-spillovers reduces TFP by on average 3%, while doubling Jacobian spillovers increases TFP by just over 19%. Table 6 also shows that on average plants located in Assisted Areas (and thus eligible for industrial assistance) had around 2-4% lower TFP.

As to the regional rankings, with the South East as the benchmark region, the (cet. par.) impact on TFP of being located in a particular region is generally significant and numerically important. Regional impacts are generally in accord with expectations based on historical differences between the 'core' and 'peripheral' regions of Great Britain. Overall, and based on taking a mean and median ranking across the eight sectors, plants located in the more rural Yorkshire-Humberside region experienced the largest negative impacts on TFP (e.g., around 9-13% lower in high- and low-tech manufacturing, and most service sectors); Wales was ranked next lowest (9-13% lower in high-tech manufacturing and most of services); followed by the North East (8-15% lower in services and low-tech manufacturing); East Midlands (7-12% lower in most of services and high- and low-tech manufacturing); West Midlands (10-12% lower in most of services); the North West (6-10% lower in services and low-tech manufacturing); and Scotland (8-20% lower in services). Other regions of Southern England (the South West and Eastern) did a little worse overall when compared to the South East (particularly in high-tech manufacturing where TFP was around 5-7% lower), while London performed on a par with the South East (slightly worse in medium low-tech manufacturing at just over 2% lower, and much better in low-tech manufacturing at 11% higher, with all other sectors not significantly different in terms of their impact on TFP). Overall regional differences were particularly marked in the service sectors, along with high- and low-tech manufacturing.

As to differences based on cities, it is not possible to consider, say, positive impacts in isolation since there is a need to take into account simultaneously the impacts of the 'place' effects associated with the region in which the city is located. This is especially important with respect to Manchester; the parameter estimate on the Manchester dummy is significantly positive in five of the eight sectors in Table 6, but in all cases these positive impacts are matched by similar negative impacts associated with the North West effect. In effect, Manchester is not better than the South East region in any sector, and neither is it significantly worse, with five of the positive 'Manchester' estimates offset by negative 'North West' impacts. What is apparent from these results is that there is little if any TFP benefit for plants located in Manchester vis-à-vis the South East, but that plants located in other areas of the North West (e.g., more rural areas) did have lower TFP levels than plants in the South East. The other city in the North West identified when estimating equation (1) is Liverpool; here there was a significant negative impact for low-tech manufacturing (9.2% lower) and a positive impact in KI market services (13% higher). However, unlike with Manchester, there were no sufficiently offsetting positive impacts in other sectors vis-à-vis the negative impacts associated with being located in the North West. Thus overall plants located in Liverpool did worse than if they had been located in the South East (having controlled for all the other plant characteristics included in equation 1), and by comparison they did worse than plants located in Manchester (but better than other non-city areas of the North West).

Plants located in the Tyneside region (i.e., the cities of Newcastle and Gateshead) did better in five sectors when compared to the South East (manufacturing excluding high-tech, and KI- and low KI-market services), but significantly worse in two (high-tech manufacturing and other low KI services); plants in the high-tech KI services sector were largely on a par with plants in the South East. In general, it was being located in other areas of the North East which resulted in a significant negative 'place' effect with regard to TFP.

With regard to cities in the West Midlands, plants located in Birmingham (cet. par.) did better than their counterparts in the South East in only two sectors (medium low- and low-tech manufacturing), and worse in the rest (in fact, the TFP impact was even lower than the West Midlands average in medium high-tech manufacturing and other low KI market services). In comparison, plants in Coventry did better than the South East in three sectors (medium high-tech and low-tech manufacturing, and low KI market services), and worse in three (high-tech manufacturing, KI- and other low-KI market services). However, in no sector did plants in Coventry perform on average worse than those located in the non-city areas of the West Midlands. Therefore in the West Midlands, it was generally beneficial to be located in one of the two main cities (particularly Coventry) compared to other parts of the region, but there was little benefit compared to TFP levels in the South East.

In the East Midlands, Leicester had no sectors that did better than the South East, while six sectors did worse. In only two sectors (KI- and low KI-market services) were plants in Leicester able to outperform plants in the rest of the region. For Nottingham, plants operating in medium high- and medium low-tech manufacturing (cet. par.) had higher TFP than their counterparts in the South East, while plants did worse in five of the other six sectors. However, when compared to the rest of the East Midlands, plants in Nottingham had a beneficial TFP 'place' effect in five of the eight sectors covered. Overall in the East

Midlands, it was generally beneficial to be located in Nottingham (but not Leicester) compared to other parts of the region, but there was overall little productivity benefit from being located in a city when compared to the South East.

Plants in Bristol did better than their counterparts in the South East in two sectors (medium low-tech manufacturing and low KI market services) and worse in four (high- and low-tech manufacturing, KI- and other low KI- market services). Compared to the rest of the South West region, plants in Bristol did better in the same two sectors in which there was an advantage over the South East; while they did worse in low-tech manufacturing and other KI-market services (in the other four sectors there was no statistically significant TFP advantage of being in the city vis-à-vis other areas in the South West). Overall, there appears to have been little overall TFP benefit from being located in Bristol, when compared to either the South East or the rest of the region.

Turning to Scotland, plants in Glasgow did better than those in the South East in two sectors (medium low- and low-tech manufacturing) and worse in five of the remaining six. Compared to the rest of Scotland, Glasgow plants did better in four sectors (additionally low- and other low-KI market services) and worse in two (medium high-tech manufacturing and high-tech KI services). Plants in Edinburgh did better than those in the South East in only low-tech manufacturing, and worse in all the other sectors with the exception of medium low-tech manufacturing; when compared to the average Scottish performance, plants in Edinburgh did better in four sectors (low-tech manufacturing, and services except KI market services) and worse in four (manufacturing except low-tech, and KI market services), indicating that overall Scotland's capital had relatively better TFP in the service sectors. Thus, compared to the South East, being located in Scotland's two major cities, and especially Edinburgh, generally resulted in lower TFP. Furthermore, TFP levels (cet. par.) were *overall* not especially higher when compared to non-city areas in Scotland, particularly for plants in Edinburgh.

Lastly, when compared to plants located in the South East, those located in the Welsh capital did better in two sectors (medium hi- and medium low-tech manufacturing) and worse in all six of the remaining sectors. Compared to the rest of Wales, plants in Cardiff had higher TFP in only three sectors: medium hi- and medium low-tech manufacturing, and KI market services. This suggests that overall plant TFP was not significantly higher from being located in Cardiff (especially in services where it might be expected that the externalities from city location would be highest).

As to which of the eight sectors were more likely to have the largest positive externalities from city locations (vis-à-vis non-city locations), plants located in the low KI market services sector (e.g., hotels & restaurants, real estate, and lower level and more labour intensive business services), and by KI market services (more knowledge-intensive business services), benefited most. These results are in line with *a priori* expectations. Other sectors also benefited to a lesser extent, except for other low KI market services and high-tech manufacturing, where it would seem that city location resulted in few external TFP benefits (and in the case of high-tech manufacturing the overall effect was closer to being negative[37]).

In summary the results for cities suggest that plants operating in London did as well as the benchmark region (the South East), but this was generally not the case for any of the other main GB cities identified in this study. Where cities did better it was usually in certain manufacturing sectors (but never high-tech manufacturing). However, there was more evidence that city-location *within* a region had a more positive impact on TFP levels, although less so in Leicester, Bristol, Edinburgh (with the exception of services), and Cardiff. These results presented so far on city location have controlled for other plant characteristics, as well as agglomeration and diversification economies. However, agglomeration and diversification economies should clearly be considered as part of the 'place' effect and therefore need to be taken account of to calculate the TFP benefits of being located in a particular city. Consequently, we present two further sets of results to complete the overall picture on whether cities are 'better' or not with respect to the level of TFP.

Firstly, we have calculated the average TFP effect based on all the (underlying) parameter estimates reported in Table 6 (holding constant all other effects listed in Tables 3-5), separately for plants located in each city for comparison with those plants located in (i) the South East; and (ii) plants located in the non-city hinterlands of the region in which a plant is located. That is we calculate separately *s* indices, one for each city, the rest of the region (excluding any cities), and the South East region:

$$T\hat{F}P_{it}^{s} = \exp[\alpha_1 \ln agglom_{it}^{s} + \alpha_2 \ln divers_{it}^{s} + \alpha_3 \ln aa_{it}^{s} + \sum_{r=1}^{10} \beta_n reg_{it}^{r} + \sum_{c=1}^{12} \delta_n city_{it}^{c}] \qquad (3)$$

where *agglom* refers to the industry agglomeration variable; *divers* refers to diversification; *aa* refers to assisted area dummy; *reg* covers each regional dummy variable; *city* refers to each city dummy variable; and α_i, β_i, δ_i are the estimated parameters in Tables A1-A8. Note we obtain the non-city index for each region by switching the regional dummy 'on' and the

[37] For high-tech, a pooled single 'main cities' dummy is significantly negative, even if the results for the individual cities in Table 6 are generally insignificant (although often large in value).

city/cities dummy ‘off’. For each city, we then generate $100.[(T\hat{F}P_{it}^{s} \div T\hat{F}P_{it}^{SE}) - 1]$ where SE refers to the South East region to generate the first set of results in Table 7; a similar formula replacing the South East with each relevant non-city part of the region is used to calculate the second set of results in the table.

Secondly, we present in Figure 8 the unconditional TFP distribution of plants located in the main cities listed in Table 6 (including London) and the TFP distribution of plants located in other areas. The first set of results (in Table 7) therefore provide the overall impact of city location on TFP (conditional on size, age, ownership, scale economies, and competition) and therefore measures the impact of spillovers and ‘place’ effects; while Figure 8 shows whether plants in cities did ‘better’ allowing for both plant characteristics and ‘place’ effects to have an impact. Considering the unconditional results first, the TFP distribution of plants in high-tech and medium high-tech manufacturing plants that operated in the main GB cities lies to the left of the distribution for plants operating elsewhere. The results for medium low-tech manufacturing show that city-location did not play a major role, while plants in low-tech manufacturing located in the main cities did (marginally) better. For services, there is stronger evidence that plants located in major cities did have a productivity advantage (the exception is other low KI market services), but to what extent this is mostly due to plant characteristics or a ‘place’ effect cannot be learnt from Figure 8. Hence we now turn to the results presented in Table 7.

The figures in italics in Table 7 indicate where a *t*-test of the null hypothesis that the difference between average TFP in each city was significantly different to average TFP in the South East or the non-city part of the region in which the plant was located. As stated above, these average TFP indicators were based only on spatial effects (i.e. those variables in Table 6), and were calculated using equation (3). Table 7 also shows if the city dummy and relevant region dummy variable in equation (1) were jointly not significant;[38] thus while there may be significant differences (based on equation 3) between average TFP in a city and the South East (or the non-city part of the region), if jointly the city and regional dummy variables were not significant in the model then differences in Table 7 needed to be treated as indicative only.

[38] For the lower half of Table 7 (the test of city versus the rest of the region), it is only the test of whether the city dummy is significant that matters (not the joint test of city and relevant region dummies).

Based on Table 6, it was concluded that there was little if any TFP benefit for plants located in Manchester vis-à-vis the South East, although being located in other areas of the North West (e.g., more rural areas) did overall have a negative impact on TFP. Table 7 generally provides confirmation of these results; concentrating on just those figures that are significant in terms of both equations (1) and (3), additionally it can be seen that Manchester does have a productivity 'place' advantage in KI market services (nearly 6% higher) and in other low KI market services (of some 7%) vis-à-vis the South East. It can also be seen that plants located in Manchester had substantial productivity advantages when compared to plants located in the non-city part of the North West, especially in the service sectors.

Turning to the results for Liverpool, Table 6 showed there was a significant negative impact for low-tech manufacturing and a positive impact in KI market services; Table 7 confirms the result for low-tech manufacturing (a disadvantage of nearly 14%) but also adds high-tech KI services as a sector where Liverpool had a significant productivity disadvantage (of over 20%) compared to the South East, while the positive impact in KI market services disappears (when agglomeration, diversification and assisted area effects are also taken into account). Thus we can confirm that overall plants located in Liverpool did worse than if they had been located in the South East, worse than plants located in Manchester, while the evidence is now weaker in support of the conclusion that they were better than other non-city areas of the North West.

Previously we found that plants located in Tyneside did better in five sectors when compared to the South East but worse in two; Table 7 suggests that the city did worse in four sectors and better in four, although productivity advantages in low-tech manufacturing, KI market services, and to a lesser extent low KI market services, are small (0.4 to 4.1%). The disadvantages for plants in high-tech manufacturing and other low KI market services were also large (between 12-21% lower TFP relative to the South East) Therefore we now conclude that Tyneside overall had lower TFP vis-à-vis the South East; although our earlier assertion, that being located in other areas of the North East resulted in a significant negative 'place' effect with regard to TFP, still stands (especially with regard to the service sectors).

With regard to cities in the West Midlands, the results based on Table 6 suggested that it was generally beneficial to be located in one of the two main cities (particularly Coventry) compared to other parts of the West Midlands, but there was little benefit compared to TFP levels in the South East. Table 7 confirms this, but also shows more prominently the large productivity advantages of plants in Coventry in medium high-tech and low-tech manufacturing (11-25% higher when compared to the South East), while similar plants in

Birmingham had only a small advantage over the South East (2-4% higher). The table also shows that Coventry did much better than non-city parts of the region in manufacturing, while Birmingham did better in high-tech KI and KI market services (Coventry was better in low KI and other low KI market services).

Based on Table 6, we found that Leicester had no sectors that did better than the South East, while six sectors did worse; in only two sectors (KI- and low KI-market services) were plants in Leicester able to outperform plants in the rest of the region. Table 7 confirms these results, providing more evidence on how poorly plants in Leicester performed (e.g., vis-à-vis the South East, the productivity disadvantage for manufacturing and high tech KI services was between 9-28%). For Nottingham, Table 7 also confirms the earlier results showing that plants operating in medium high- and medium low-tech manufacturing (cet. par.) had higher TFP than their counterparts in the South East (some 8-9% higher), while plants did worse in five of the other six sectors (between 3-20% worse). Moreover, when compared to the rest of the East Midlands, with the exception of high-tech manufacturing, plants in Nottingham had a beneficial TFP 'place' effect confirming that it was generally beneficial to be located in Nottingham (but not Leicester) compared to other parts of the region, but there was overall little benefit from being located in a city when compared to TFP levels in the South East.

Using the results in Table 7 allows us to soften the earlier conclusion that there appears to have been little overall TFP benefit from being located in Bristol, when compared to either the South East or particularly the rest of the region. Vis-à-vis the South East, Bristol did better in medium low-tech manufacturing and other low KI market services (when previously, when other spatial impacts were ignored, the result was worse), and only significantly worse in one sector (low-tech manufacturing) instead of four sectors (in addition to other low KI market services, Bristol is now not worse in KI market services). Also, there is now more evidence in Table 7 to suggest that there was a TFP advantage of being in the city for some sectors vis-à-vis other areas in the South West.

Turning to Scotland, based on Table 6 we concluded that plants in Glasgow did better than those in the South East in two sectors (medium low- and low-tech manufacturing) and worse in five of the remaining six. Table 7 shows that other low KI market services now moves from being worse to better. In addition, when compared to other non-city areas of Scotland, plants in Glasgow now only do marginally worse in medium high-tech manufacturing (1% lower TFP). For Edinburgh, we can confirm our earlier results: plants in Edinburgh did better than those in the South East in only low-tech manufacturing, while compared to non-city areas Scotland's capital had relatively better TFP in low-tech manufacturing and most of the service sectors. Overall, the better performance of Glasgow vis-à-vis Edinburgh is more pronounced in Table 7.

