AMERICANS DO I.T. BETTER:
US MULTINATIONALS AND THE PRODUCTIVITY MIRACLE

Nicholas Bloom[1], Raffaella Sadun[2] and John Van Reenen[3]

[1] *Stanford, Centre for Economic Performance and NBER*
[2] *London School of Economics and Centre for Economic Performance*
[3] *London School of Economics, Centre for Economic Performance, CEPR and NBER*

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Abstract

The US experienced a sustained increase in productivity growth in the decade after 1995, particularly in sectors that intensively use information technologies (IT). This "productivity miracle" did not occur in Europe. This paper uses two distinct micro datasets to show that US multinationals operating in Europe also experienced a "productivity miracle". US multinationals obtained higher productivity from IT than non-US multinationals in Europe, particularly in the sectors responsible for the US productivity acceleration. Furthermore, establishments that were taken over by US multinationals increased the productivity of their IT, whereas observationally identical establishments taken over by non-US multinationals did not. Combining a new pan-European IT dataset with our firm-level management practices survey, we find that the US advantage in IT is primarily due to its "people management" practices on promotions, rewards, hiring and firing. US-style people management appears to be associated with the ability to adopt new IT more effectively. As a result US firms at home and abroad experienced large increases in productivity growth when IT investment rose sharply after 1995. We can account for about half of the US-EU difference in productivity growth using our estimates.

Key words: *Productivity, Information Technology, Multinationals, Management.*

JEL classification: *O47, F23, E22, O3*

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One of the most startling economic facts of recent years has been the reversal in the long-standing catch-up of Europe's productivity level with the United States. American labor productivity growth slowed after the early 1970s Oil Shocks but accelerated sharply after 1995. Although European productivity growth experienced the same slowdown, it has not enjoyed the same rebound (see Figure 1)[1]. For example, Inklaar, Timmer and Van Ark (2008) show that US GDP per hour growth accelerated from 1.3% 1980-1995 to 2.2% 1995-2006, whereas in Europe productivity growth slowed from 2.3% to 1.4%. Although some part of the observed European slowdown may be due to labor market reforms getting less skilled workers into jobs, most analysts agree there was still a substantial gap in productivity growth between the US and EU over the course of a decade. Nor is it obvious that the 2008/09 recession will change this picture as US productivity growth appears to have held up surprisingly well for this stage of the cycle[2].

Decompositions of US productivity growth show that a large fraction of this recent growth occurred in those sectors that either produce IT (information technologies) or intensively use IT. Closer analysis has shown that European countries had a similar productivity acceleration as the US in IT *producing* sectors (such as semi-conductors and computers) but failed to achieve the spectacular levels of productivity growth in the sectors that *used* IT intensively - predominantly market service sectors, including wholesale, retail and financial services (e.g. Van Ark, O'Mahony and Timmer, 2008). In the light of the credit crunch, the measured productivity gains in finance may prove illusory - which is why we focus on non-financial firms in the paper - but the productivity gains in other sectors like retail and wholesale are likely to be real and persistent. Consistent with these trends, Figure 2 shows that IT intensity appears to be substantially higher in the US than Europe and this gap has not narrowed over time. Given the common availability of IT throughout the world at broadly similar prices, it is a major puzzle why these IT related productivity effects have not been more widespread in Europe.

[1] Examples of early studies include Jorgenson (2001) and Oliner and Sichel (2000). Looking at more recent data, Jorgenson, Ho and Stiroh (2008) document that average annual US labor productivity growth was similar in the 2000-2006 period to the 1995-2000 period (and well above the 1.5% of 1973-1995). Only after 2005 is their any sign of a return to more "normal" levels of productivity growth as IT prices declines have slowed.

[2] For example, the BLS reported an annualized 2.8% productivity growth in 2008 and 1.6% growth in the first quarter of 2009 (http://www.bls.gov/news.release/prod2.nr0.htm). Given the large falls in employment and stabilization of output in the second quarter of 2009 the 2009 Q2 productivity growth figures are predicted to show an even larger increase.

There are at least two broad classes of explanation for this puzzle. First, there may be some "natural advantage" to being located in the US, enabling firms to make better use of the opportunity that comes from rapidly falling IT prices. These natural advantages could be tougher product market competition, lower regulation, better access to risk capital, more educated[3] or younger workers, larger market size, greater geographical space, or a host of other factors. A second class of explanations stresses that it is not the US environment *per se* that matters but rather the way that US firms are managed that enables better exploitation of IT ("the US management hypothesis")[4].

These explanations are not mutually exclusive. In this paper we sketch a model that has elements of both (see Appendix B and Bloom, Sadun and Van Reenen, 2007). Nevertheless, one straightforward way to test whether the US management hypothesis has any validity is to *examine the IT performance of US owned organizations in a European environment*. If US multinationals partially transfer their business models to their overseas affiliates– and a walk into McDonald's or Starbucks anywhere in Europe suggests that this is not an unreasonable assumption – then analyzing the IT performance of US multinational establishments in Europe should be informative. Finding a systematically better use of IT by American firms outside the US suggests that we should take the US management hypothesis seriously. Such a test could not be performed easily only with data on plants located in the US because any findings of higher efficiency of plants owned by US multinationals might arise because of the advantage of operating on the multinational's home turf ("home bias")[5].

