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Productivity Levels and Dynamics: UK Service Sector Firms 1988-1998

By S Girma and R. Kneller

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Abstract

This paper attempts to explain the level and dynamics of firm level productivity through a model of convergence, for UK service sector firms over the period 1988 to 1998. Firms of different characteristics have different productivity levels and rates of catch-up. We find strong evidence to relate differences in the rate of convergence to the ownership status of the firm and weak evidence that it is related to firm age. Given the high initial productivity of foreign owned firms we suggest that these firms have high absorptive capacity.

Outline

Non-Technical Summary

Recent cross-country comparisons of service sector productivity among OECD countries have found strong evidence for productivity convergence over the post war period. Countries in which the initial level of productivity was low have experienced faster productivity growth than those countries in which the initial productivity level was higher, such that by the end of the time period productivity levels were more similar than at the start. No such evidence for convergence has been found among manufacturing industries. The explanation given for this difference in the pattern of productivity growth has been that the technologies used by service sector firms are likely to be similar. As knowledge of new technology spreads out amongst firms and they become more efficient at using this technology any productivity gap that exists closes.

In this paper we consider whether these patterns exist among service sector firms in the UK over the period 1988 to 1998. The time period used is of interest as it overlaps with a period of obvious and rapid investment in new technology in the service sector. According to the estimates made in Kneller & Young (2001) investment in information and communication technology (in constant prices) in the U.K. increased by an average annual rate of 15.4 per cent between 1988 and 1994 and an average annual rate of 37.6 per cent between 1995 and 1998. The service sector as a whole accounted for close to 80 per cent of all investment in computer equipment in 1998.

We find from our analysis evidence that significant cross-firm productivity differences in the service sector exist. However we also find that the ranking of firm in the productivity distribution is low. From this we might conclude that firms are not consistent in their performance across time, their productivity differs from one time period to the next. In a convergence model this difference in the cross-time performance of the firm might be explained by the effort they apply in understanding new technologies. We might expect differences to differ according to the characteristics of the firm. For example, younger firms may be more dynamic than older firms and more willing to adopt new technologies, or older firms may be more experienced at spotting which technologies might work and how best to apply them. Similarly foreign firms may have better access to new ideas from abroad, but then domestic firms may understand domestic conditions better.

We study this by testing whether the rate at which the firm closes the productivity gap depends on the age and ownership status of the firm, and whether there are permanent differences in the level of productivity according to these characteristics. We find from evidence that the rate of convergence differs according to the ownership status of the firm (foreign firms converge faster than domestic ones), but there is no evidence of permanent differences in the level of productivity. Foreign owned firms, which also have higher average productivity levels, exhibit faster rates of convergence than their domestically-owned counterparts. One possible explanation for this result is that the high levels of average productivity in foreign owned firms acts as a proxy for high levels of absorptive capacity, which are necessary for the successful imitation and adoption of new technologies. No relationship with the age of the firm is found.

1. Introduction

Recent firm-level studies have established the existence of large differences in productivity levels across firms, even within narrowly defined industries (see Bartelsman & Doms, 2000 for a comprehensive review). A less reported result from the same literature is that the amount of change in the productivity distribution across time is non-trivial. In this paper we consider whether a model of convergence in cross-firm productivity levels is capable of jointly accounting for heterogeneity in the level of productivity as well as their dynamics across time in a sample of UK service sector firms over the period 1988 to 1998. To our knowledge this is the first study that considers both productivity levels and dynamics for UK service sector firms.

Strong evidence for productivity convergence amongst service industries at the aggregate level in OECD countries leads us to consider the convergence model as the appropriate model to study productivity dynamics at the firm level (Bernard & Jones, 1996; Gouyette & Perelman, 1997; Broadberry, 1998). Bernard & Jones (1996) argue that convergence has been specific to the service sector because the technologies used are likely to be similar across firms. By contrast, there is little or no evidence convergence has occurred amongst manufacturing industries in OECD countries (Bernard & Jones, 1996; Carree et al., 2000; Togo, 2000).

The time period used in the study is also of interest as it overlaps with a period of obvious and rapid investment in new technology in the service sector. According to the estimates made in Kneller & Young (2001) investment in information and communication technology (in constant prices) in the U.K. increased by an average annual rate of 15.4 per cent between 1988 and 1994 and an average annual rate of 37.6 per cent between 1995 and 1998. The service sector as a whole accounted for close to 80 per cent of all investment in computer equipment in 1998.

Using regression as well as transition matrix analyses, we find significant cross-firm productivity differences in the service sector. However we also find that the persistence of a given firm in the productivity distribution is too low to be explained completely by a model of fixed firm characteristics. Somewhat remarkably Bailey, Hulten & Campbell (1992) and Bartelsman & Dhrymes (1998) report similar findings for US manufacturing firms. To account for this low persistence Bailey et al. (1992) suggest developing a model that combines a fixed firm effects model with one in which firms are subject to random shocks, whereas we take an alternative approach and study a model of convergence. Within the convergence model firms imitate best practice technology enabling them to close any productivity gap over time. The greater the size of the productivity gap the faster the rate of growth is expected to be.

In an extension of the model we add greater complexity to the dynamics of productivity by allowing the rate of convergence and the position of the frontier to differ amongst firms. From this we find that service sector firms appear to be converging to the same steady state within a given industry. We therefore modify the Bernard & Jones (1996) hypothesis that technology in the service sector is global to one in which technology is global within each industry. Firms differ in the rate of technology catch-up because they apply different levels of effort in the absorption of new technologies. These differences are measured by observable firm level characteristics such as age, size and ownership. Here we find only weak evidence that the rate of convergence differs according to the age of the firm, but stronger evidence that ownership is important. Foreign owned firms, which also have higher average productivity levels, exhibit faster rates of convergence than their domestically-owned counterparts. One possible explanation for this result is that the high levels of average productivity in foreign owned firms acts as a proxy for high levels of absorptive capacity, which are necessary for the successful imitation and adoption of new technologies.