Lastly, Table 7 shows that when compared to plants located in the South East, those located in the Welsh capital did better in only one sector (11% better in medium low-tech manufacturing) and worse (or no better) in all of the remaining seven sectors. Compared to the rest of Wales, Table 7 shows that plants in Cardiff had higher TFP in four sectors: medium hi- and medium low-tech manufacturing, KI market services, and other low KI market services (the last sector is now included when taking account of agglomeration effects). Thus we can confirm our earlier view that overall plant TFP was not significantly higher than the South East, from being located in Cardiff, but that the city did do better than other areas of Wales.

As to which of the eight sectors were more likely to have the largest positive externalities from city locations (vis-à-vis non-city locations), the results in Table 7 provide stronger confirmation that plants in services benefited most, while again the result for high-tech manufacturing was overall negative. Table 7 also shows that vis-à-vis the South East, city locations are particularly associated with lower TFP in high-tech manufacturing *and* services.

Based on the (conditional) results in Tables 6 and 7, as well as our (unconditional) results presented in Figure 8, our overall conclusion is that with the exception of London, the main cities of Great Britain did not have higher TFP when compared to the South East region (our frontier benchmark), but they did tend to have higher productivity when compared to their non-city hinterlands (especially with respect to TFP in services). As expected, our results show that not all cities do equally as well (e.g., Leicester vs. Nottingham; Liverpool vs. Manchester; Edinburgh vs. Glasgow), and indeed there is no overwhelming evidence from this study in support of British cities being the ideal locations for encouraging growth, particularly in high-technology industries; especially as diversification (or urbanisation) economies were largely negative.

4. Summary & Conclusion

This paper has examined the determinants of total factor productivity (TFP) using a GB plant-level dataset. It has considered the role of the following four plant characteristics: internal and external knowledge; foreign ownership, multi-plant economies of scale and competition; and spatial spillovers and 'place' effects. Estimates were obtained using system GMM as this allows for both fixed effects and endogenous regressors. The sample was disaggregated into manufacturing and services and by technology to show whether different sectors perform differently.

In relation to the first driver of TFP, performing R&D was found to lead to higher TFP for all sectors with the exception of medium low-tech and low-tech manufacturing. The finding of a positive impact accords with a priori expectations as performing R&D should lead to both innovations and the development of absorptive capacity. The time trend (representing technical progress) was positive and significant for all sectors except low knowledge-intensive (KI) market services and other low KI market services. Older plants are found to have lower levels of TFP in all sectors with the exception of KI market services. This suggests that the older vintages of technology embodied in the capital of older plants is outweighing any learning-by-doing effect.

In general, foreign ownership is associated with higher TFP. The low KI market services sector is the major exception to this rule – within this sector, 'greenfield' US, 'brownfield' US, 'greenfield' other FO and 'brownfield' other FO plants all have lower TFP levels. This suggests that in low KI market services, foreign-ownership may be used to source knowledge whereas, in other sectors, inward FDI generally results in the exploitation of proprietary assets belonging to the investing firm. There is no obvious TFP ranking across sector in terms of which home country of the owner does better, or in terms of the method by which FDI is undertaken (i.e. 'greenfield' or 'brownfield').

Turning to scale effects and competition, manufacturing industries were generally found to operate under conditions of increasing returns-to-scale while service industries generally had decreasing returns. The exceptions to this rule are medium high-tech manufacturing and low KI market services. Generally single plant enterprises had higher TFP than plants belonging to multi-plant enterprises operating in only one region. This may reflect X-inefficiency; however, plants belonging to multi-plant enterprises operating in more than one region generally had higher TFP levels than single plant enterprises. This suggests that economies of scale arising from membership of a multi-plant enterprise may only become important over a large geographical area (and where supplying nearby markets is important). This is of course consistent with (and provides support for) the type of models that feature in new economic geography and new trade theory (Fujita et. al., 1999); i.e., spatial productivity effects arise from firm level increasing returns to scale and indivisibilities in production which interact with transport costs to provide benefits from proximity to markets and suppliers. Finally, plants operating in more concentrated industries had higher TFP in low-tech manufacturing, high-tech KI services and other low KI market services. To the extent that concentration is a measure of competition, this is an unexpected result and may reflect problems with the Herfindahl index as a measure of competition. On the other hand, it may reflect the need for monopoly rents to encourage innovation. The negative and significant coefficient on this variable for the medium high-tech and low KI market services sectors conforms more to expectations.

As expected, the coefficient on the agglomeration variable is positive and significant for three of the four service sectors. However, of the four manufacturing sectors agglomeration is only significantly positive for medium high-tech manufacturing. The diversification measure is negatively associated with TFP for most sectors although this association is only significant for four out of eight sectors. As suggested by Baldwin et al (2010) who obtain a similar result, this may suggest that congestion diseconomies are important. As expected, plants situated in an assisted area have lower TFP for all sectors (although the coefficient is not significant in high-tech manufacturing). The regional rankings of TFP are broadly in line with expectations, with plants in the South-East and London generally experiencing a productivity advantage associated with being located in these regions. Our results also suggest that plants located in cities generally perform better than plants in the same region outside of these cities; but with the exception of London, plants in the South-East have higher TFP levels suggesting that the spatial externalities associated with city location are not as important as the benefits of being situated in the South East. The reasons for the dominance of this region clearly deserve more research and a better (and more detailed) understanding.

In terms of the long-running debate concerning whether government should attempt to directly improve the (knowledge) assets of firms or whether policy should aim to create a favourable environment for business, our results provide evidence to support both approaches. In terms of the former, the positive impact of performing R&D suggests support for policies such as R&D tax credits. The higher TFP of foreign-owned plants suggests that capital grants schemes such as Grants for Business Investment in England and Regional Selective Assistance in Scotland, which are often used to attract FDI, should have a positive impact on aggregate productivity. However, for these schemes to have this impact, they must be targeted on high-productivity FDI plants. Given their method of safeguarding and creating employment by assisting projects which cannot obtain funding from the private sector, there is concern that they may assist a poorer subset of plants and therefore not have the desired impact on aggregate productivity (Harris and Robinson, 2004a and 2005; Criscuolo, et. al., 2009; Harris, 2010). Turning to the age variables, assuming that our finding that age is negatively related to TFP is driven by a vintage effect, capital grants schemes, such as those mentioned, are also supported by our results on the grounds that such schemes allow plants to upgrade their vintage of technology.

On the other hand, support can also be found from the results for policies to support the environment in which firms operate. For those industries with positive coefficients on the industry agglomeration variable, policies to encourage clusters and to facilitate collaborative research should be encouraged. Further research is required to enable the interpretation of the sometimes large differences in the coefficient on the region and city dummies as this will allow the development of policy to allow regions and cities to emulate the best performers. For now our results point to the conclusion that the South East still is the ‘place’ to be to benefit from higher TFP.

References

Ackerberg, D. A., Caves, K. & Frazer, G. (2006) Structural Identification of Production Functions, *Working Paper*, UCLA, Los Angeles.

Aghion, P. & Howitt, P. (1992) A Model of Growth through Creative Destruction, *Econometrica,* 60**,** 323-351.

Aghion, P. & Howitt, P. (1999) *Endogenous Growth Theory.* Cambridge, Mass.; London: The MIT Press.

Aghion, P., Bloom, N., Blundell, R., Griffith, R. & Howitt, P. (2005) Competition and Innovation: An Inverted-U Relationship, *Quarterly Journal of Economics,* 120**,** 701-728.

Aghion, P., Harris, C., Howitt, P. & Vickers, J. (2001) Competition, Imitation and Growth with Step-by-Step Innovation, *The Review of Economic Studies,* 68**,** 467-492.

Aitken, B. J. & Harrison, A. E. (1999) Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela, *American Economic Review,* 89**,** 605-618.

Angeriz, A., McCombie, J. & Roberts, M. (2008) New Estimates of Returns to Scale and Spatial Spillovers for EU Regional Manufacturing, 1986-2002, *International Regional Science Review,* 31**,** 62-87.

Angeriz, A., McCombie, J. & Roberts, M. (2009) Increasing Returns and the Growth of Industries in the EU Regions: Paradoxes and Conundrums, *Spatial Economic Analysis,* 4**,** 127-148.

Aoki, M. (1988) *Information, Incentives and Bargaining in the Japanese Economy.* Cambridge, UK; New York: Cambridge University Press.

Arrow, K. J. (1962) The Economic Implications of Learning by Doing, *The Review of Economic Studies,* 29**,** 155-173.

Audretsch, D. B. (1995) *Innovation and industry evolution,* Cambridge, Mass. ; London, MIT Press.

Aw, B. Y., Roberts, M. J. & Xu, D. Y. (2008) R&D Investments, Exporting, and the Evolution of Firm Productivity, *American Economic Review,* 98**,** 451-56.

Baily, M. N., Hulten, C. & Campbell, D. (1992) Productivity Dynamics in Manufacturing Plants, *Brookings Papers on Economic Activity***,** 187-249.

Baldwin, J. R., Beckstead, D., Brown, W. M. & Rigby, D. L. (2010) Agglomeration Economies: Microdata panel Estimates from Canadian Manufacturing, *Journal of Regional Science,* 50**,** 915-934.

Barney, J. (1991) Firm Resources and Sustained Competitive Advantage, *Journal of Management,* 17**,** 99-120.

Barney, J. (2001) Is the Resource-Based "View" a Useful Perspective for Strategic Management Research? Yes, *The Academy of Management Review,* 26**,** 41-56.

Bartelsman, E. J. & Dhrymes, P. J. (1998) Productivity Dynamics: U.S. Manufacturing Plants, 1972-1986, *Journal of Productivity Analysis,* 9**,** 5-34.

Battese, G. E. & Coelli, T. J. (1995) A model for technical inefficiency effects in a stochastic frontier production function for panel data, *Empirical Economics,* 20**,** 325-332.

Baumol, W. (1984) On productivity growth in the long run, *Atlantic Economic Journal,* 12**,** 4-10.

Bernard, A. B. & Jensen, J. B. (2007) Firm Structure, Multinationals, and Manufacturing Plant Deaths, *Review of Economics and Statistics,* 89**,** 193-204.

BERR (2008) BERR's role in raising productivity: New evidence. *BERR economics paper 1.* http://www.bis.gov.uk/files/file44504.pdf.

Biggs, T., Shah, M. & Srivastava, P. (1996) Technological Capabilities and Learning in African Enterprises, *Regional Program of Enterprise Development (RPED) Case Study Series,* World Bank, Washington, DC.

Blundell, R. & Bond, S. (1998) Initial Conditions and Moment Restrictions in Dynamic Panel Data Models, *Journal of Econometrics,* 87**,** 115-143.

Blundell, R., Griffith, R. & Van Reenen, J. (1995) Dynamic Count Data Models of Technological Innovation, *The Economic Journal,* 105**,** 333-344.

Blundell, R., Griffith, R. & Van Reenen, J. (1999) Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms, *The Review of Economic Studies,* 66**,** 529-554.

Brouwer, E. & Van der Wiel, H. (2010) Competition and Innovation: Pushing Productivity Up or Down?, *CentER Discussion Papers,* 52, CentER, Tilburg.

Brouwer, P., de Kok, J. & Fris, P. (2005) Can firm age account for productivity differences?, *SCALES paper,* N200421, SCALES, Zoetermeer.

Bruno, G. S. F. (2005) Approximating the bias of the LSDV estimator for dynamic unbalanced panel data models, *Economics Letters,* 87**,** 361-366.

Buckley, P. J. & Casson, M. C. (1998) Analyzing Foreign Market Entry Strategies: Extending the Internalization Approach, *Journal of International Business Studies,* 29**,** 539-561.

Cabral, L. M. B. (2000) *Introduction to industrial organization.* Cambridge, Mass.; London: MIT Press.

Cameron, G., Proudman, J. & Redding, S. (2005) Technological convergence, R&D, trade and productivity growth, *European Economic Review,* 49**,** 775-807.

Cantwell, J. A., Dunning, J. H. & Janne, O. E. M. (2004) Towards a technology-seeking explanation of U.S. direct investment in the United Kingdom, *Journal of International Management,* 10**,** 5-20.

Capello, R. (2002) Entrepreneurship and spatial externalities: Theory and measurement, *The Annals of Regional Science,* 36**,** 387-402.

Carlin, W., Schaffer, M. & Seabright, P. (2004) A Minimum of Rivalry: Evidence from Transition Economies on the Importance of Competition for Innovation and Growth, *Contributions to Economic Analysis and Policy,* 3**,** 1-43.

Carlsson, B., Audretsch, D. B. & Acs, Z. J. (1994) Flexible Technology and Plant Size: U.S. Manufacturing and Metalworking Industries, *International Journal of Industrial Organization,* 12**,** 359-372.

Chandler, A. D. (1962) *Strategy and Structure: Chapters in the History of the American Industrial Enterprise.* Cambridge, Mass.; London: MIT Press.

Chapple, W., Morrison Paul, C.J. and Harris, R. (2005) Manufacturing and Corporate Environmental Responsibility: Cost Implications of Voluntary Waste Minimisation. *Structural Change & Economic Dynamics*, 16: 347-373.

Chinitz, B. (1961) Contrasts in Agglomeration: New York and Pittsburgh, *The American Economic Review,* 51**,** 279-289.

Cohen, W. M. & Levinthal, D. A. (1989) Innovation and Learning: The Two Faces of R & D, *The Economic Journal,* 99**,** 569-596.

Cohen, W. M. & Levinthal, D. A. (1990) Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly,* 35**,** 128-152.

Collins, A. & Harris, R. (2002) Does Plant Ownership Affect the Level of Pollution Abatement Expenditure?, *Land Economics,* 78**,** 171-189.

Collins, A. & Harris, R. (2005) The Impact of Foreign Ownership and Efficiency on Pollution Abatement Expenditure by Chemical Plants: some UK Evidence, *Scottish Journal of Political Economy,* 52**,** 747-768.

Coriat, B. (1995) Variety, Routines and Networks: The Metamorphosis of Fordist Firms, *Industrial and Corporate Change,* 4**,** 205-227.

Crepon, B., Duguet, E. & Mairesse, J. (1998) Research, Innovation And Productivity: An Econometric Analysis At The Firm Level, *Economics of Innovation and New Technology,* 7**,** 115 - 158.

Criscuolo, C. & Leaver, M. (2006) Offshore Outsourcing and Productivity, OECD, Paris.

Criscuolo, C. & Martin, R. (2005) Multinationals and US Productivity Leadership: Evidence from Great Britain, *CEP Discussion Papers,* Centre for Economic Performance, LSE, London.

Criscuolo, C; Martin, R; Overman H and Van Reenen, J (2009) The causal effects of an industrial policy, mimeo. Available from: http://federation.ens.fr/ydepot/semin/texte0809/CAU2009OVE.pdf.

David, P. A. (1985) Clio and the Economics of QWERTY, *The American Economic Review,* 75**,** 332-337.

De Loecker, J. (2007) Product Differentiation, Multi-product Firms and Estimating the Impact of Trade Liberalization on Productivity, *National Bureau of Economic Research Working Paper Series,* No. 13155.

Del Gatto, M., Liberto, A. D. & Petraglia, C. (2010) Measuring Productivity, *Journal of Economic Surveys***,** no-no.

Dhawan, R. (2001) Firm Size and Productivity Differential: Theory and Evidence from a Panel of US Firms, *Journal of Economic Behavior and Organization,* 44**,** 269-293.

Diewert, W. E. & Fox, K. J. (2008) On the Estimation of Returns to Scale, Technical Progress and Monopolistic Markups, *Journal of Econometrics,* 145**,** 174-193.

Disney, R., Haskel, J. & Heden, Y. (2003a) Entry, Exit and Establishment Survival in UK Manufacturing, *Journal of Industrial Economics,* 51**,** 91-112.

Disney, R., Haskel, J. & Heden, Y. (2003b) Restructuring and productivity growth in uk manufacturing, *The Economic Journal,* 113**,** 666-694.

Dixit, A. K. & Stiglitz, J. E. (1977) Monopolistic Competition and Optimum Product Diversity, *American Economic Review,* 67**,** 297-308.

Doms, M. E. & Jensen, J. B. (1998). Comparing Wages, Skills, and Productivity between Domestically and Foreign Owned Manufacturing Establishments in the United States, In: Baldwin, R. E., Lipsey, R. & Richardson, J. D. (eds.) *Geography and Ownership as Bases for Economic Accounting.* Chicago: Chicago Press.

Dosi, G., Hobday, M. & Marengo, L. (2000) Problem-Solving Behaviours, Organisational Forms and the Complexity of Tasks, *LEM Papers Series,* 6, Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa.

Driffield, N. & Love, J. H. (2007) Linking FDI Motivation and Host Economy Productivity Effects: Conceptual and Empirical Analysis, *Journal of International Business Studies,* 38**,** 460-473.

Dunne, T. (1994) Plant Age and Technology use in U.S. Manufacturing Industries, *The RAND Journal of Economics,* 25**,** 488-499.

Dunne, T., Roberts, M. J. & Samuelson, L. (1989) The Growth and Failure of U. S. Manufacturing Plants, *The Quarterly Journal of Economics,* 104**,** 671-698.

Dunning, J. H. (1988) *Multinationals, technology and competitiveness.* London: Unwin Hyman.

Ericson, R. & Pakes, A. (1992) An Alternative Theory of Firm and Industry Dynamics, *Cowles Foundation Discussion Papers,* 1041, Cowles Foundation for Research in Economics, Yale University, New Haven.

Fosfuri, A. & Motta, M. (1999) Multinationals without Advantages, *Scandinavian Journal of Economics,* 101**,** 617-630.

Funakoshi, M. & Motohashi, K. (2009) A Quantitative Analysis of Market Competition and Productivity, *Japanese Economy,* 36**,** 27-47.

Fujita, M., Krugman, P. & Venables, A. J. (1999) *The Spatial Economy; Cities, Regions and International trade*. Cambridge, Mass.; London: MIT Press.

Gatto, M. D., Liberto, A. D. & Petraglia, C. (2010) Measuring Productivity. *Journal of Economic Surveys***,** in press.

Geroski, P. & Gugler, K. (2004) Corporate Growth Convergence in Europe, *Oxford Economic Papers,* 56**,** 597-620.

Geroski, P. A. (1990) Innovation, Technological Opportunity, and Market Structure, *Oxford Economic Papers, N. S.,* 42**,** 586-602.

Geroski, P. A. and Gugler, K. (2004) Corporate Growth Convergence in Europe, *Oxford Economic Papers*, 56, 597-620.

Gertler, M. S. (2003) Tacit Knowledge and the Economic Geography of Context, or the Undefinable Tacitness of Being (There), *Journal of Economic Geography,* 3**,** 75-99.

Gittleman, M., ten Raa, T. & Wolff, E. N. (2006) The vintage effect in TFP-growth: An analysis of the age structure of capital, *Structural Change and Economic Dynamics,* 17**,** 306-328.

Graham, D. J. (2009) Identifying urbanisation and localisation externalities in manufacturing and service industries, *Papers in Regional Science,* 88**,** 63-84.

Griffith, R. & Simpson, H. (2003) Characteristics of Foreign-Owned Firms in British Manufacturing, *NBER Working Papers,* 9573,

Griffith, R. (1999) Using the ARD Establishment Level Data to Look at Foreign Ownership and Productivity in the United Kingdom, the *Economic Journal*, 109, F416-F442.

Griffith, R., Redding, S. & Van Reenen, J. (2004) Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries, *Review of Economics and Statistics,* 86**,** 883-895.

Griliches, Z. (1980). Returns to Research and Development Expenditure in the Private Sector, In: Kendrick, J. W. & Vaccara, B. N. (eds.) *New Developments in Productivity Measurement and Analysis.* Chicago: The University of Chicago Press.

Griliches, Z. (1981) Market value, R&D, and patents, *Economics Letters,* 7**,** 183-187.

Grossman, G. M. & Helpman, E. (1991) Trade, Knowledge Spillovers, and Growth, *European Economic Review,* 35**,** 517-526.

Grossman, G. M. & Helpman, E. 1991. Trade, knowledge spillovers, and growth. *European Economic Review,* 35**,** 517-526.

Hamberg, D. (1964) Size of Firm, Oligopoly, and Research: The Evidence, *The Canadian Journal of Economics and Political Science / Revue canadienne d'Economique et de Science politique,* 30**,** 62-75.

Harris, R. (1989) *The growth and structure of the UK regional economy 1963-85.* Aldershot: Avebury.

Harris, R. (1991) External Ownership of Industry and Government Policy: Some Further Evidence for Northern Ireland, *Regional Studies,* 25**,** 45-62.

Harris, R. & Drinkwater, S. (2000) UK Plant and Machinery Capital Stocks and Plant Closures, *Oxford Bulletin of Economics and Statistics,* 62**,** 243-265.

Harris, R. (2001) Comparing Regional Technical Efficiency in UK Manufacturing Plants: The Case of Northern Ireland 1974-1995, *Regional Studies,* 35**,** 519 - 534.

Harris, R. (2002) Foreign Ownership and Productivity in the United Kingdom—Some Issues When Using the ARD Establishment Level Data, *Scottish Journal of Political Economy,* 49**,** 318-335.

Harris, R. & Hassaszadeh, P. (2002) The impact of ownership changes and age effects on plant exits in UK manufacturing, 1974-1995, *Economics Letters,* 75**,** 309-317.

Harris, R. & Robinson, C. (2002) The Effect of Foreign Acquisitions on Total Factor Productivity: Plant-Level Evidence from U.K. Manufacturing, 1987-1992, *The Review of Economics and Statistics,* 84**,** 562-568.

Harris, R. & Robinson, C. (2003) Foreign Ownership and Productivity in the United Kingdom Estimates for U.K. Manufacturing Using the ARD, *Review of Industrial Organization,* 22**,** 207-223.

Harris, R. & Robinson, C. (2004a) Industrial Policy in Great Britain and Its Effect on Total Factor Productivity in Manufacturing Plants, 1990-1998, *Scottish Journal of Political Economy,* 51**,** 528-543.

Harris, R. & Robinson, C. (2004b) Productivity Impacts and Spillovers from Foreign Ownership in the United Kingdom, *National Institute Economic Review,* 187**,** 58-75.

Harris, R. (2004). DTI Industrial Support Policies: Key Findings from New Micro-data Analysis, In: DTI (ed.) *Raising UK productivity – Developing the Evidence Base for Policy, DTI Economics Paper No. 8.* London.

Harris, R.I.D. (2005a) Economics of the Workplace: Special Issue Editorial. *Scottish Journal of Political Economy*, 52(3): 323-343.

Harris, R.I.D. (2005b) Deriving Measures of Plant-level Capital Stock in UK Manufacturing, 1973-2001, *Report to DTI,* Available at: http://www.gla.ac.uk/media/media_64430_en.pdf.

Harris, R., Siegel, D. S. & Wright, M. (2005) Assessing the Impact of Management Buyouts on Economic Efficiency: Plant-Level Evidence from the United Kingdom, *Review of Economics and Statistics,* 87**,** 148-153.

Harris, RID and Robinson, C. (2005) The Impact of Regional Selective Assistance on Sources of Productivity Growth: Plant Level Evidence from UK Manufacturing 1990-1998, *Regional Studies*, vol. 39, 751-765

Harris, R., O'Mahony, M. & Robinson, C. (2006) Research on Scottish Productivity, *Report to Scottish Executive Office of the Chief Economic Advisor,* Available at: http://www.scotland.gov.uk/Resource/Doc/919/0047033.pdf.

Harris, R. & Li, Q. C. (2007) Firm Level Empirical Study of the Contribution of Exporting to Productivity Growth, *Report to UKTI*.

Harris, R. & Li, Q. C. (2009) Exporting, R&D, and Absorptive Capacity in UK Establishments, *Oxford Economic Papers,* 61**,** 74-103.

Harris, R.I.D., Li, Q.C. and M. Trainor (2009) Is a Higher Rate of R&D Tax Credit a Panacea for Low Levels of R&D in Disadvantaged Regions?, *Research Policy,* 38(1), 192-205

Harris, R. (2009) The Effect of Foreign Mergers and Acquisitions on UK Productivity and Employment, *Report to UKTI,* Available at: http://www.parliament.uk/deposits/depositedpapers/2010/DEP2010-0099.pdf.

Harris, R. (2010) The impact of SDI support: Inward Investment 2001-2006, *Report to SDI,* Available at: http://workspace.imperial.ac.uk/business-school/Public/CAED/H-Harris_Inward%20Invest%20report%20for%20CAED.doc.

Haskel, J. (2000) What Raises Productivity? The Microeconomics of UK Productivity Growth, *Queen Mary, University of London Research Paper,* Queen Mary, University of London, London.

Hay, D. A. & Liu, G. S. (1997) The Efficiency of Firms: What Difference Does Competition Make?, *Economic Journal*, 107**,** 597-617.

Herfindahl, O. (1950) Concentration in the US Steel Industry, *PhD Thesis,* Columbia University, New York.

Hermalin, B. E. (1992) The Effects of Competition on Executive Behavior, *The RAND Journal of Economics,* 23**,** 350-365.

Hill, H. & Kalirajan, K. P. (1993) Small enterprise and firm-level technical efficiency in the Indonesian garment industry, *Applied Economics,* 25**,** 1137-1144.

Ho, Y. P., Wong, P. K. & Toh, M. H. (2009) The Impact of R&D on the Singapore Economy: An Empirical Evaluation, *The Singapore Economic Review,* 54**,** 1-20.

Hymer, S. (1976) *The international operations of national firms : a study of direct foreign investment.* Cambridge, Mass.; London: M.I.T. Press.

Innocenti, A. & Labory, S. (2004) Outsourcing and Information Management: A Comparative Analysis of France, Italy and Japan in Both Small and Large Firms, *European Journal of Comparative Economics,* 1**,** 107-125.

Jacobs, J. (1970) *The economy of cities.* London: Jonathan Cape.

Jacobs, J. (1986) *Cities and the wealth of nations.* Harmondsworth: Penguin.

Jarmin, R. (1999) Government Technical Assistance Programs and Plant Survival: The Role of Plant Ownership Type, *Working Papers,* 2, Center for Economic Studies, U.S. Census Bureau, Working Papers, Washington.

Jensen, J. B., McGuckin, R. H. & Stiroh, K. J. (2001) The Impact of Vintage and Survival on Productivity: Evidence from Cohorts of U.S. Manufacturing Plants, *Review of Economics and Statistics,* 83**,** 323-332.

Jensen, J. B., Mcguckin, R. H. & Stiroh, K. J. 2001. The impact of vintage and survival on productivity: Evidence from cohorts of u.S. Manufacturing plants. *Review of Economics and Statistics,* 83**,** 323-332.

Jovanovic, B. & Nyarko, Y. (1996) Learning by Doing and the Choice of Technology, *Econometrica,* 64**,** 1299-1310.

Jovanovic, B. (1982) Selection and the Evolution of Industry, *Econometrica,* 50**,** 649-670.

Kafouros, M. I. (2005) R&D and Productivity Growth: Evidence from the UK, *Economics of Innovation and New Technology,* 14**,** 479-497.

Katayama, H., Lu, S. & Tybout, J. R. (2009) Firm-level productivity studies: Illusions and a solution, *International Journal of Industrial Organization,* 27**,** 403-413.

Kelley, M. R. & Harrison, B. (1990) The subcontracting behavior of single vs. multiplant enterprises in US manufacturing: Implications for economic development, *World Development,* 18**,** 1273-1294.

Kneller, R. (2005) Frontier Technology, Absorptive Capacity and Distance, *Oxford Bulletin of Economics and Statistics,* 67**,** 1-23.

Kogut, B. & Chang, S. J. (1991) Technological Capabilities and Japanese Foreign Direct Investment in the United States, *The Review of Economics and Statistics,* 73**,** 401-413.

Kraft, K. (1989) Market Structure, Firm Characteristics and Innovative Activity, *The Journal of Industrial Economics,* 37**,** 329-336.

Krugman, P. (1991) *Geography and trade.* Cambridge, Mass.; London: MIT Press.

Krugman, P. (1997) *The age of diminished expectations : U.S. economic policy in the 1990s.* Cambridge, Mass.; London: MIT Press.

Lambson, V. E. (1991) Industry evolution with sunk costs and uncertain market conditions, *International Journal of Industrial Organization,* 9**,** 171-196.

Leibenstein, H. (1966) Allocative Efficiency vs. "X-Efficiency", *The American Economic Review,* 56**,** 392-415.

Levinsohn, J. & Petrin, A. (2003) Estimating Production Functions Using Inputs to Control for Unobservables, *The Review of Economic Studies,* 70**,** 317-341.

Lieberman, M. B. (1990) Exit from Declining Industries: 'Shakeout' or 'Stakeout'?, *RAND Journal of Economics,* 21**,** 538-554.

Lokshin, B., Belderbos, R. & Carree, M. (2008) The Productivity Effects of Internal and External R&D: Evidence from a Dynamic Panel Data Model, *Oxford Bulletin of Economics and Statistics,* 70**,** 399-413.

Love, J. H. (2003) Technology Sourcing versus Technology Exploitation: An Analysis of US Foreign Direct Investment Flows, *Applied Economics,* 35**,** 1667-1678.

Lundvall, K. & Battese, G. E. (2000) Firm size, age and efficiency: Evidence from Kenyan manufacturing firms, *Journal of Development Studies,* 36**,** 146 - 163.

Mansfield, E. (1969) *Industrial research and technological innovation : an econometric analysis.* Harlow: Published for the Cowles Foundation for Research in Economics at Yale University by Longmans.

Marshall, A. (1890) *Principles of Economics.* London: Macmillan.

Martin, R (2008) Productivity Dispersion, Competition and Productivity Measurement, CEP Discussion Paper No 692.

Martin, R. (2010) Productivity Spreads, Market Power Spreads and Trade, *CEP Discussion Paper,* Centre for Economic Performance, London School of Economics and Political Science, London.

Martin, S. (1993) Endogenous Firm Efficiency in a Cournot Principal-Agent Model, *Journal of Economic Theory,* 59**,** 445-450.

Mate-Garcia, J. J. & Rodriguez-Fernandez, J. M. (2008) Productivity and R&D: An Econometric Evidence from Spanish Firm-Level Data, *Applied Economics,* 40**,** 1827-1837.

Matthias Arnold, J. & Javorcik, B. S. (2009) Gifted kids or pushy parents? Foreign direct investment and plant productivity in Indonesia, *Journal of International Economics,* 79**,** 42-53.

McGuckin, R. H. & Nguyen, S. V. (1995) On the Productivity and Plant Ownership Change: New Evidence from the Longitudinal Research Database, *RAND Journal of Economics,* 26**,** 257-276.

Meyer, M. A. & Vickers, J. (1997) Performance Comparisons and Dynamic Incentives, *The Journal of Political Economy,* 105**,** 547-581.

Mourre, G. (2009) What explains the differences in income and labour utilisation and drives labour and economic growth in Europe? A GDP accounting perspective, *Report to Directorate General Economic and Monetary Affairs, European Commission,* Available at: http://ec.europa.eu/economy_finance/publications/publication13796_en.pdf.

Nelson, R. R. & Winter, S. G. (1982) *An evolutionary theory of economic change.* Cambridge, Mass.; London: Belknap Press.