The rest of the paper is organised as follows. In Section 2 we briefly review some of the models of productivity dynamics. Section 3 outlines our empirical strategy and the convergence model. Section 4 presents the empirical findings, and the last section concludes.

2. Some models of productivity dynamics

Bailey Hulten & Campbell (1992) summarise the possible patterns of firm level productivity dynamics using four simple models. Changes in the distribution of productivity among firms arise as a result of various combinations of random shocks, differences in the vintage of capital or fixed plant heterogeneity. Empirical application of these models by Bailey et al. (1992) leads them to favour a combination of the model in which random shocks affect the level of productivity and the fixed plant effects model. We describe these two models and their relationship to more complex models of firm behaviour in this section and leave the description of the alternative model of convergence to the next section.

Random Shocks to the level of Productivity

In the random productivity level model, the production technology of the plant or firm is determined through a combination of random economic shocks to the level of productivity and deterministic growth (equations 1 and 2). More formally, output in firm i at time t is a function of the production technology F, where K is physical capital and L is labour, and productivity A. The level of productivity, given by equation (2), is in turn equal to the exponential of deterministic productivity growth, β, and ε a random shock. Shocks are assumed to be drawn from an i.i.d. distribution.

$$Y_{it} = F(K_{it}, L_{it})A_{it} \tag{1}$$

$$A_{it} = e^{\beta t + \varepsilon_{it}} \tag{2}$$

Deterministic growth ensures that average level of productivity in the entire distribution rises over time, whereas the variance of the productivity distribution of firms relative to the mean remains constant if the distribution from which shocks are drawn remains constant. The model also predicts that the productivity of an individual firm relative to the industry mean will be uncorrelated across time. This holds because the relative position of a firm in the productivity distribution is determined solely by its draw from the distribution of shocks in a given period. It follows that firms with above average productivity in one time period are likely to exhibit below average productivity the next time period. The rank of a firm in the productivity distribution will therefore display low cross time persistence.

Fixed Plant Effects

The plant fixed effects model can be thought of as lying at the other extreme of firm behaviour. In this model firms display permanent differences in their productivity levels. This is captured by v_i in equation (3) below. The variance of the entire productivity distribution and the position of a firm within this distribution will remain fixed over time. Even if random shocks (ε_{it} in equation 3) are allowed to affect the productivity level of the firm, the model predicts the position of the firm will remain broadly stable, for example within the same quintile of the distribution. Given the expected value of ε_{it} is zero this relationship will be stronger the longer the time period considered.

$$A_{it} = v_i + \beta t + \varepsilon_{it} \tag{3}$$

These models provide useful statistical descriptions of the dynamics arising from models better grounded in economic theory, for example the passive learning model of Javanovic (1982) and the active learning model of Ericson & Pakes (1995). Javanovic (1982) puts forth a productivity evolution model that is based on firm heterogeneity and selection. At birth each firm is endowed with some time-invariant cost of production parameters, which it is only able to identify slowly as it keeps producing. Firms decide whether to stay within the industry or exit the industry according to it's current (imperfect) cost information, so that unproductive producers might stay in business until they realised their inefficiency. So firms passively learn about some immutable productivity parameter.

In contrast to the Bayesian learning model of Javanovic (1982) with its fixed efficiency parameter, the theoretical framework of Hopenhayn (1992) assumes that firms are subject to random productivity shocks every period. This productivity shock follows a first-order Markov process, and the distribution of future productivity is increasing in current productivity. Hopenhayn (1992) predicts that low productivity firms are more likely to exit, and younger cohort firms are less productive than older ones.

The active exploration model of Ericson and Pakes (1995) assumes that firms know their current productivity/profitability parameter. However, this parameter changes over time in a stochastic manner following the firms' investments and the actions of other firms in the market. So as firms strive to improve their quality, their productivity may improve. But the introduction of a stochastic firm-level efficiency means that a negative productivity shock can cause previously efficient firms to suffer losses in productivity. Firms don't passively receive random productivity shocks however; rather the decision to exit is the result of an explicit profit maximising choice.

Pakes and Ericson (1998) attempt to discriminate between the two alternative models of firm dynamics. They derive the empirical implications of both models and devise nonparametric tests. The basic intuition of Pakes and Ericson (1998) is as follows. Consider the following stochastic process generating sales (S) conditional on survival,

$$E[S_t \mid S_{t-1} = s_{t-1}, \ldots S_k = s_k, S_1 = s_1] \tag{4}$$

where the subscript indexes time periods.

Pakes and Ericson (1998) argue that the passive learning model implies that the regression function (1) depends on the initial value s_1, and it should be strictly increasing in it. The Javanovic (1982) model therefore predicts, like the fixed firm effects model, that the productivity differences are permanent (i.e. productivity shocks are fixed effects). In contrast, active learning on the part of firms implies that for large enough *t*, the regression function (1) is independent of s_1. This is consistent with the predictions of the random shocks model.

3. Empirical strategy

The convergence model provides an alternative description of differences in firm level productivity and dynamics. The model draws on the fixed firm effects model to describe differences in the level of productivity, while the productivity dynamics describe learning (imitation) by firms.