Neven, D. & Siotis, G. (1996) Technology sourcing and FDI in the EC: An empirical evaluation, *International Journal of Industrial Organization,* 14**,** 543-560.

Nickell, S. (1996) Competition and Corporate Performance, *The Journal of Political Economy,* 104**,** 724-746.

Nickell, S., Nicolitsas, D. & Dryden, N. (1997) What makes firms perform well?, *European Economic Review,* 41**,** 783-796.

O'Mahony, M. and Timmer, M.P. (2009) Output, Input and productivity Measures at the Industry Level: the EU KLEMS Database, *Economic Journal*, 119, F374-F403.

Okamoto, Y. (1999) Multinationals, Production Efficiency, and Spillover Effects: The Case of the U.S. Auto Parts Industry, *Weltwirtschaftliches Archiv/Review of World Economics,* 135**,** 241-260.

Olley, G. S. & Pakes, A. (1996) The Dynamics of Productivity in the Telecommunications Equipment Industry, *Econometrica,* 64**,** 1263-1297.

Olsen, K. (2006) Productivity Impacts of Offshoring and Outsourcing, *OECD Science, Technology and Industry Working Papers,* 1, OECD, Paris.

O'Mahony, M. & Timmer, M. P. (2009) Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database, *Economic Journal,* 119**,** F374-F403.

Ortega-Argiles, R., Piva, M., Potters, L. & Vivarelli, M. (2010) Is corporate R&D investment in high-tech sectors more effects?, *Contemporary Economic Policy,* 28**,** 353-365.

Ospina, S. & Schiffbauer, M. (2010) Competition and Firm Productivity: Evidence from Firm-Level Data, *IMF Working Papers,* 10/67, International Monetary Fund, Washington.

Oulton, N. (1997) The ABI Respondents Database: A New Resource for Industrial Economics Research, *Economic Trends*, 528, 46-57.

Pakes, A. & Ericson, R. (1998) Empirical Implications of Alternative Models of Firm Dynamics, *Journal of Economic Theory,* 79**,** 1-45.

Pavitt, K. (1984) Sectoral patterns of technical change: Towards a taxonomy and a theory, *Research Policy,* 13**,** 343-373.

Penrose, E. T. (1959) *The Theory of the Growth of the Firm.* Oxford: Oxford University Press.

Power, L. (1998) The Missing Link: Technology, Investment, and Productivity, *Review of Economics and Statistics,* 80**,** 300-313.

Pratten, C.F. (1971) *Economies of Scale in Manufacturing Industries*, Department of Applied Economics Occasional Papers No. 28, CUP.

Reed, J. & Parker, G. (2010) Cable signals end to aid for car industry, *Financial Times*.

Romer, P. M. (1986) Increasing Returns and Long-run Growth, *Journal of Political Economy,* 94**,** 1002-1037.

Romer, P. M. (1990) Endogenous Technological Change, *Journal of Political Economy,* 98**,** S71-102.

Salvanes, K. G. & Tveteras, R. (2004) Plant Exit, Vintage Capital and the Business Cycle, *The Journal of Industrial Economics,* 52**,** 255-276.

Scherer, F. M. (1975) *The economics of multi-plant operation : an international comparisons study.* Cambridge, Mass.; London: Harvard University Press.

Scherer, F. M. (1980) *Industrial market structure and economic performance.* Chicago: Rand McNally College Publ.

Scherer, F. M. (1991). Changing Perspectives on the Firm Size Problem, In: Acs, Z. J. & Audretsch, D. B. (eds.) *Innovation and technological change: An international comparison.* Ann Arbor: University of Michigan Press.

Schumpeter, J. A. (1943) *Capitalism, Socialism, and Democracy.* London: George Allen & Unwin Ltd.

Silberston, A. (1972) Economies of Scale in Theory and Practice, *Economic Journal*, 82, 369-391.

Spence, M. (1984) Cost Reduction, Competition, and Industry Performance, *Econometrica,* 52**,** 101-121.

Sutton, J. (2007) Market Share Dynamics and the 'Persistence of Leadership' Debate, *American Economic Review,* 97**,** 222-241.

Symeonidis, G. (2001) Price Competition, Innovation and Profitability: Theory and UK Evidence, *C.E.P.R. Discussion Papers* 2816, C.E.P.R. , London.

Tang, J. & Wang, W. (2005) Product Market Competition, Skill Shortages and Productivity: Evidence from Canadian Manufacturing Firms, *Journal of Productivity Analysis,* 23**,** 317-339.

Teece, D. J. & Pisano, G. (1998). The Dynamic Capabilities of Firms: An Introduction, In: Dosi, G., Teece, D. J. & Chytry, J. (eds.) *Technology, Organization, and*

Competitiveness. Perspectives on Industrial and Corporate Change. Oxford: Oxford University Press.

Townroe, P. M. & Roberts, N. J. (1980) *Local-external economies of British manufacturing industry.* Aldershot: Gower.

Tsai, K. & Wang, J. (2004) R&D Productivity and the Spillover Effects of High-tech Industry on the Traditional Manufacturing Sector: The Case of Taiwan, *World Economy,* 27**,** 1555-1570.

Utterback, J. M. (1994) *Mastering the dynamics of innovation: how companies can seize opportunities in the face of technological change.* Boston, Mass.: Harvard Business School Press.

Van Beveren, I. (2007) Total factor productivity estimation: A practical review, *LICOS Discussion Papers,* 18207, Katholieke Universiteit Leuven, Leuven.

Van Biesebroeck, J. (2005) Exporting raises productivity in sub-Saharan African manufacturing firms, *Journal of International Economics,* 67**,** 373-391.

Van der Panne, G. (2004) Agglomeration externalities: Marshall versus Jacobs, *Journal of Evolutionary Economics,* 14**,** 593-604.

Vernon Henderson, J. (2003) Marshall's scale economies, *Journal of Urban Economics,* 53**,** 1-28.

Wernerfelt, B. (1984) A resource-based view of the firm, *Strategic Management Journal,* 5**,** 171-180.

Wibe, S. (1984) Engineering Production Functions: A Survey, *Economica*, 51, 401-11.

Wieser, R. (2005) Research And Development Productivity And Spillovers: Empirical Evidence At The Firm Level, *Journal of Economic Surveys,* 19**,** 587-621.

Williamson, O. E. (1967). The Economics of Defense Contracting: Incentives and Performance, In: McKean, R. N. (ed.) *Issues in Defense Economics.* New York: Columbia University Press.

Wooldridge, J. M. (2009) On estimating firm-level production functions using proxy variables to control for unobservables, *Economics Letters,* 104**,** 112-114.

Yang, C.-H. & Chen, K.-H. (2009) Are Small Firms Less Efficient?, *Small Business Economics,* 32**,** 375-395.

Zahra, S. A. & George, G. (2002) Absorptive Capacity: A Review, Reconceptualization, and Extension, *The Academy of Management Review,* 27**,** 185-203.

Table 1: Variable definitions used in BERD-ARD panel dataset for 1997-2006

Variable	***Definitions***	***Source***
Real gross output	Plant level gross output data deflated by 2-digit ONS producer price (output) indices. Data are in £'000 (2000 prices)	ARD
Real intermediate inputs	Plant level intermediate inputs (gross output minus GVA) deflated by 2-digit ONS producer price (input) indices (non-manufacturing only has a single PPI). Data are in £'000 (2000 prices)	ARD
Employment	Number of employees in plant.	ARD
Capital	Plant & machinery capital stock (£m 1995 prices) plus real value of plant and machinery hires (deflated by producer price index) in plant. Source: Harris and Drinkwater (2000, updated).	ARD
Age	Number of years plant has been in operation based on year of entry	ARD/ IDBR
Single-plant	Dummy coded 1 when plant comprises a single-plant enterprise	ARD
>1 region multiplant	Dummy variable =1 if plant belongs to multiplant enterprise operating in more than 1 UK region	ARD
Greenfield US-owned	Dummy coded 1 if US-owned and newly opened during 1997-2006	ARD
Brownfield US-owned	Dummy coded 1 if US-owned and not newly opened during 1997-2006	ARD
Greenfield EU-owned	Dummy coded 1 if EU-owned and newly opened during 1997-2006	ARD
Brownfield EU-owned	Dummy coded 1 if EU-owned and not newly opened during 1997-2006	ARD
Greenfield Other foreign-owned	Dummy coded 1 if foreign-owned by another country and newly opened during 1997-2006	ARD
Brownfield Other foreign-owned	Dummy coded 1 if foreign-owned by another country and not newly opened during 1997-2006	ARD
Herfindahl	Herfindahl index of industry concentration (3-digit level).	ARD
Industry agglomeration	% of industry output (at 5-digit SIC level) located in local authority district in which plant is located – MAR-spillovers	ARD
Diversification	% of 5-digit industries (from over 650) located in local authority district in which plant is located – Jacobian spillovers	ARD
R&D undertaken*	Dummy variable = 1 if plant had positive R&D stock based on undertaking intramural and/or extramural R&D since 1997	BERD
Assisted Area	Dummy variable = 1 if plant located in assisted area	ARD
Region	Dummy variable = 1 if plant located in particular Government Office region	ARD
City	Dummy variable = 1 plant located in major GB city (defined by NUTS3 code)	ARD
Industry	Dummy variable = 1 depending on 1992 SIC of plant (used at 2-digit level).	ARD

* R&D stocks were computed using perpetual inventory method with 30% depreciation rate for the largest components of R&D spending (intra-mural current spending and extra-mural R&D). See Harris et. al. (2009) for details of methods used.

Table 2: Mean (weighted) values 1997-2006, by sector[a]

Sector	Manufacturing				Services			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Real gross output	22787.0	17634.2	12159.1	14773.9	9347.8	10561.8	1798.1	2028.6
Real intermediate inputs	15243.4	12489.9	8173.8	9959.4	5008.5	5152.9	1023.4	1554.8
Capital	5.9	7.3	7.0	6.0	7.0	4.4	0.5	0.3
Employment	141	114	112	118	64	98	32	22
Age	4.4	4.7	6.1	6.2	5.7	11.7	7.8	8.2
Single-plant	0.245	0.254	0.121	0.105	0.030	0.097	0.022	0.025
>1 region multiplant	0.513	0.524	0.702	0.654	0.800	0.801	0.849	0.823
Greenfield US-owned	0.040	0.046	0.024	0.029	0.040	0.015	0.010	0.066
Brownfield US-owned	0.049	0.053	0.036	0.037	0.067	0.053	0.042	0.037
Greenfield EU-owned	0.042	0.049	0.047	0.033	0.017	0.011	0.037	0.002
Brownfield EU-owned	0.042	0.060	0.090	0.043	0.041	0.035	0.040	0.009
Greenfield Other foreign-owned	0.022	0.021	0.016	0.015	0.007	0.003	0.002	0.001
Brownfield Other foreign-owned	0.024	0.018	0.019	0.027	0.024	0.012	0.008	0.002
Herfindahl	0.023	0.018	0.028	0.015	0.083	0.011	0.026	0.064
Industry agglomeration	1.00	1.40	3.26	2.35	0.83	1.78	0.60	0.65
Diversification	52.3	54.6	57.5	55.5	53.9	70.2	58.9	57.5
R&D undertaken	0.242	0.206	0.171	0.117	0.048	0.035	0.002	0.002
Assisted Area	0.196	0.228	0.205	0.200	0.156	0.174	0.165	0.171

[a] (1) High-tech: Pharmaceuticals (SIC244); Office machinery & computers (SIC30); Radio, TV & communications equipment (SIC32); Medical & precision instruments (SIC33); Aircraft & spacecraft (SIC353);
(2) Medium high-tech: Chemicals (SIC24 exc. Pharmaceuticals, SIC244); Machinery & equipment (SIC29); Electrical machinery (SIC31); Motor vehicles (SIC34); Other transport equipment (SIC 35 exc. Ships & boats, SIC351, and Aircraft & spacecraft, SIC353);
(3) Medium low-tech: Coke & petroleum (SIC23); Rubber & plastics (SIC25); Other non-metallic (SIC26); Basic metals (SIC 27); Fabricated metals (SIC28); Ships & boats (SIC351);
(4) Low-tech: Food & beverages (SIC15); Tobacco (SIC16); Textiles (SIC17); Clothing (SIC18); Leather goods (SIC 19); Wood products (SIC 20); Paper products (SIC21); Publishing, printing (SIC22); Furniture and other manufacturing (SIC36); recycling (SIC37);
(5) High-tech KI: Telecoms (SIC642); Computer & related (SIC72 exc. Maintenance & repair, SIC725); R&D (SIC73); Photographic activities (SIC7481); Motion pictures (SIC 921); Radio & TV activities (SIC922); Artistic & literary creation (SIC9231);
(6) KI services: Water transport (SIC61); Air transport (SIC62); Legal, accountancy & consultancy (SIC741 exc. Management activities of holding companies, SIC7415); Architecture & engineering (SIC742); Technical testing (SIC 743); Advertising (SIC744);
(7) Low KI: Hotels & restaurants (SIC55); Land transport (SIC60); Support for transport (SIC63); real estate (SIC70); Renting machinery (SIC 71); Maintenance & repair of office machines (SIC725); Management activities of holding companies (SIC7415); Labour recruitment (SIC745); Investigation services (SIC746); Industrial cleaning (SIC747); Packaging (SIC7482); Secretarial services (SIC7483); Other business services (SIC7484); Sewage & refuse (SIC90);
(8) Other low KI: Postal services (SIC641); Membership organisations (SIC91); Other entertainment services (SIC923 exc. Artistic & literary creation, SIC9231); News agencies (SIC924); Sporting activities (SIC926); Other recreational activities (SIC927); Other services (SIC93).

Table 3: Increase in TFP due to Knowledge-based Determinants, 1997-2006, Great Britain

	R&D undertaken_t^a	*t*	*ln* age_t
High-tech manufacturing	0.042	0.048	-0.187
Medium high-tech manufacturing	0.114	0.019	-0.184
Medium low-tech manufacturing	*0.001*	0.023	-0.140
Low-tech manufacturing	*0.006*	0.023	-0.154
High-tech KI services	0.252	0.006	-0.173
KI market services	0.127	0.005	*-0.042*
Low KI market services	0.165	-0.004	-0.062
Other low KI market services	0.564	*0.000*	-0.070

[a] Parameter values for dummy variables are converted using exp(x) − 1.

Figures in italics not significant at 10% level. Source: Tables A1-A8

Table 4: Increase in TFP due to being Foreign-owned, 1997-2006, Great Britain[a]

	High-tech manufacturing	Medium high-tech manufacturing	Medium low-tech manufacturing	Low-tech manufacturing	High-tech KI services	KI market services	Low KI market services	Other low KI market services
Greenfield US-owned$_t$	0.179	0.043	*0.024*	0.124	0.214	0.099	-0.069	*0.043*
Brownfield US-owned$_t$	0.130	0.125	*0.034*	0.080	0.428	*0.045*	-0.088	-0.141
Greenfield EU-owned$_t$	0.112	0.080	*0.068*	0.179	0.191	0.172	0.069	0.120
Brownfield EU-owned$_t$	0.088	0.104	0.043	0.225	0.201	*0.008*	*-0.049*	0.124
Greenfield Other FO$_t$	0.140	0.133	0.358	*0.016*	0.362	0.190	-0.169	*-0.032*
Brownfield Other FO$_t$	*0.083*	0.125	*-0.024*	*0.026*	-0.033	0.221	-0.117	0.196

[a] Parameter values for dummy variables are converted using exp(x) − 1.

Figures in italics not significant at 10% level.