Firms in the convergence model are assumed to apply frontier technology with a firm-specific efficiency parameter, where differences in efficiency may exist because of differences in managerial ability (Lucas, 1978; Javonovic, 1982) or absorptive capacity (Abromovitz, 1986; Cohen & Levinthal, 1989; Fagerberg, 1988; Verspagen, 1991).[1] Productivity growth occurs because of technical transfer. Firms that lag in their productivity levels can imitate from firms that lie on the technical frontier. If, as seems likely, imitation is less costly than innovation and the cost of imitation is increasing in the complexity of the technology then firms with low initial productivity will display faster growth than firms with high initial productivity. The greater the size of the productivity gap the greater the scope for imitation and catch-up. Differences in firm fixed effects imply that this convergence is conditional rather than absolute; firms converge to their own steady state.

It is possible, however, that the same factors that determine the steady state level of efficiency of the firm may also affect the rate of convergence. Firms that have better management and higher absorptive capacity of its workforce may converge more quickly to their steady state productivity levels than firms that lack these properties. Firms of this type are better at learning about new technologies and applying them in the workplace. We therefore extend the model to account for this possibility of heterogeneity in the speed of convergence.

The above properties are summarised in equation (5) below, which describes the rate of productivity growth in firm *i* at time *t*. The parameter α_{oi} captures firm level fixed effects, α_{2j} fixed industry effects and α_{1i} the rate of convergence. Initial productivity is measured relative to the technical leader in the industry (*j*) in which firm *i* operates.

$$\Delta \ln(A_{ijt}) = \alpha_{oi} - \alpha_{1i} \ln(\frac{A_{ij}}{A_{Fj}})_{t-1} + \alpha_{2j} + \varepsilon_{ijt} \qquad (5)$$

Unfortunately it is not possible to measure individual firm's learning effort in the dataset used in this paper (see data appendix for detail). Instead we hypothesise that firms with similar observable characteristics (*CHAR)* apply similar learning effort and have identical absorptive capacity. Thus equation (5) can be rewritten as:

$$\Delta \ln(A_{ijt}) = \alpha_{oCHAR} - \alpha_{1CHAR} \ln(\frac{A_{ij}}{A_{Fj}})_{t-1} + \alpha_{2j} + \varepsilon_{ijt} \qquad (6)$$

We measure *CHAR* using the age of the firm, the size of the firm and whether the firm is foreign or domestically owned. Firm age is an attempt to capture possible effects of firm vintage, while size captures possible economies (diseconomies) of scale effects among service sector firms. Finally, in the manufacturing sector (Griffiths & Simpson, 2002; Girma et al., 2001) productivity is found to be significantly higher in foreign over domestically owned firms. The productivity advantage of foreign owned firms is interpreted as resulting from better access to new technologies and managerial techniques. There is some debate as to whether this reflects differences in the average size of domestic and foreign owned firms or specific advantages of foreign owned firms and so we control for differences in firm size when using this variable.

If technical knowledge is global then we would expect firms to converge towards some fixed industry parameter in the long run, given by the industry specific fixed effect. However, within equation (6) we also allow for the possibility that firms may have permanent differences in their productivity levels, firms converge towards their own individual steady state. These steady states are captured by the fixed characteristics effects. If the argument put forward by Bernard & Jones (1996) that the technology used in the service sectors are similar across firms is correct, we might then expect that the estimated coefficients on these fixed characteristics effects to be jointly insignificant.

In addition to these convergence regressions we also study the evolution of the distribution of productivity in the U.K. service sector firms by using transition matrix analysis.[2] Quah (1993) argues at the cross-country level that transition matrices are more informative about the evolution of the distribution and possible convergence than convergence regressions of the type outlined above. We draw on evidence from both methodologies. Productivity transition matrices also allow us to discern the role of observable firm level characteristics such as age, size and ownership structure on the probability of improvement or decline in productivity. We construct five-period TFP transition matrices with typical element $M_{t+5}(i,j)$, by calculating the percentage of firms in productivity quintile *j* at time *t+5*, conditional on having been on in quintile *i* at time *t*. TFP is estimated as a residual from a Cobb-Douglas production function regression with time dummies, and in recognition of the fact that different industry might employ different combination of factor inputs (labour and capital), separate regressions are run for each of the 61 SIC92 three-digit industries in our sample.

4. Empirical Results

Productivity Levels

In order to provide initial evidence in support of the convergence model we begin with results for differences in the level of productivity between firms. Our sample covers the period 1988 to 1998[3]. Since exit from the sample cannot be clearly identified, we concentrate on firms that survive over each of the 5-year periods, 1988 to 1993 and 1993 to 1998[4]. In line with many of the studies based on micro data, we find from this analysis that firms differ markedly in their productivity levels. These differences are found to be related to observable firm characteristics, although, in contrast to the firm fixed effects model, they are not always stable across time. We infer from this finding that firm level dynamics are also important.

Table 1 reports productivity differentials across firm age groups.[5] In the first period under consideration, firms aged 10 to 21 years in 1988 enjoy a productivity advantage of 8.1 per cent relative to the other age groups.[6] Differences between the other age groups and the youngest firms (the omitted category) are not significant, although the point parameter estimates indicate that the youngest firms have on average the lowest productivity levels. In contrast, the results from the second period are consistent with the youngest firms having the highest average level of productivity. The average productivity level of firms in all the other age groups is significantly lower than that of firms aged 1 to 5 years in 1993. The results also suggest that the absolute magnitude of these productivity differences is increasing with age. Of the firms that survived between 1993 and 1998 the very oldest firms in the sample have an average productivity level close to 19 per cent lower than the very youngest firms in 1993. For firms aged 10-21 years and 5-10 years in 1993, the productivity differential is 13 per cent 9 per cent respectively. This appears to suggest that the cohort of firms that entered the market after 1993 and survived, are highly productive.