Source: Tables A1-A8

Table 5: Increase in TFP due to Multiplant Economies and Competition Effects, 1997-2006, Great Britain

	Returns-to-scale	Single-plant enterprise$_t$[a]	Enterprise operates in >1 region$_t$	*ln* Herfindahl$_t$
High-tech manufacturing	1.056	0.080	0.093	*0.015*
Medium high-tech manufacturing	0.856	0.013	0.070	-0.025
Medium low-tech manufacturing	*1.015*	0.083	0.127	*0.021*
Low-tech manufacturing	1.024	0.123	0.143	0.034
High-tech KI services	*0.946*	*0.021*	*-0.128*	0.092
KI market services	0.927	0.111	0.235	*-0.007*
Low KI market services	1.023	*-0.023*	*-0.032*	-0.099
Other low KI market services	0.949	0.530	0.459	0.012

[a] Parameter values for dummy variables are converted using exp(x) − 1.

Figures in italics not significant at 10% level. Source: Tables A1-A8

Table 6: Increase in TFP due to Spatial Effects, 1997-2006, Great Britain

	High-tech manufacturing	Medium high-tech manufacturing	Medium low-tech manufacturing	Low-tech manufacturing	High-tech KI services	KI market services	Low KI market services	Other low KI market services
ln Industry agglomeration$_t$	-0.034	0.065	-0.036	*-0.005*	0.058	0.068	*0.003*	0.056
ln Diversification$_t$	0.193	-0.094	-0.185	*0.035*	*-0.167*	-0.168	*0.002*	*-0.004*
Located in Assisted Area$_t$	*-0.010*	-0.025	-0.026	-0.046	-0.030	-0.034	-0.013	0.050
North East$_t$	-0.051	-0.024	-0.042	-0.091	-0.155	-0.134	-0.081	-0.082
Yorks-Humberside$_t$	-0.092	-0.050	0.067	-0.130	-0.119	-0.105	-0.088	-0.129
North West$_t$	*-0.053*	-0.048	0.049	-0.065	-0.094	-0.102	-0.085	-0.064
West Midlands$_t$	-0.070	-0.043	*-0.003*	-0.044	-0.106	-0.101	-0.037	-0.122
East Midlands$_t$	-0.108	-0.030	*-0.010*	-0.100	-0.115	-0.118	-0.074	-0.050
South West$_t$	-0.068	*-0.010*	0.022	*-0.005*	*-0.012*	-0.027	*0.000*	-0.041
Eastern$_t$	-0.050	0.018	*-0.014*	*0.000*	-0.021	-0.016	-0.026	-0.049
London$_t$	*0.025*	*0.003*	-0.023	0.108	*-0.007*	*0.008*	*-0.001*	*-0.015*
Scotland$_t$	*0.019*	-0.031	0.080	*0.006*	-0.196	-0.080	-0.134	-0.176
Wales$_t$	-0.092	-0.054	*0.022*	-0.054	-0.133	-0.113	-0.103	-0.046
Tyneside$_t$	-0.128	0.095	0.078	0.155	0.154	0.171	0.145	-0.164
Manchester$_t$	*0.014*	0.042	*0.040*	0.078	*0.021*	0.108	0.091	0.023
Liverpool$_t$	*0.083*	0.031	*-0.050*	-0.092	0.031	0.126	*0.005*	*-0.032*
Birmingham$_t$	*-0.034*	-0.020	0.064	0.104	0.036	0.060	*0.001*	-0.064
Coventry$_t$	*0.046*	0.090	*0.079*	0.398	0.090	*0.023*	0.060	0.068
Leicester$_t$	-0.171	-0.156	-0.051	-0.059	-0.156	0.132	0.069	*-0.021*
Nottingham$_t$	-0.154	0.111	0.114	*0.052*	0.111	0.050	0.049	*0.007*
Bristol$_t$	*-0.015*	*0.009*	0.122	-0.039	*0.030*	*-0.019*	0.147	-0.021
Glasgow$_t$	*0.026*	-0.018	0.107	0.077	-0.036	*0.012*	0.057	0.093
Edinburgh$_t$	-0.106	-0.046	-0.064	0.111	0.046	-0.083	0.026	0.066
Cardiff$_t$	*-0.091*	0.077	0.113	*-0.002*	-0.086	0.049	-0.023	-0.041

[a] Parameter values for dummy variables are converted using exp(x) − 1.

Figures in italics not significant at 10% level. Source: Tables A1-A8

Table 7: Relative mean TFP in Main Cities, 1997-2006, Great Britain (figures are percentages)

(i) City − South East	High-tech manufacturing	Medium high-tech manufacturing	Medium low-tech manufacturing	Low-tech manufacturing	High-tech KI services	KI market services	Low KI market services	Other low KI market services
London$_t$	6.2[a]	-2.4[a]	-2.3	8.3	3.0[a]	10.0[a]	0.3[a]	7.6[a]
Tyneside$_t$	-12.1	8.0	-4.6	0.4	-5.0	0.6	4.1	-20.7
Manchester$_t$	1.3[a]	*0.7*	2.1[a]	0.9	-4.2[a]	5.7	0.5	7.5
Liverpool$_t$	3.8[a]	-3.3	*	-13.8	-20.1	*0.2*	-8.9[a]	9.5[a]
Birmingham$_t$	-6.7[a]	1.8	-9.1	4.0	-5.0	*0.1*	-3.4[a]	-7.4
Coventry$_t$	-3.3[a]	10.8	*0.6*[a]	25.4	-16.0	-9.7[a]	1.9	*-0.3*[a]
Leicester$_t$	-21.3	-13.3	-9.3	-12.2	-27.6	*-0.3*	-0.8	-1.7[a]
Nottingham$_t$	-19.8	8.7	8.3	-4.2	-7.0	-4.6	-2.6	5.5[a]
Bristol$_t$	-4.0[a]	*0.0*[a]	9.0	-3.1	2.9[a]	*0.0*[a]	15.2	1.3
Glasgow$_t$	8.9[a]	-6.2	11.2	3.0	-21.3	-3.8	-9.3	10.7
Edinburgh$_t$	-6.7	-8.8	*-0.5*	9.2	-12.9	-9.4	-11.0	-5.1
Cardiff$_t$	-14.6[a]	*-0.7*	11.4	-4.6[a]	-18.1	-4.7	-12.8	-1.1
(ii) City − rest of region								
Tyneside$_t$	-6.8	8.1	*0.3*	11.7	18.7	19.4	14.6	-16.0
Manchester$_t$	4.9[b]	4.0	*1.7*[a]	8.0	10.2[b]	20.4	10.5	11.1
Liverpool$_t$	7.5[b]	*-0.1*	*	-7.8	-8.1	14.0	0.1[b]	13.2[b]
Birmingham$_t$	-1.6[b]	2.7	-1.8	8.0	9.3	13.8	0.6[b]	9.3
Coventry$_t$	2.1[b]	11.8	8.6[b]	30.3	-3.3	2.7[b]	6.1	17.6
Leicester$_t$	-14.1	-12.1	-6.1	-4.4	-13.4	16.2	7.5	6.8[b]
Nottingham$_t$	-12.5	10.3	12.2	4.3[b]	11.2	11.1	5.5	14.6[b]
Bristol$_t$	2.1[b]	*0.8*[b]	7.7	-2.5	8.8[b]	6.2[b]	15.3	8.8
Glasgow$_t$	8.1[b]	-1.4	5.2	4.9	1.3	6.1[b]	5.6	34.4
Edinburgh$_t$	-7.4	-4.2	-5.9	11.2	12.2	*0.0*	3.7	15.2
Cardiff$_t$	-6.3[b]	3.1	9.1	*0.2*[b]	*0.2*	12.3	-2.2	5.9

* suppressed to maintain confidentiality.
[a] A test that city and relevant region dummies in Table 6 are jointly zero could not be rejected at 10% level
[b] City-dummies were not significant in Table 6.
Figures in italics not significant at 10% level.

Source: see text for details (especially equation 3)

Figure 1: TFP distribution for plants with non-zero/zero R&D stocks, 1997-2006

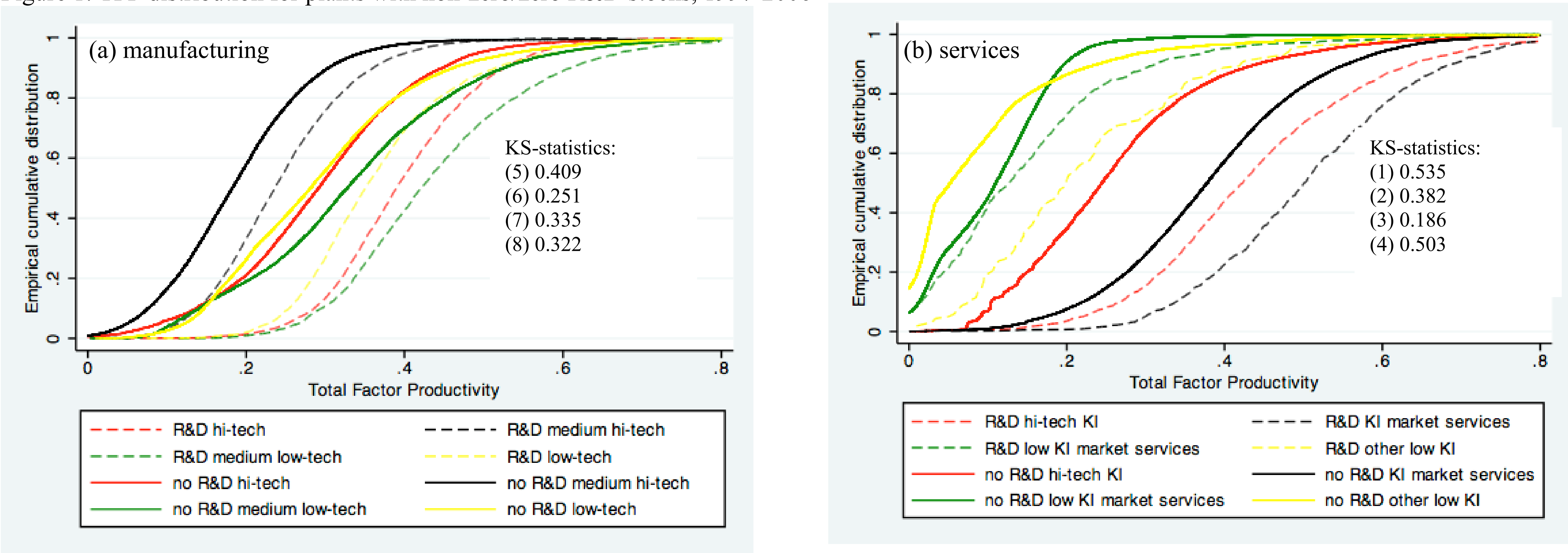


Figure 2: TFP distribution for plants aged 5+ years and aged less than 5 years, 1997-2006

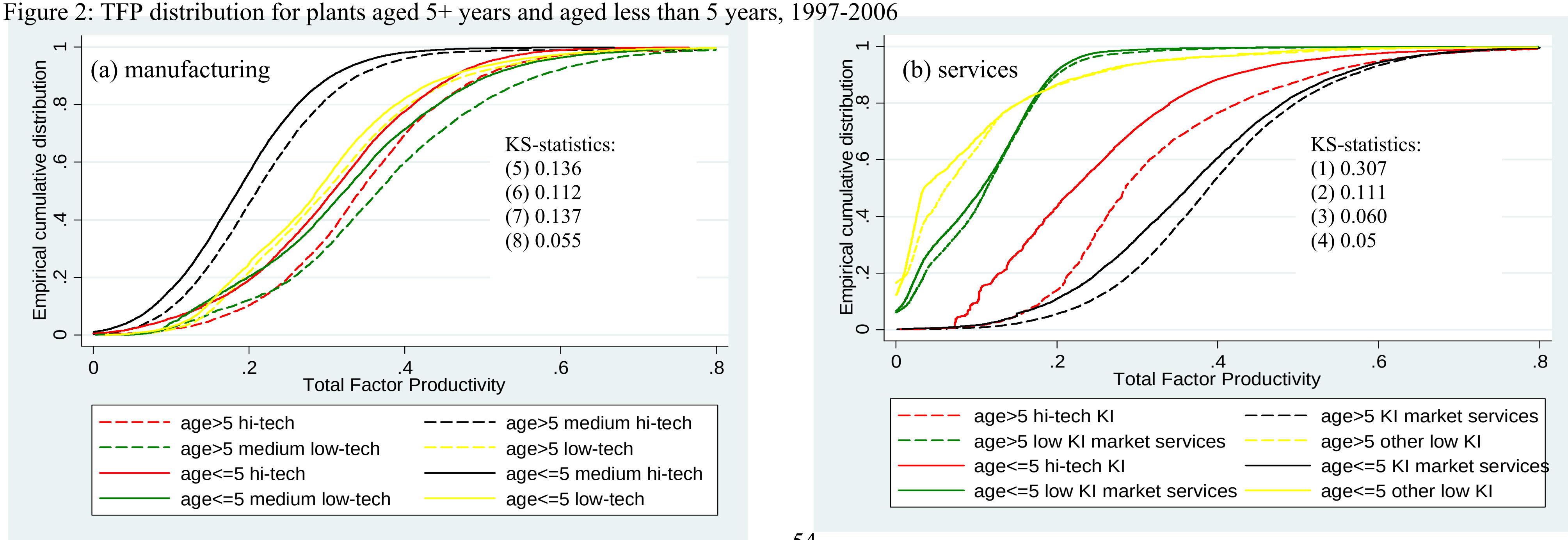
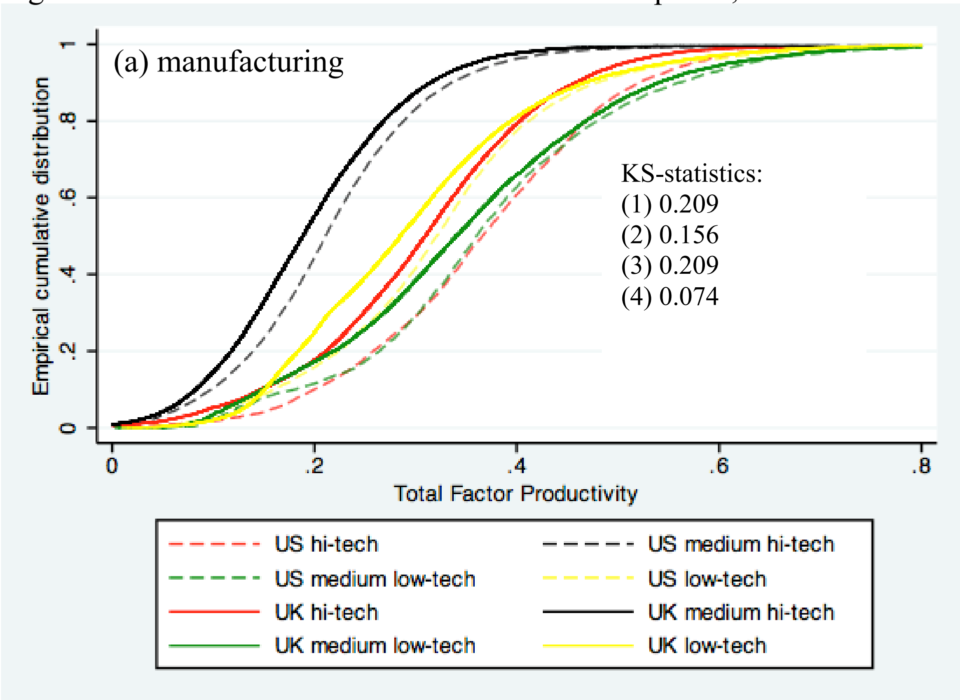