Table 1 [Here]

In Table 2 we present the extent of productivity differences among service sector firms in our sample that are due to ownership status and size bands. Foreign ownership appears to be an important determinant of differences in the level of productivity across firms.[7] Between 1988 and 1993 foreign owned firms have higher productivity than the domestically owned counterpart in the very small and large size bands. For very small firms the productivity gap with respect to very small domestic firms (the omitted category) is close to 20 per cent, whereas for large firms this gap is around 18 per cent. Small and medium firms did not display a statistically significant pattern of productivity compared to very small domestic firms.

When we compare foreign-domestic productivity differentials within the same size band, foreign firms are uniformly superior and the size of the productivity gap increases with the size band. This productivity gap ranges from the 20 per cent for very small firms to 31.2 per cent[8] for the large firms. For the 1993-1998 period, the productivity advantage of very small foreign firms over very small foreign firms rises from 19.8 per cent to 34.1per cent. It seems that very small foreign firms have enjoyed faster productivity growth over the second time period, although differences in the firms included in the two sub-samples prevents us from making a firmer conclusion. It is also worthwhile to note that the productivity gap between small domestic firms and very small domestic firms falls from 21.2 per cent in the first period to 13.8 per cent in the second.

Table 2 [Here]

Productivity Dynamics

The results for the level of productivity suggest that there are large differences in the level of productivity across firms. However, there is also evidence of variation in the results according to the time period chosen. To study these dynamics in more detail, we estimate transition matrices of movements in firms productivity between the start and the end of each periods. Table 3 provides age-stratified information on the percentage of firms that moved up, down or stayed within the same quintile, and Table 4 reports results from transition matrix analysis by ownership status and firm size. The results for the transition matrix over the 1988 to 1993 period suggest for example that, for younger firms, 52.1 per cent remained within the same quintile of the distribution, 24.5 per cent of firms moved to a lower quintile and 23.2 per cent to a higher quintile.

Perhaps the most noticeable result from these tables is that the degree of persistence in relative productivity across time for a firm. Around half of all surviving firms remain within the same quintile of the distribution over a 5-year period. This result is in line with Bartelsamn & Dhyrmes (1998) and Bailey et al. (1992) both for US manufacturing. The stability of the results across the literature and for what are very different samples of firms is interesting.

As with differences in the level of productivity there is also evidence of differences in firm level dynamics according to observable characteristics, although the differences are again sometimes small and often unstable across time. Over the first time period the degree of movement up or down the distribution appear to depend little on the age of the firm. For example, the percentage of the youngest firms moving down the distribution is only 2 percentage points different from the age group with the highest proportion of firms moving down the distribution, that of firms aged 5 to 10 years. However, the probability of moving down the distribution is more clearly associated with age over the second time period. Compared to the youngest firms the oldest firms in the sample are 5 per cent more likely to remain within the same quintile of the distribution and 5 per cent less likely to move down the distribution. But the probability of moving up the distribution is not clearly related to age in either period. This contrasts with Bartelsamn & Dhyrmes (1998) who find evidence of learning-by-doing in the evolution of productivity of the youngest firms.

Table 3: Transition Matrix by Age

	1988-93			**1993-98**		
Firm Age	*Stay*	*lose*	*gain*	*stay*	*lose*	*Gain*
<5	0.521	0.245	0.234	0.507	0.258	0.234
5-10	0.494	0.264	0.242	0.505	0.243	0.252
10-21	0.513	0.262	0.224	0.530	0.240	0.230
>21	0.539	0.259	0.203	0.557	0.208	0.235

As with differences in the level of productivity, we find somewhat stronger ownerhip-size effects in our transition matrix analysis. Broadly speaking domestically owned firms are more likely to move down the distribution and less likely to move up the productivity distribution than foreign subsidiaries. These differences are quite large. For example, the percentage of firms moving down the distribution is around 7 and 5 percentage points lower for large foreign owned firms than very small domestic firms in the first and second periods respectively. This is despite the fact that foreign owned firms also have a higher average productivity level than domestically owned firms

In accordance with Bartelsman & Dhrymes (1998) the probability of staying within the same quintile of the distribution is increasing in size, although these results are stronger for domestic over foreign owned firms. Broadly smaller firms are also more likely to move up or down the distribution, although again these relationships appear stronger for domestic over foreign firms. In the first period, foreign owned firms exhibit the highest propensity to move up the productivity distribution. Interstingly, the proportion of these firms moving down the distribution is no lower than the other size and ownership bands, such that these firms are much less likely to stay within the same quintile than other types of firms.

The above pattern seems to be stable across time. In the 1993 to 1998 period, a greater percentage of foreign owned firms moved up the distribution and a greater percentage of domestically owned firms moved down the distribution. The exception to this pattern is for large foreign owned firms. The percentage of firms moving up the distribution over this period is now lower than that for domestically owned counterparts in the same size band, whereas the percentage of firms moving down the distribution higher.[9]

Table 4 [Here]

To summarise our key findings; irrespective of firm size, age and ownership status the relative productivity level of firms is reasonably persistent across time. Around, and often greater than, 50 per cent of firms end the 5-year period in the same quintile of the distribution that they started in. These changes in the distribution appear weakly associated with age and more strongly associated with ownership status. Foreign owned firms are more likely to move up the distribution and less likely to move down even when controlling for differences in size.

Convergence

From the evidence presented in the previous two sections of this paper, it is difficult to make a firm conclusion in favour of either the fixed plant effects model or the random shocks model. In this respect we are in the same position as Bailey et al. (1992). In what follows, we test if our data lend support to the convergence model expressed in equation (6). Thus we allow for heterogeneity in the rate of convergence and the steady state according to the same observable characteristics used above.

Convergence of productivity levels can either be absolute, if the standard deviation of the productivity distribution falls across time, or conditional, if firms converge to their own steady states. In table 5 we report the results for absolute convergence, the standard deviation of the distribution of firms that survived, from 1988 to 1999. There is no evidence of absolute convergence in productivity levels within the sample. Although the end of-period standard deviation is smaller than at the start, the spread of the distribution is in fact at its lowest during the first five years of the 1990's.

Table 5: Sigma Convergence

Year	Standard Deviation	*Year*	Standard Deviation
1988	0.823	*1994*	0.766
1989	0.786	*1995*	0.751
1990	0.777	*1996*	0.762
1991	0.758	*1997*	0.778
1992	0.761	*1998*	0.779
1993	0.770	*1999*	0.814

In the first column of Table 6 we report estimates from the base specification, which is a pooled regression of TFP growth on initial relative TFP and industry specific fixed effects. As expected, the coefficient on initial relative productivity is negative. Firms that are out of steady state converge back over time. Although not reported the industry specific fixed effects are significantly different from zero. This confirms the results from Table 5 that convergence in this data set is conditional rather than absolute.

We then augment the base specification to allow for differences in the growth rate of productivity and the position of the steady state according to firm age (regression 6.2) and size/ownership (regression 6.3). In the final two rows of the table we provide the test statistic (and *p-value*) from a test of the joint significance of the inclusion of observable firm level characteristics and their interaction with the productivity gap. From these test statistics it is clear that there are large differences in the rate of convergence across firms, whereas the evidence for permanent differences in the rate of productivity growth across firm characteristics is less conclusive. Given this latter result in combination with the joint significance of the industry specific fixed effects we can reject the idea of absolute convergence across all service sector industries, but we cannot reject the possibility of absolute convergence of service sector firms within a given industry. That is service sector firms appear to be converging to the same steady state within a given industry. From this we can modify the Bernard & Jones (1996) hypothesis that technology in the service sector is global to one in which technology is global within each industry.

There appear to be no permanent differences in the rate of growth that depend upon the ownership structure of the firm (interacted with size), while the same null can be rejected at the 5 per cent level, but not the 10 per cent level for the age of the firm. In regression 6.2 the results suggest that the greater the vintage of the firm, the slower it converges towards its steady state level of productivity compared to the very youngest firms. Little or no difference in the rate of convergence among domestic firms is evident from regression 6.3, whereas there is evidence that foreign owned firms catch-up more quickly. The rate of convergence is quickest for small and very small foreign owned firms.

Table 6 [Here]

To test the robustness of these results we re-estimate the same regressions for each of the two time periods, 1988 to 1993 and 1993 to 1998. These regressions are estimated imposing the restriction of no permanent differences in productivity growth across firm characteristics. In regressions 6.4 and 6.5, the coefficients are allowed to vary by the age of the firm and in regressions 6.6 and 6.7 by ownership (interacted with size).[10]

In regressions 6.4 and 6.5 we find evidence of convergence in the level of productivity amongst firms, the coefficients on the relative TFP terms are significant and negative. But differences in the rate of productivity convergence according to the age of the firm are not statistically significant: a Wald test of the joint significance of the age/relative TFP interaction terms can be rejected at the 10 per cent level. Individually the rate of convergence is significantly different for firms aged over 21 years. Thus there is weak evidence that convergence rate is slower the older are firms in the period 1988-93. This finding is supported by the results from the second period displayed in regression 6.5. Evidence again exists from this regression the rate of convergence is slower for the 10-21 year old age group, although again no difference is evident for firms aged 5- 10 years old in comparison to the base group of youngest firms.

The evidence that the rate of convergence differs according to firm level characteristics is stronger in the regression results reported in the last two column of Table 6. The test statistics from a Wald tests of the joint significance of the ownership and size interaction terms is well above conventional critical values. The results suggest that the rate of convergence is faster for foreign firms than domestic firms: the coefficient on each of the foreign interaction terms is negative, whereas those for domestic firms are all positive. These differences are statistically significant in the case of very small foreign firms and large foreign firms only however. In both regressions the rate of convergence is fastest for very small foreign firms. At the end of the spectrum the rate of convergence is slowest for small and medium domestic firms in the first period, and for the latter group of firms in the second time period.

These results from these exercises are interesting because they suggest that the rate of convergence is associated with initial productivity levels. Groups of firms that have the highest average productivity also have the fastest rate of convergence towards the technical frontier. These results occur whether the rate of convergence is allowed to differ across age groups or through size and ownership. They are also robust across time.

In the final column of Table 6 we present the results from the GMM estimation of equation 6.3, but excluding the fixed characteristic effects. The estimation of convergence regressions using GMM has been shown by Caselli, Esqivel & Lefort (1996) to be important in the cross-country literature.[11] Initial relative TFP and interactions are instrumented with 4th lag and the square of this lag all interacted with the category dummies. The tests of the overidentifying restrictions (robust form of Sargan test) show that the instruments are valid. The p-value of the Sargan test is 0.978. The estimated parameter on the initial relative TFP term is somewhat smaller in this model compared to that from regression 6.3. This would appear to confirm the downward bias on the convergence parameter found from the OLS estimation of models of this sort. Of the interaction parameters none are now significant at the 5 per cent level. However upon closer inspection it is evident that many of the parameter values do not change much between regressions 6.3 and 6.8 and we cannot reject the null hypothesis that the interaction terms are collectively significant. The interaction terms are significant at the 4 per cent level.