Figure 3: TFP distribution for US- and UK-owned plants, 1997-2006



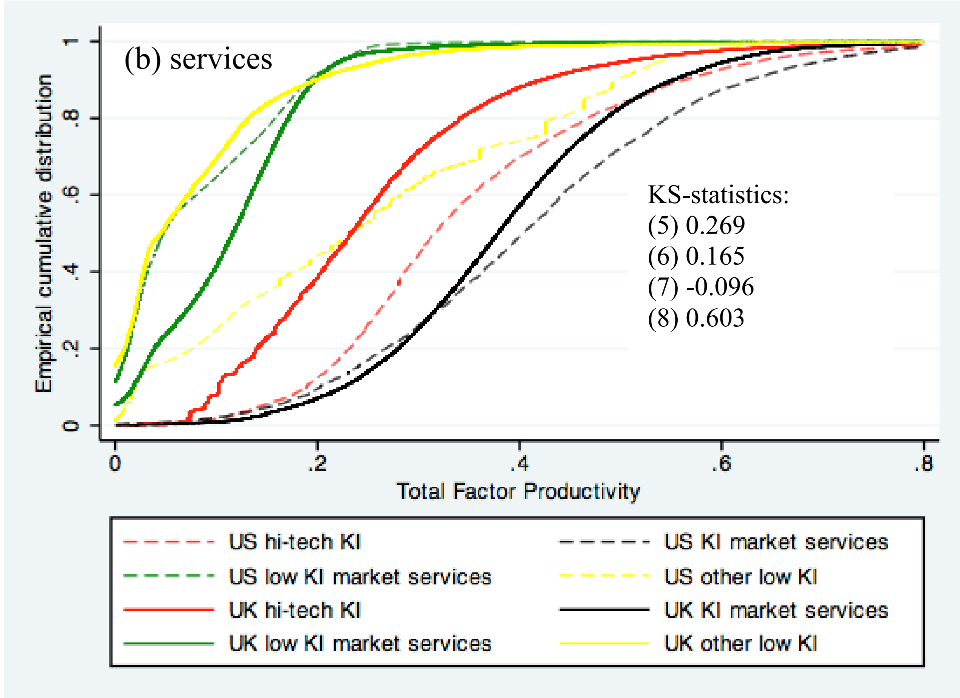
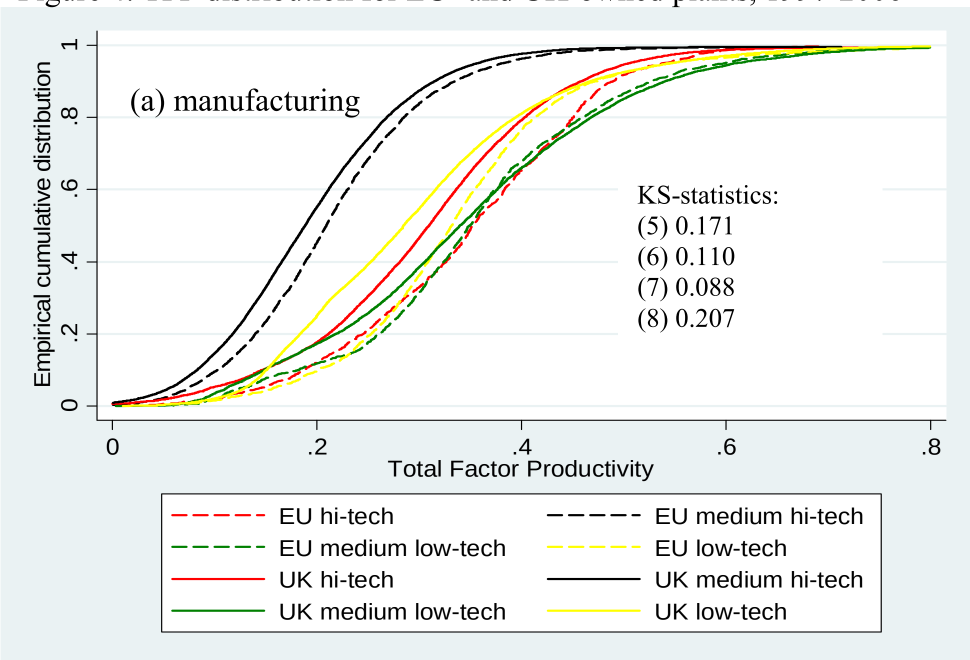


Figure 4: TFP distribution for EU- and UK-owned plants, 1997-2006



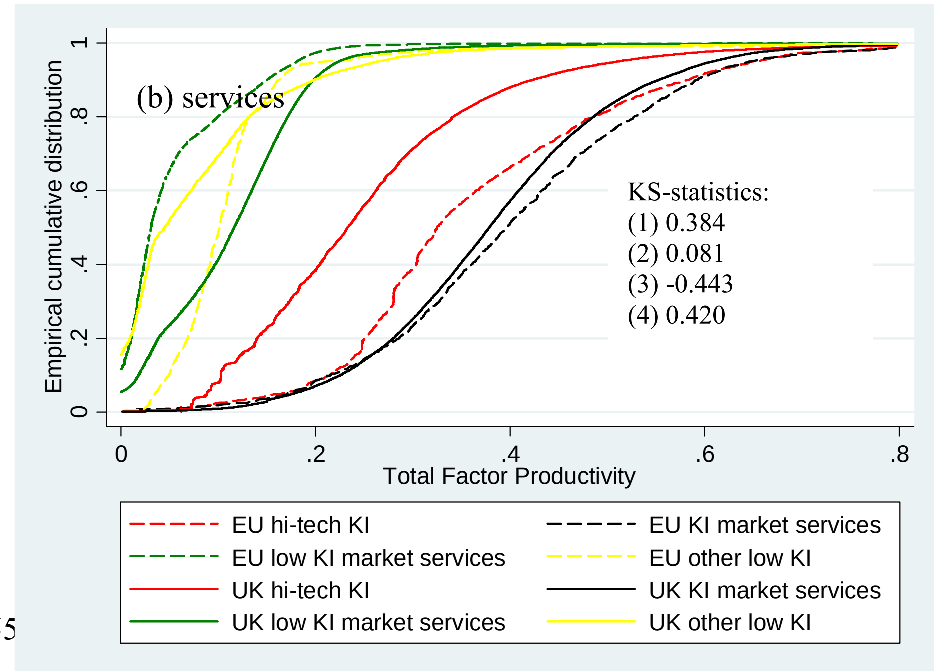
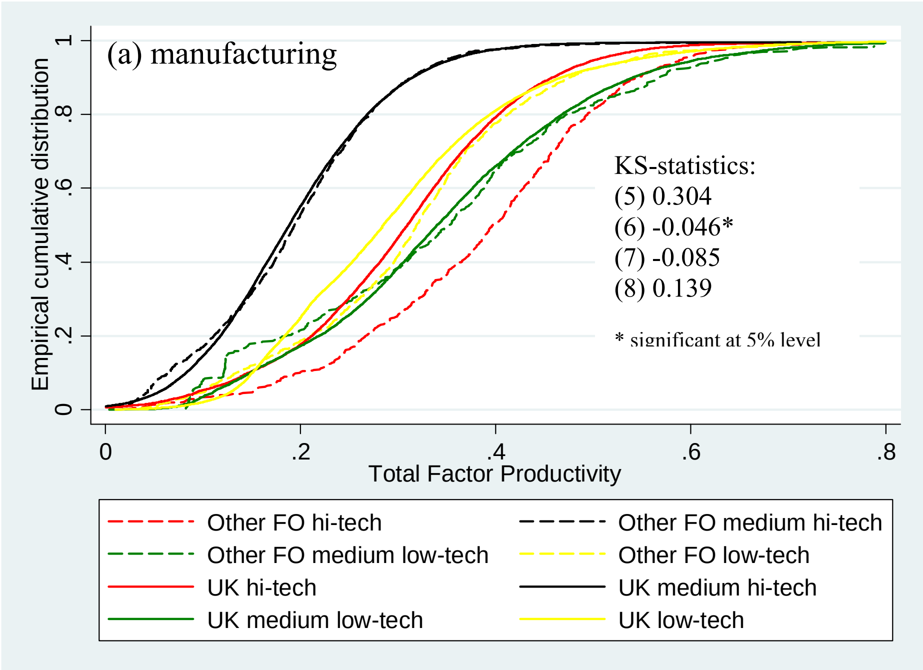


Figure 5: TFP distribution for Other foreign- and UK-owned plants, 1997-2006



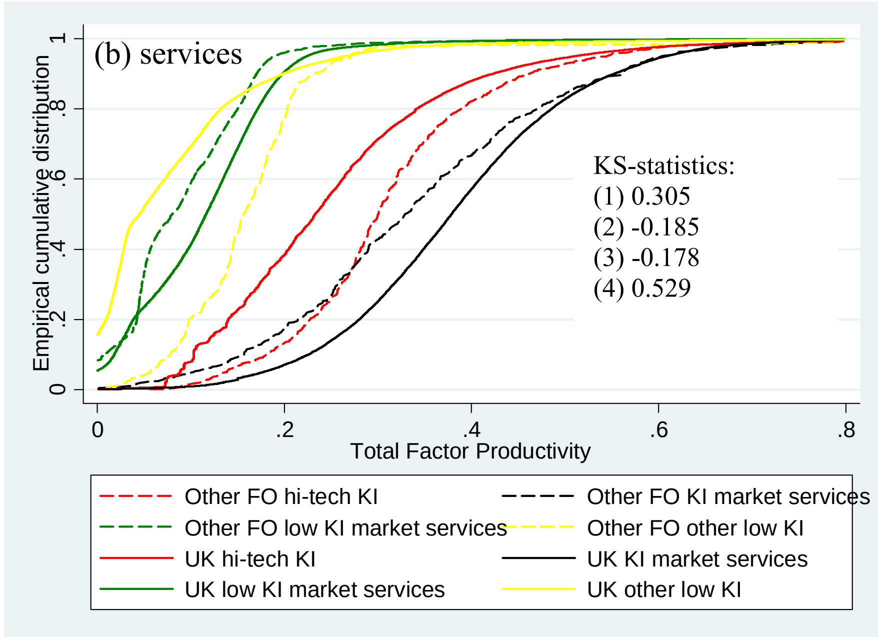
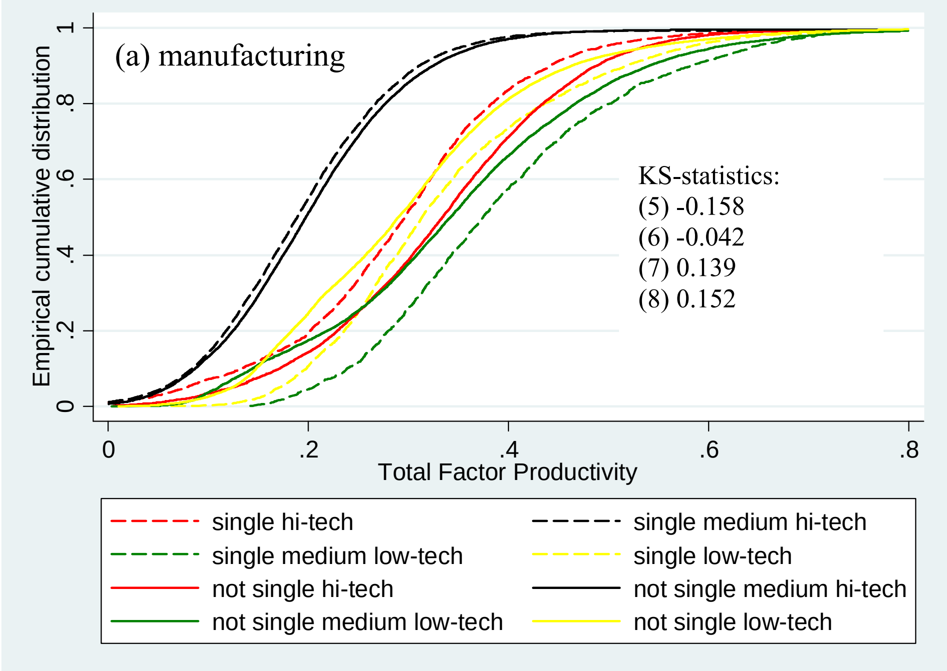


Figure 6: TFP distribution for single-plant/multi-plant enterprises, 1997-2006



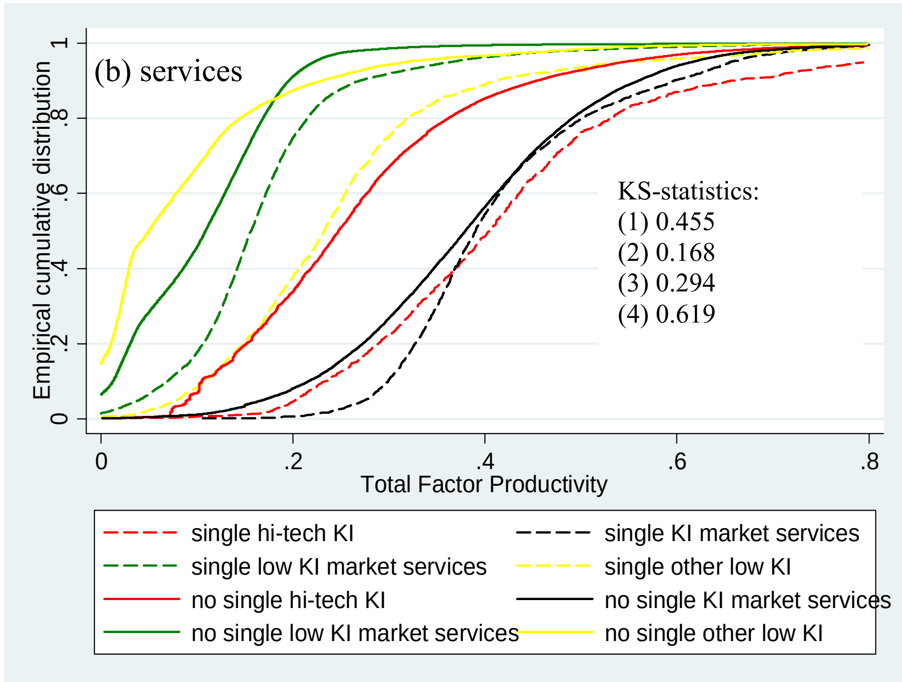


Figure 7: TFP distribution for multi-region/not multi-region enterprises, 1997-2006

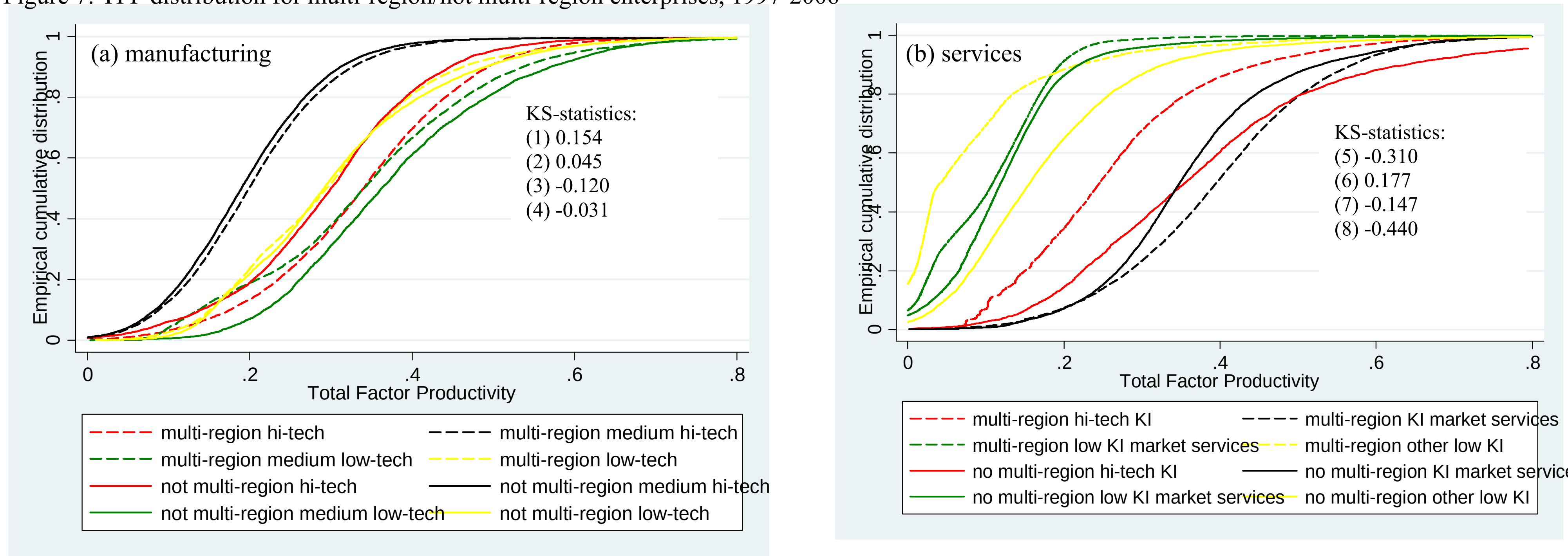


Figure 8: TFP distribution for main cities (including London) and the rest of GB, 1997-2006