Within Table 6 the rate of convergence appears to differ significantly amongst firms. One question that arises out of these results is whether this rate of convergence is more strongly related to the age of the firm or to the ownership status of the firm. To gauge the relative importance of each we split the sample either by ownership (and size) or by firm age. For each of the separate age bands we then include the relative TFP term interacted with ownership (and size) and in each of the ownership (and size) bands we interact relative TFP with age. That is, controlling for age we test whether heterogeneity in the rate of convergence according to ownership status remains. These results are then compared to those generated when ownership status is controlled for and catch-up is allowed to vary by age. Given the large number of regressions estimated, sixteen regressions are estimated controlling for ownership and eight when controlling for firm age, in Table 7 we just report the results from a Wald test of the joint significance of these interaction terms for the first and second time periods rather than the full set of results.

When the data are split by ownership and age is interacted with relative TFP (the left hand side of the table) we find evidence that the rate of convergence differs between different firm vintages in less that half of the 16 estimated regressions. The Wald test statistics are significant at the 5 per cent level in 3 of the regressions and significant at the 10 per cent level in a further 3. There is also little consistency in the results across the two time periods. At the 10 per cent level the rate of convergence differs for firm vintages among very small foreign, medium foreign and large domestic firms in the first time period, but among small domestic, medium domestic and large domestic firms in the second time period.

The evidence for the importance of ownership is much stronger (the results in the right hand side of Table 7). Controlling for firm age the rate of ownership to differ significantly for foreign and domestically owned firms in 7 of the 8 regressions at the 5 per cent level and all of the regressions at the 10 per cent level. The pattern of coefficients (not reported) in each of these regressions match those found in Table 6. Domestically owned firms are consistently found to converge at a slower rate than foreign owned firms. From Table 7 we suggest that ownership (and size) appear more important than firm age for the rate of catch-up.

Table 7 [Here]

5. Conclusions

The empirical evidence presented in this paper suggests that a model of convergence in the level of productivity amongst firms is able to capture the dynamics present in UK service sector data from 1988 to 1998. Differences in the level of productivity across firms are found in the data, where these differences are related to the age and the ownership (interacted with size) of the firm. However the results from transition matrices along with the stability of the results from these levels regressions across time suggests significant differences in the rate of change of firm level productivity also exist. These patterns are weakly related to the age of the firm, but do appear to be related to the ownership structure of the firm. The ownership status of the firm would appear important for the level and rate of change of productivity.

When the level and dynamics of firm level productivity are studied together using a convergence regression we find strong evidence for conditional convergence amongst firms. Firms that lie further below their steady state level of productivity grow more quickly than firms that lie closer to their steady state level of productivity at time *t*. The position of the steady state was not found to be related to the age or ownership status of the firm whereas the rate of productivity growth was. Once again these results were more stable for the ownership variable. Foreign owned firms were found to converge towards the industry specific steady state level of productivity more quickly than their domestic counterparts. This difference occurs at each of the different firm size bands considered. The rate of convergence was not found to be clearly related to the size of the firm. Overall the results from this paper support findings at the cross-country level that convergence of productivity levels occurs among service sector firms. Like Bernard & Jones (1996) we conjecture that convergence occurs because the technologies used by different service sector firms within a given industry are similar.

What is the role of globalisation of the service industry in facilitating the productivity catch-up by laggard firms? Can the findings reported in this paper be mirrored in firms level data from other OECD countries? Data permitting, it is certainly worth investigation these and other questions for a fuller understanding of the major factors behind and extent of productivity convergence in the service industry.

References

Abromovitz, M., (1986). 'Catching up, forging ahead, and falling behind', *Journal of Economic History*, 46, 386-406.

Baily, M.N., Hulten, C. and Campbell, D. (1992). ' The distribution of productivity in manufacturing firms', *Brooking Papers: Microeconomics*, Washington D.C.

Bartelman, E.J. and Dhrymes, P.J. (1998). ' Productivity dynamics: U.S. manufacturing plants, 1972-1986', *Journal of Productivity Analysis*, 9, 5-34.

Bartelman, E.J. and Doms, M. (2000). 'Understanding productivity: Lessons from longitudinal microdata', *Journal of Economic Literature*, 38, pp.569-595.

Bernard, A.B. and Jones, C.I. (1996). 'Comparing apples to oranges: productivity convergence and measurement across industries and countries', *American Economics Review*, 86, 1216-1252.

Broadberry, S. (1998). 'The role of services in aggregate productivity performance: Britain, the United States and Germany, 1870-1990', Working Paper, University of Warwick.

Carree, M.A., Klomp, L. and Thurik, A.R. (2000). 'Productivity convergence in OECD industries', *Economic Letters*, 66, 337-345.

Caselli, F., Esquivel, G., and Lefort, F. (1996). 'Reopening the convergence debate: A new look at cross-country growth empirics' *Journal of Economic Growth*, 1, 363-389.

Cohen, W., and Levinthal, D. (1989). 'Innovation and learning: Two faces of R&D', *Economic Journal*, 107, 139-49.

Ericson, R. and Pakes, A. (1995). 'Markov-perfect industry dynamics: A framework for empirical work' *Review of Economic Studies*, 62, 53-82.

Fagerberg, J., (1994). '*Technology and international differences in growth rates*', *Journal of Economic Literature*, 32 (September), 1147-1175.

Girma, S., Greenaway, D. and Wakelin, K. (2001), "Who benefits from foreign direct investment in the UK?", *Scottish Journal of Political Economy,* 48, 119-133.

Griffith, R. and Simpson, H. (2002), "Characteristics of foreign-owned firms in British manufacturing", in Blundell, R., D. Card and R. Freeman (eds.), *Creating a Premier League Economy*, Chicago: Chicago University Press, forthcoming.