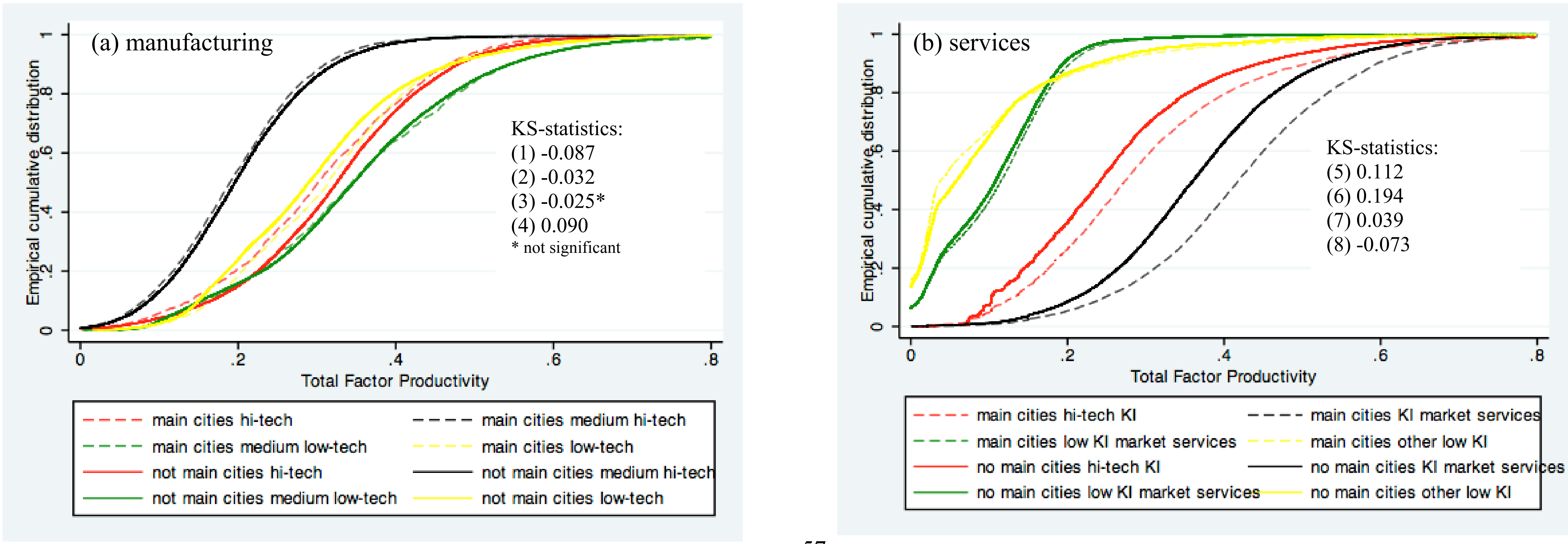


Table A.1: Long-run weighted systems GMM production function, high-tech sector[a], 1997-2006

Dependent variable: *ln* gross output$_t$	$\hat{\beta}$	z-statistic	$\hat{\beta}$	z-statistic
ln intermediate inputs$_t$	0.435***	5.14	0.438***	5.15
ln employment$_t$	0.429***	4.43	0.427***	4.43
ln capital$_t$	0.195***	3.41	0.191***	3.37
t	0.049***	8.69	0.048***	8.59
ln age$_t$	-0.191***	-3.61	-0.187***	-3.56
Single-plant enterprise$_t$	0.077***	3.71	0.077***	3.79
Enterprise operates in >1 region$_t$	0.088***	2.97	0.089***	2.98
Greenfield US-owned$_t$	0.164***	3.08	0.165***	3.13
Brownfield US-owned$_t$	0.124***	2.97	0.122***	2.93
Greenfield EU-owned$_t$	0.112**	2.17	0.106**	2.07
Brownfield EU-owned$_t$	0.086*	1.73	0.084*	1.69
Greenfield Other FO$_t$	0.132*	1.64	0.131*	1.64
Brownfield Other FO$_t$	0.081	1.25	0.080	1.24
ln Industry agglomeration$_t$	-0.036*	-1.68	-0.034	-1.59
ln Diversification$_t$	0.157**	2.23	0.193**	2.23
ln Herfindahl$_t$	0.016	1.55	0.015	1.45
R&D undertaken$_t$	0.041**	2.18	0.041**	2.20
Located in Assisted Area$_t$	0.002	0.09	-0.010	-0.49
North East$_t$	-0.096***	-2.65	-0.052***	-1.31
Yorks-Humberside$_t$	-0.089***	-2.67	-0.097***	-2.86
North West$_t$	-0.054	-1.50	-0.054	-1.47
West Midlands$_t$	-0.075***	-2.84	-0.073***	-2.67
East Midlands$_t$	-0.142***	-4.10	-0.114***	-3.39
South West$_t$	-0.072***	-2.92	-0.070***	-2.80
Eastern$_t$	-0.051**	-2.28	-0.051**	-2.32
London$_t$	0.029	0.96	0.025	0.83
Scotland$_t$	0.005	0.17	0.019	0.58
Wales$_t$	-0.112***	-3.50	-0.096***	-3.09
Tyneside$_t$	–	–	-0.137*	-1.78
Manchester$_t$	–	–	0.014	0.18
Liverpool$_t$	–	–	0.080	1.19
Birmingham$_t$	–	–	-0.035	-0.62
Coventry$_t$	–	–	0.045	0.79
Leicester$_t$	–	–	-0.187	-2.45
Nottingham$_t$	–	–	-0.167	-1.05
Bristol$_t$	–	–	-0.015	-0.22
Glasgow$_t$	–	–	0.026	0.41
Edinburgh$_t$	–	–	-0.112*	-1.64
Cardiff$_t$	–	–	-0.095	-1.00
Industry dummies	yes		yes	
AR(1) z-statistic	-6.71***		-6.71***	
AR(2) z-statistic	1.19		1.19	
Hansen test χ^2 (df)	27.60 (23)		27.60 (23)	
No. of Obs.	12,906		12,906	
No. of groups	5,386		5,386	

[a] See Table 2 for definition
***/**/* significant at 1%/5%/10% level.

Table A.2: Long-run weighted systems GMM production function, medium high-tech sector[a], 1997-2006

Dependent variable: *ln* gross output$_t$	$\hat{\beta}$	z-statistic	$\hat{\beta}$	z-statistic
ln intermediate inputs$_t$	0.375***	6.12	0.377***	6.15
ln employment$_t$	0.192***	3.93	0.192***	3.93
ln capital$_t$	0.289***	10.95	0.287***	10.73
t	0.019***	15.06	0.019***	15.51
ln age$_t$	-0.184***	-11.92	-0.184***	-11.69
Single-plant enterprise$_t$	0.014*	1.83	0.013*	1.69
Enterprise operates in >1 region$_t$	0.070***	4.76	0.068***	4.63
Greenfield US-owned$_t$	0.043*	1.86	0.042*	1.84
Brownfield US-owned$_t$	0.122***	4.17	0.118***	4.08
Greenfield EU-owned$_t$	0.079***	4.18	0.077***	4.13
Brownfield EU-owned$_t$	0.098***	5.72	0.099***	5.71
Greenfield Other FO$_t$	0.126***	4.42	0.125***	4.39
Brownfield Other FO$_t$	0.120***	5.45	0.118***	5.38
ln Industry agglomeration$_t$	0.065***	7.77	0.065***	7.57
ln Diversification$_t$	-0.092***	-5.92	-0.094***	-6.22
ln Herfindahl$_t$	-0.025***	-6.53	-0.025***	-6.64
R&D undertaken$_t$	0.109***	4.49	0.108***	4.42
Located in Assisted Area$_t$	-0.024***	-7.26	-0.025***	-7.34
North East$_t$	-0.005	-0.89	-0.024***	-3.86
Yorks-Humberside$_t$	-0.052***	-11.12	-0.051***	-10.02
North West$_t$	-0.047***	-10.60	-0.049***	-10.45
West Midlands$_t$	-0.043***	-7.81	-0.044***	-8.03
East Midlands$_t$	-0.038***	-5.49	-0.030***	-4.79
South West$_t$	-0.009	-1.46	-0.010	-1.49
Eastern$_t$	0.018***	4.04	0.018***	4.03
London$_t$	0.002	0.33	0.003	0.48
Scotland$_t$	-0.036***	-7.34	-0.031***	-6.13
Wales$_t$	-0.050***	-7.49	-0.056***	-8.56
Tyneside$_t$	–	–	0.091***	7.50
Manchester$_t$	–	–	0.041***	3.44
Liverpool$_t$	–	–	0.031**	2.19
Birmingham$_t$	–	–	-0.020**	-1.99
Coventry$_t$	–	–	0.086***	5.92
Leicester$_t$	–	–	-0.170***	-8.03
Nottingham$_t$	–	–	0.105***	6.81
Bristol$_t$	–	–	0.009	0.81
Glasgow$_t$	–	–	-0.018*	-1.81
Edinburgh$_t$	–	–	-0.047***	-3.16
Cardiff$_t$	–	–	0.074***	5.11
Industry dummies	yes		yes	
AR(1) z-statistic	-27.05***		-26.76***	
AR(2) z-statistic	-0.95		-0.99	
Hansen test χ^2 (df)	22.22 (15)		22.41 (15)	
No. of Obs.	40,834		40,834	
No. of groups	15,957		15,957	

[a] See Table 2 for definition
***/**/* significant at 1%/5%/10% level.

Table A.3: Long-run weighted systems GMM production function, medium low-tech sector[a], 1997-2006

Dependent variable: *ln* gross output$_t$	$\hat{\beta}$	z-statistic	$\hat{\beta}$	z-statistic
ln intermediate inputs$_t$	0.387**	2.03	0.451***	2.64
ln employment$_t$	0.466***	2.75	0.423***	2.76
ln capital$_t$	0.160***	3.78	0.141***	3.97
t	0.024***	4.34	0.023***	4.59
ln age$_t$	-0.155***	-4.42	-0.140***	-4.74
Single-plant enterprise$_t$	0.086***	4.09	0.080***	4.41
Enterprise operates in >1 region$_t$	0.146*	1.79	0.120*	1.64
Greenfield US-owned$_t$	0.032	0.65	0.024	0.56
Brownfield US-owned$_t$	0.033	1.12	0.033	1.22
Greenfield EU-owned$_t$	0.084	1.04	0.066	0.91
Brownfield EU-owned$_t$	0.048**	2.04	0.042**	2.03
Greenfield Other FO$_t$	0.361**	2.21	0.306**	2.10
Brownfield Other FO$_t$	-0.016	-0.54	-0.024	-0.93
ln Industry agglomeration$_t$	-0.039**	-2.18	-0.036**	-2.26
ln Diversification$_t$	-0.146*	-1.84	-0.185**	-2.11
ln Herfindahl$_t$	0.025	0.97	0.021	0.87
R&D undertaken$_t$	-0.002	-0.13	0.001	0.08
Located in Assisted Area$_t$	-0.025***	-3.58	-0.026***	-4.28
North East$_t$	-0.029	-1.48	-0.043**	-2.08
Yorks-Humberside$_t$	0.060**	2.52	0.065***	2.69
North West$_t$	0.050***	2.58	0.048***	2.76
West Midlands$_t$	-0.002	-0.25	-0.003	-0.35
East Midlands$_t$	-0.011	-0.71	-0.010	-0.66
South West$_t$	0.034***	3.76	0.022***	2.64
Eastern$_t$	-0.012	-0.71	-0.014	-0.93
London$_t$	-0.031**	-2.08	-0.023*	-1.81
Scotland$_t$	0.088***	4.11	0.077***	4.57
Wales$_t$	0.034**	2.10	0.022	1.54
Tyneside$_t$	–	–	0.075***	3.48
Manchester$_t$	–	–	0.039	1.44
Liverpool$_t$	–	–	-0.051	-0.76
Birmingham$_t$	–	–	0.062***	2.63
Coventry$_t$	–	–	0.076	1.45
Leicester$_t$	–	–	-0.052*	-1.67
Nottingham$_t$	–	–	0.108**	2.52
Bristol$_t$	–	–	0.115**	1.97
Glasgow$_t$	–	–	0.102***	3.64
Edinburgh$_t$	–	–	-0.066**	-2.06
Cardiff$_t$	–	–	0.107***	5.14
Industry dummies	yes		yes	
AR(1) z-statistic	-3.84***		-3.88***	
AR(2) z-statistic	0.42		0.14	
Hansen test χ^2 (df)	9.34 (6)		9.34 (6)	
No. of Obs.	14,218		14,218	
No. of groups	4,854		4,854	

[a] See Table 2 for definition

$^{***}/^{**}/^{*}$ significant at 1%/5%/10% level.

Table A.4: Long-run weighted systems GMM production function, low-tech sector[a], 1997-2006

Dependent variable: *ln* gross output$_t$	$\hat{\beta}$	z-statistic	$\hat{\beta}$	z-statistic
ln intermediate inputs$_t$	0.505***	5.86	0.500***	5.72
ln employment$_t$	0.390***	4.11	0.401***	4.16
ln capital$_t$	0.131***	3.02	0.123***	2.77
t	0.023***	6.15	0.023***	6.09
ln age$_t$	-0.158***	-6.13	-0.154***	-5.82
Single-plant enterprise$_t$	0.120***	8.68	0.116***	8.18
Enterprise operates in >1 region$_t$	0.130***	2.67	0.134***	2.71
Greenfield US-owned$_t$	0.112***	4.45	0.117***	4.61
Brownfield US-owned$_t$	0.072*	1.69	0.077*	1.75
Greenfield EU-owned$_t$	0.157**	2.48	0.165***	2.56
Brownfield EU-owned$_t$	0.197***	3.16	0.203***	3.18
Greenfield Other FO$_t$	0.009	0.16	0.016	0.27
Brownfield Other FO$_t$	0.022	0.62	0.026	0.72
ln Industry agglomeration$_t$	-0.007	-0.26	-0.005	-0.19
ln Diversification$_t$	0.077*	1.77	0.035	0.81
ln Herfindahl$_t$	0.032**	2.12	0.034**	2.23
R&D undertaken$_t$	-0.009	-0.10	0.006	0.07
Located in Assisted Area$_t$	-0.050***	-4.21	-0.047***	-4.02
North East$_t$	-0.057***	-3.12	-0.095***	-4.11
Yorks-Humberside$_t$	-0.140***	-2.87	-0.139***	-2.78
North West$_t$	-0.066**	-2.04	-0.067***	-2.17
West Midlands$_t$	-0.023	-1.28	-0.045***	-2.71
East Midlands$_t$	-0.101***	-3.59	-0.105***	-3.92
South West$_t$	-0.006	-0.56	-0.005	-0.43
Eastern$_t$	-0.000	-0.04	-0.000	-0.03
London$_t$	0.101***	4.58	0.103***	4.52
Scotland$_t$	0.024	1.56	0.006	0.35
Wales$_t$	-0.051***	-3.47	-0.055***	-3.21
Tyneside$_t$	–	–	0.144***	4.97
Manchester$_t$	–	–	0.075***	3.52
Liverpool$_t$	–	–	-0.097**	-2.41
Birmingham$_t$	–	–	0.099***	4.75
Coventry$_t$	–	–	0.335***	6.14
Leicester$_t$	–	–	-0.061***	-2.86
Nottingham$_t$	–	–	0.051	1.41
Bristol$_t$	–	–	-0.040*	-1.88
Glasgow$_t$	–	–	0.074***	3.91
Edinburgh$_t$	–	–	0.105***	4.78
Cardiff$_t$	–	–	-0.002	-0.06
Industry dummies	yes		yes	
AR(1) z-statistic	-6.14***		-6.32***	
AR(2) z-statistic	-1.16		-1.09	
Hansen test χ^2 (df)	10.39 (6)		10.37 (6)	
No. of Obs.	24,096		24,096	
No. of groups	7,750		7,750	

[a] See Table 2 for definition
***/**/* significant at 1%/5%/10% level.