Gouyette C. and Perelman, S. (1997). 'Productivity convergence in OECD service industries', *Structural Change and Economic Dynamics*, 8, 279-295.

Hopenhayn, H.A. (1992). 'Entry, exit, and firm dynamics in the long run' *Econometrica*, 60, 1127-1150.

Jovanovic, B. (1982). 'Selection and the evolution of industry' *Econometrica*, 50, 649-679.

Kneller, R. and Young, G. (2001). 'The New British Economy', *National Institute Economic Review*, July, 2001.

Lucas, R. (1978). ' On the size distribution of business firms', *Bell Journal of Economics*, 9, 508-523.

Oulton, N. (1998). 'Labour productivity and foreign ownership in the UK', NIESR Discussion Paper No.143.

Pakes, A. and Ericson, R. (1998). 'Empirical implications of alternative models of firm dynamics' *Journal of Economic Theory*, 79, 1-45.

Togo, F. (2002). 'Productivity convergence in Japan's manufacturing industries', *Economic Letters*,75, 61-67.

Quah, D., (1993). 'Empirical cross-section dynamics in economic growth', *European Economic Review*, 37, 426-434.

Verspagen, B. (1991), 'A new empirical approach to catching up or falling behind', *Structural Change and Economic Dynamics,* 2(2), pp. 359-80.

Table 1: Productivity Differences Across Age Groups

	Period	
Firm age	*1988-93*	*1993-1998*
5-10	0.033 (1.10)	-0.091 (2.63)**
10-21	0.081 (2.73)**	-0.131 (4.04)**
> 21	0.007 (0.24)	-0.193 (5.94)**
Constant	-0.029 (1.42)	0.186 (6.61)**
Observations	6783	7360

Note:

(i) Robust t-statistics in parentheses

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

Table 2 Productivity Differences Across Size and Ownership

	Period	
Firm class	*1988-1993*	*1993-1998*
Very small foreign	0.198 (2.57)*	0.341 (5.04)**
Small Domestic	-0.212 (5.36)**	-0.138 (3.50)**
Small foreign	0.075 (1.35)	0.049 (0.98)
Medium domestic	-0.237 (6.25)**	-0.217 (5.83)**
Medium foreign	0.044 (0.79)	0.041 (0.81)
Large domestic	-0.147 (3.92)**	-0.122 (3.35)**
Large foreign	0.179 (3.50)**	0.190 (4.10)**
Constant	0.087 (2.65)**	0.113 (3.41)**
Observations	6783	7360

Note:

(i) Robust t-statistics in parentheses

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

(iii) A very small firm is defined as one employing less than 13 people (which corresponds to the 25th percentile value). Small firms employ between 13 and 33 (median value) workers. Medium firms have between 33 and 79 (75th percentile) employees. The rest are classified as large firms.

Table 4 Transition Matrix by Ownership and Size

	1988-93			1993-98		
Firm class	*Stay*	*lose*	*gain*	*stay*	*lose*	*gain*
V. small Domestic	0.486	0.277	0.237	0.511	0.263	0.226
V. small Foreign	0.437	0.230	0.333	0.468	0.245	0.287
Small Domestic	0.503	0.277	0.220	0.516	0.248	0.235
Small Foreign	0.545	0.205	0.250	0.486	0.243	0.270
Medium Domestic	0.524	0.269	0.208	0.531	0.234	0.235
Medium Foreign	0.519	0.262	0.219	0.476	0.219	0.305
Large Domestic	0.535	0.254	0.211	0.583	0.194	0.223
Large Foreign	0.577	0.207	0.217	0.590	0.219	0.190

Table 6

Conditional Convergence

Dependent variable TFP growth

Regression number	**(6.1)**	**(6.2)**	**(6.3)**	**(6.4)**	**(6.5)**	**(6.6)**	**(6.7)**	**(6.8)**
	1988-1998	1988-1998	1988-1998	1988-1993	1993-1998	1988-1993	1993-1998	1988-1998
A_i/A_F	*-0.217 (24.70)***	*-0.243 (18.62)***	*-0.216 (14.74)***	*-0.311 (21.86)***	*-0.263 (16.72)***	*-0.331 (22.25)***	*-0.265 (16.78)***	*-0.159 (7.65)***
Age(5-10)		*-0.011 (0.25)*						
Age(10-21)		*0.065 (1.54)*						
Age(21+)		*0.073 (1.60)*						
V.Small For			*-0.080 (0.79)*					
Small Dom.			*-0.066 (1.17)*					
Small For.			*-0.102 (1.29)*					
Med. Dom.			*-0.010 (0.18)*					
Med. For			*-0.050 (0.67)*					
Large.Dom.			*-0.054 (0.93)*					
Large. For.			*-0.014 (0.21)*					
A_i/A_F *Age (5-10)		*-0.001 (0.07)*		*-0.003 (0.44)*	*0.001 (0.08)*			
A_i/A_F *Age (10-21)		*0.036 (2.90)***		*0.006 (0.98)*	*0.016 (2.42)**			
A_i/A_F *Age (21+)		*0.046 (3.46)***		*0.009 (1.68)*	*0.027 (4.02)***			
A_i/A_F * (V.S.F.)			*-0.064 (2.30)**			*-0.055 (3.95)***	*-0.033 (2.32)**	*-0.062 (1.80)*
A_i/A_F* (S. Dom.)			*-0.003 (0.20)*			*0.034 (4.74)***	*0.021 (2.40)**	*-0.001 (0.05)*
A_i/A_F* (S. For.)			*-0.046 (2.15)**			*-0.016 (1.44)*	*-0.014 (1.27)*	*-0.001 (0.05)*
A_i/A_F * (M. Dom.)			*0.019 (1.28)*			*0.035 (5.01)***	*0.034 (4.01)***	*0.017 (0.87)*
A_i/A_F * (M. For.)			*-0.026 (1.28)*			*-0.005 (0.44)*	*-0.009 (0.95)*	*-0.031 (1.05)*
A_i/A_F * (L. Dom.)			*-0.011 (0.68)*			*0.021 (2.87)***	*0.008 (1.02)*	*-0.005 (0.16)*
A_i/A_F * (L. For.)			*-0.035 (1.81)*			*-0.028 (2.84)***	*-0.022 (2.28)**	*0.012 (0.22)*
Constant	*-0.681 (21.95)***	*-0.727 (16.37)***	*-0.670 (12.46)***	*-0.916 (20.12)***	*-0.867 (15.96)***	*-0.954 (21.05)***	*-0.901 (16.73)***	*-0.564* (12.72)**
Observations	*14110*	*14110*	*14110*	*6750*	*7337*	*6750*	*7337*	*13745*
Wald test (p-value)		2.27 *(0.08)*	*0.63 (0.73)*					