Table A.5: Long-run weighted systems GMM production function, high-tech knowledge intensive sector[a], 1997-2006

Dependent variable: *ln* gross output$_t$	$\hat{\beta}$	z-statistic	$\hat{\beta}$	z-statistic
ln intermediate inputs$_t$	0.413***	4.42	0.420***	4.52
ln employment$_t$	0.467***	6.44	0.466***	6.53
ln capital$_t$	0.062***	4.27	0.060***	4.10
t	0.006**	2.40	0.006***	2.57
ln age$_t$	-0.175***	-8.38	-0.173***	-8.39
Single-plant enterprise$_t$	0.020	0.41	0.021	0.41
Enterprise operates in >1 region$_t$	-0.143*	-1.65	-0.137	-1.60
Greenfield US-owned$_t$	0.193***	13.50	0.194***	13.47
Brownfield US-owned$_t$	0.359***	10.05	0.356***	9.95
Greenfield EU-owned$_t$	0.179**	2.41	0.175***	2.35
Brownfield EU-owned$_t$	0.185***	5.96	0.183***	5.87
Greenfield Other FO$_t$	0.316***	3.72	0.309***	3.60
Brownfield Other FO$_t$	-0.033**	-2.65	-0.034***	-2.75
ln Industry agglomeration$_t$	0.060*	1.87	0.058*	1.77
ln Diversification$_t$	-0.174	-1.32	-0.167	-1.37
ln Herfindahl$_t$	0.093***	5.40	0.092***	5.39
R&D undertaken$_t$	0.227**	2.51	0.225**	2.45
Located in Assisted Area$_t$	-0.043***	-5.47	-0.030***	-3.93
North East$_t$	-0.117***	-5.32	-0.169***	-6.48
Yorks-Humberside$_t$	-0.126***	-8.19	-0.127***	-7.33
North West$_t$	-0.102***	-6.05	-0.099***	-5.86
West Midlands$_t$	-0.108***	-6.83	-0.112***	-6.42
East Midlands$_t$	-0.137***	-6.30	-0.122***	-6.33
South West$_t$	-0.008	-0.82	-0.012	-1.32
Eastern$_t$	-0.021**	-2.38	-0.021**	-2.43
London$_t$	-0.007	-0.72	-0.007	-0.57
Scotland$_t$	-0.212***	-5.31	-0.218***	-5.97
Wales$_t$	-0.161***	-6.13	-0.143***	-7.57
Tyneside$_t$	–	–	0.143***	5.41
Manchester$_t$	–	–	0.021	0.90
Liverpool$_t$	–	–	0.031**	2.19
Birmingham$_t$	–	–	0.035**	2.27
Coventry$_t$	–	–	0.086***	5.92
Leicester$_t$	–	–	-0.170***	-8.03
Nottingham$_t$	–	–	0.105***	6.81
Bristol$_t$	–	–	0.030	1.15
Glasgow$_t$	–	–	-0.037*	-1.66
Edinburgh$_t$	–	–	0.045**	2.50
Cardiff$_t$	–	–	-0.090**	-1.96
Industry dummies	yes		yes	
AR(1) z-statistic	-4.99***		-4.96***	
AR(2) z-statistic	-0.64		-0.77	
Hansen test χ^2 (df)	7.32* (3)		7.41* (3)	
No. of Obs.	32,971		32,971	
No. of groups	12,696		12,696	

[a] See Table 2 for definition
$^{***}/^{**}/^{*}$ significant at 1%/5%/10% level.

Table A.6: Long-run weighted systems GMM production function, knowledge-intensive market sectors[a], 1997-2006

Dependent variable: *ln* gross output$_t$	$\hat{\beta}$	z-statistic	$\hat{\beta}$	z-statistic
ln intermediate inputs$_t$	0.435***	8.86	0.441***	7.72
ln employment$_t$	0.381***	6.21	0.390***	5.79
ln capital$_t$	0.116***	3.61	0.096***	2.59
t	0.004***	2.98	0.005***	3.10
ln age$_t$	-0.061**	-2.11	-0.042	-1.19
Single-plant enterprise$_t$	0.098***	6.94	0.105***	6.91
Enterprise operates in >1 region$_t$	0.211***	7.61	0.211***	6.66
Greenfield US-owned$_t$	0.118***	2.84	0.094**	2.01
Brownfield US-owned$_t$	0.040	1.48	0.044	1.45
Greenfield EU-owned$_t$	0.160***	2.93	0.159**	2.51
Brownfield EU-owned$_t$	0.001	0.03	0.008	0.24
Greenfield Other FO$_t$	0.154**	2.22	0.174**	1.99
Brownfield Other FO$_t$	0.204***	3.42	0.200***	2.91
ln Industry agglomeration$_t$	0.068***	7.49	0.068***	6.96
ln Diversification$_t$	-0.123***	-4.32	-0.168***	-5.19
ln Herfindahl$_t$	-0.013	-0.64	-0.007	-0.35
R&D undertaken$_t$	0.180***	3.32	0.120*	1.65
Located in Assisted Area$_t$	-0.021***	-3.48	-0.035***	-5.26
North East$_t$	-0.085***	-7.51	-0.144***	-9.35
Yorks-Humberside$_t$	-0.123***	-12.15	-0.111***	-8.59
North West$_t$	-0.083***	-10.73	-0.108***	-11.61
West Midlands$_t$	-0.094***	-9.25	-0.106***	-8.32
East Midlands$_t$	-0.109***	-8.91	-0.126***	-8.62
South West$_t$	-0.032***	-3.87	-0.027***	-2.58
Eastern$_t$	-0.017**	-2.07	-0.016**	-2.02
London$_t$	-0.005	-0.31	0.008	0.51
Scotland$_t$	-0.110***	-9.08	-0.083***	-5.65
Wales$_t$	-0.109***	-7.91	-0.120***	-6.90
Tyneside$_t$	–	–	0.158***	6.26
Manchester$_t$	–	–	0.103***	6.98
Liverpool$_t$	–	–	0.119***	5.59
Birmingham$_t$	–	–	0.058***	3.96
Coventry$_t$	–	–	0.023	0.87
Leicester$_t$	–	–	0.124***	4.85
Nottingham$_t$	–	–	0.049***	2.61
Bristol$_t$	–	–	-0.019	-1.37
Glasgow$_t$	–	–	0.012	0.76
Edinburgh$_t$	–	–	-0.087***	-5.34
Cardiff$_t$	–	–	0.048***	2.97
Industry dummies	yes		yes	
AR(1) z-statistic	-4.18***		-4.15***	
AR(2) z-statistic	1.31		1.33	
Hansen test χ^2 (df)	7.84 (6)		8.27 (6)	
No. of Obs.	27,995		27,995	
No. of groups	13,319		13,319	

[a] See Table 2 for definition
***/**/* significant at 1%/5%/10% level.

Table A.7: Long-run weighted systems GMM production function, low knowledge-intensive market services sector[a], 1997-2006

Dependent variable: *ln* gross output$_t$	$\hat{\beta}$	z-statistic	$\hat{\beta}$	z-statistic
ln intermediate inputs$_t$	0.810***	20.67	0.821***	19.95
ln employment$_t$	0.170***	2.97	0.159***	2.71
ln capital$_t$	0.043***	2.90	0.043***	2.92
t	-0.005***	-3.06	-0.004**	-2.46
ln age$_t$	-0.061***	-2.95	-0.062***	-3.00
Single-plant enterprise$_t$	-0.015	-0.46	-0.023	-0.68
Enterprise operates in >1 region$_t$	-0.020	-0.47	-0.033	-0.73
Greenfield US-owned$_t$	-0.065***	-4.27	-0.071***	-4.37
Brownfield US-owned$_t$	-0.090***	-15.40	-0.092***	-16.28
Greenfield EU-owned$_t$	0.063*	1.95	0.067**	2.04
Brownfield EU-owned$_t$	-0.035	-0.75	-0.050	-1.01
Greenfield Other FO$_t$	-0.167*	-1.87	-0.185**	-2.00
Brownfield Other FO$_t$	-0.114***	-2.68	-0.124***	-2.81
ln Industry agglomeration$_t$	0.006	1.33	0.003	0.58
ln Diversification$_t$	0.043*	1.69	0.002	0.10
ln Herfindahl$_t$	-0.100***	-30.15	-0.099***	-29.20
R&D undertaken$_t$	0.181**	2.12	0.153*	1.75
Located in Assisted Area$_t$	-0.015***	-7.08	-0.013***	-8.31
North East$_t$	-0.043***	-13.71	-0.085***	-9.80
Yorks-Humberside$_t$	-0.102***	-31.75	-0.092***	-49.47
North West$_t$	-0.079***	-6.49	-0.089***	-6.73
West Midlands$_t$	-0.039***	-6.66	-0.038***	-5.63
East Midlands$_t$	-0.065***	-7.68	-0.077***	-6.97
South West$_t$	0.015***	4.91	-0.000	-0.10
Eastern$_t$	-0.024***	-4.91	-0.026***	-5.02
London$_t$	-0.008*	-1.82	-0.001	-0.35
Scotland$_t$	-0.130***	-6.71	-0.144***	-6.40
Wales$_t$	-0.110***	-6.76	-0.109***	-5.75
Tyneside$_t$	–	–	0.135***	4.43
Manchester$_t$	–	–	0.087***	7.59
Liverpool$_t$	–	–	0.005	0.81
Birmingham$_t$	–	–	0.001	0.09
Coventry$_t$	–	–	0.058***	10.16
Leicester$_t$	–	–	0.067***	6.40
Nottingham$_t$	–	–	0.048***	3.11
Bristol$_t$	–	–	0.137***	7.72
Glasgow$_t$	–	–	0.055***	12.08
Edinburgh$_t$	–	–	0.026*	1.82
Cardiff$_t$	–	–	-0.023**	-2.29
Industry dummies	yes		yes	
AR(1) z-statistic	-5.80***		-6.80***	
AR(2) z-statistic	-1.60		-1.50	
Hansen test χ^2 (df)	3.42 (3)		3.24 (3)	
No. of Obs.	351,721		351,721	
No. of groups	131,150		131,150	

[a] See Table 2 for definition.
$^{***}/^{**}/^{*}$ significant at 1%/5%/10% level.

Table A.8: Long-run weighted systems GMM production function, other low knowledge-intensive services sector[a], 1997-2006

Dependent variable: *ln* gross output$_t$	$\hat{\beta}$	z-statistic	$\hat{\beta}$	z-statistic
ln intermediate inputs$_t$	0.723***	69.72	0.722***	68.61
ln employment$_t$	0.182***	3.55	0.179***	3.30
ln capital$_t$	0.052***	4.44	0.048***	3.95
t	-0.001	-0.39	-0.000	-0.26
ln age$_t$	-0.074***	-7.56	-0.070***	-6.88
Single-plant enterprise$_t$	0.416***	7.78	0.425***	7.60
Enterprise operates in >1 region$_t$	0.378***	13.92	0.378***	13.40
Greenfield US-owned$_t$	0.052	1.53	0.042	1.16
Brownfield US-owned$_t$	-0.152***	-14.45	-0.152***	-14.49
Greenfield EU-owned$_t$	0.112**	2.16	0.113**	2.09
Brownfield EU-owned$_t$	0.109**	2.37	0.117**	2.44
Greenfield Other FO$_t$	-0.050	-0.81	-0.033	-0.52
Brownfield Other FO$_t$	0.153*	1.65	0.179*	1.80
ln Industry agglomeration$_t$	0.053***	2.84	0.056***	2.65
ln Diversification$_t$	-0.009	-0.31	-0.004	-0.14
ln Herfindahl$_t$	0.011***	3.80	0.012***	3.93
R&D undertaken$_t$	0.422***	5.37	0.447***	5.58
Located in Assisted Area$_t$	0.043***	10.66	0.049***	10.47
North East$_t$	-0.136***	-17.38	-0.086***	-5.95
Yorks-Humberside$_t$	-0.132***	-7.92	-0.138***	-6.89
North West$_t$	-0.062***	-5.08	-0.066***	-5.82
West Midlands$_t$	-0.137***	-11.04	-0.130***	-13.85
East Midlands$_t$	-0.051***	-5.67	-0.051***	-7.21
South West$_t$	-0.042***	-5.79	-0.042***	-6.11
Eastern$_t$	-0.049***	-14.10	-0.050***	-13.92
London$_t$	-0.012	-0.97	-0.015	-0.94
Scotland$_t$	-0.162***	-5.89	-0.194***	-6.58
Wales$_t$	-0.051***	-4.00	-0.047***	-3.53
Tyneside$_t$	–	–	-0.179***	-10.72
Manchester$_t$	–	–	0.023*	1.81
Liverpool$_t$	–	–	-0.033	-1.05
Birmingham$_t$	–	–	-0.066**	-2.37
Coventry$_t$	–	–	0.066***	6.67
Leicester$_t$	–	–	-0.021	-1.13
Nottingham$_t$	–	–	0.007	0.53
Bristol$_t$	–	–	-0.021*	-1.74
Glasgow$_t$	–	–	0.089***	5.84
Edinburgh$_t$	–	–	0.064***	9.06
Cardiff$_t$	–	–	-0.042***	-4.76
Industry dummies	yes		yes	
AR(1) z-statistic	-5.88***		-5.73***	
AR(2) z-statistic	-1.28		-1.18	
Hansen test χ^2 (df)	2.42 (3)		2.30 (3)	
No. of Obs.	91,942		91,942	
No. of groups	32,975		32,975	

[a] See Table 2 for definition.
***/**/* significant at 1%/5%/10% level.

BERR
Department for Business
Enterprise & Regulatory Reform

Communities
and Local Government

E·S·R·C
ECONOMIC
& SOCIAL
RESEARCH
COUNCIL

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Spatial Economics Research Centre (SERC)
London School of Economics
Houghton Street
London WC2A 2AE

Tel: 020 7852 3565
Fax: 020 7955 6848
Web: www.spatialeconomics.ac.uk

SERC is an independent research centre funded by the Economic and Social Research Council (ESRC), Department for Business, Enterprise and Regulatory Reform (BERR), the Department for Communities and Local Government (CLG) and the Welsh Assembly Government.