CHAR fixed effects							
Wald test (p-value) CHAR A_i/A_F*		*8.05 (0.00)*	*4.05 (0.00)*	*1.9 (0.13)*	*10.4 (0.00)*	*16.65 (0.00)*	*13.79 (0.00)*	*14.75 (0.04)*

Notes:

(i) Robust t-statistics in parentheses

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

Table 7 Ownership or age? Wald Test Statistics (and p-values)

Firm class	*1988-1993*	*1993-1998*	**Firm age**	*1988-1993*	*1993-1998*
Very small domestic	0.74 (0.529)	1.75 (0.154)	*< 5*	2.37 (0.020)	2.56 (0.010)
Very small foreign	2.44 (0.065)	0.93 (0.424)			
Small Domestic	0.65 (0.584)	2.48 (0.056)	*5-10*	5.48 (0.000)	1.95 (0.058)
Small foreign	0.54 (0.658)	0.25 (0.861)			
Medium domestic	1.74 (0.158)	3.80 (0.010)	*10-21*	6.46 (0.000)	5.03 (0.000)
Medium foreign	2.59 (0.053)	0.36 (0.784)			
Large domestic	4.33 (0.005)	4.70 (0.003)	*> 21*	6.93 (0.000)	7.56 (0.000)
Large foreign	0.27 (0.850)	1.17 (0.322)			

Data Appendix

The primary source of information used in the study is the OneSource database of private and public companies. This data is derived from the accounts that companies are legally required to deposit at Companies House[1]. The inclusion criteria for the OneSource database are given as : "*All public limited companies, all companies with employees greater than 50, and the top companies based on turnover, net worth, total assets, or shareholders funds (whichever is largest) up to a maximum of 110,000 companies*". The database does not include companies that are dissolved or in the process of liquidation. The data are deflated to constant prices using SIC 4 digit price deflators from the ONS.

Table A.1

Number of observations in the panel by 2-digit industries

Industry	1988-1993	1993-1998
Sales, maintenance and repairs of motor vehicles; retail sale of automotive fuels	7318	9305
Wholesale trade and commission trade, except for motor vehicles and motor cycles	24924	33057
Retail trade, except for motor vehicles and motor cycles; repair of personal and household goods	4721	6101
Hotels and restaurants	2736	4253
Land transport; transport via pipelines	2437	3353
Water transport	338	330
Air transport	204	265
Supporting and auxiliary transport activities; activities of travel agencies	3842	5034
Post and telecommunications	487	941
Real estate activities	3123	6461
Renting of machinery and equipment without operator and of personal and household goods	1257	1788
Computer and related activities	2173	3998
Research and development	444	774
Other business activities	9069	14451

The average annual growth rate of TFP across all firms in the sample was 2.7 per cent. Average growth over the first half of the period than the second. The average annual growth rate of TFP was 3.0 per cent from 1989 to 1994 and 2.4 per cent from 1995 to 1999.

These rates of growth and changes over time are similar to those for the service sector at the aggregate level in Kneller & Young (2001).

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[1] Technology is interpreted very broadly within the paper and includes therefore all business knowledge such as management strategy.
[2] See Bartelsman and Dhrymes (1998) and Togo (2002) for recent studies based on transition matrices analysis.
[3] While information exists for firms in 1999 the number is lower than proceeding years, the decision was therefore made to use 1998 as the end point in the sample.
[4] Firms included in the two sub-sample are not necessarily the same because they represent firms that survived between two different time periods.
[5] Table 3 reports the results for the average productivity differential at the start of the 5-year period i.e. 1988 and 1993. These results are robust to the use of end-of-period year data.
[6] These results are robust to the inclusion of industry specific fixed effects.
[7] The productivity advantage of foreign owned firms is long established in the empirical literature, see Oulton (1998) for references and additional results using the data set employed here.
[8] This is obtained by subtracting the large domestic firm differential (-14.7 per cent) from the large foreign firm differential (-17.9 per cent) in Table 2.
[9] We also try the interaction of ownership with age with similar results.
[10] In a separate set of regressions not reported we included and tested for differences in the position of the steady state according to the age and ownership/size of the firm. In each case we could accept the null hypothesis that the steady state was independent on the age or ownership/size of the firm.
[11] A Hausman specification test indicates that accounting for endogeneity in the regression may be important.

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[1] For our analysis we used the OneSource CD-ROM entitled "UK companies, Vol. 1" for October 2000.