In this paper, we examine the differences in IT-related productivity between establishments owned by US multinationals, establishments owned by non-US multinationals and purely domestic establishments. We exploit two distinct rich and original panel datasets. The first is from the UK Census Bureau (the Office of National Statistics, ONS) and contains over 11,000 establishments. The UK is a useful testing ground because (a) it has extensive foreign ownership with frequent

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[3] For example, if IT is complementary with human capital then the larger stock of college educated workers in the US than Europe may mean that productivity grows faster in the US when IT prices are falling rapidly.

[4] Another possibility is international differences in productivity measurement (Blanchard, 2004). This is possible, but the careful work of O'Mahony and Van Ark (2003) focusing on the same sectors in the US and EU, using common adjustments for hedonic prices, software capitalization and demand conditions, still find a difference in US-EU relative productivity growth rates.

[5] Doms and Jensen (1998) find that plants owned by US multinationals have higher productivity than non-US multinationals. But since this study was based only on located in the US, it could just be a reflection of home bias.

ownership changes and (b) the UK Census Bureau has collected panel data on IT expenditure and productivity in both manufacturing and services since the mid-1990s. The second dataset is a firm-level panel covering seven European countries and combines our own international survey of management practices, a private sector IT survey and company accounting data. Although this European dataset is smaller, the use of observable measures of management practices allows a more direct test of the theory.

We report that foreign affiliates of US multinationals appear to obtain higher productivity than non-US multinationals (and domestic firms) from their IT capital and are also more IT intensive. This is true in both the UK establishment-level dataset and the European firm-level dataset. These findings are robust to a number of tests, including an examination of establishments before and after they are taken over by a US multinational compared to those taken over by a non-US multinational. Using our new international management practices dataset we then show that American firms have higher scores on "people management" practices defined in terms of promotions, rewards, hiring and firing[6]. This holds true for both domestically based US firms as well as US multinationals operating in Europe. Using our European firm-level panel we find these management practices account for most of the higher output elasticity of IT of US firms. This appears to be because people management practices enable US firms to better exploit IT technologies.

Our paper is related to several other literatures. First, there is a large body of work on the impact of IT on productivity at the aggregate or industry-level[7]. Second, there is growing evidence that the returns to IT are linked to the internal organization of firms. On the econometric side, Bresnahan, Brynjolfsson and Hitt (2002), Caroli and Van Reenen (2001) and Crespi, Criscuolo and Haskel (2006) find that internal organization and other complementary factors, such as human capital, are important in generating significant returns to IT. On the case study side, there is also a large range of evidence[8]. Third, in a reversal of the Solow Paradox, the firm-level productivity literature describes returns to IT that are larger than one would expect under the standard growth accounting assumptions. Brynjolfsson and Hitt (2003) argue that this is due to complementary investments in

[6] It is plausible that higher scores reflect "better" management, but we do not assume this. All we claim is that American firms have different people management practices than European firms, and these are complementary with IT.
[7] See, for example, Basu, Fernald, Oulton and Srinavasan (2003) and Stiroh (2002, 2004).
[8] Blanchard et al (2002) discuss a number of industry-specific examples. Baker and Hubbard (2004) is an excellent example of applying econometric techniques to a case study of on-board computers in the US trucking industry.

"organizational capital" that are reflected in the coefficients on IT capital. Fourth, there is a literature on the superior establishment-level productivity of US multinationals versus non-US multinationals, both in the US and in other countries[9]. We suggest that the main reason for this difference is the way in which US multinationals use new technologies more effectively than other multinationals. Finally, our paper is linked to the literature on multinationals and comparative advantage. A recent body of theoretical work emphasizes the importance of firm-level comparative advantage in multinationals[10]. In these models firms have some productivity advantage, which their multinationals transplant to their overseas affiliates. Our evidence on the systematically different people management practices of US overseas affiliates provides empirical support for this assumption. Interestingly, these results are also consistent with the literature reporting that US multinationals appear to be earning extremely high rates of return abroad from intangible capital ("dark matter"), particularly since the mid 1990s (e.g. McGrattan and Prescott 2008). Our results suggest one factor could be that the management practices of US multinationals enable them to more effectively use of IT.

The structure of this paper is as follows. Section I describes the empirical framework, the UK establishment-level data is described in Section II and the results from this panel presented in Section III. The European firm-level data is described in Section IV and the results from this panel are presented in Section V. Section VI offers some concluding remarks.

I. Empirical Modelling Strategy

We sketch our basic modelling strategy with more formal details in Appendix B. Here, sub-section A describes the basic approach, sub-section B describes the equations we can estimate when we do not directly observe management practices, as is standard in most economic datasets (this is the case for our UK establishment-level panel). By contrast, sub-section C describes the equations we are able to estimate when we *do* directly observe management practices (this can be implemented on our pan-European firm-level panel).

A. Basic Empirical Model

[9] See, for example, Doms and Jensen (1998) on US plants, Haltiwanger, Jarmin and Schank (2003) on German plants, Criscuolo and Martin (2005) on British plants and Benfratello and Sembenelli (2006) on Italian plants.

Consider the following production function:

$$Q_{it} = A_{it} O_{it}^{\alpha^O} C_{it}^{\alpha^C + \sigma O_{it}} L_{it}^{\alpha^L - \sigma O_{it}} K_{it}^{\alpha^K} M_{it}^{\alpha^M} \quad (1)$$

where *Q* denotes gross output of establishment (or firm) *i* in year *t*. *A* is a Hicks-neutral efficiency term, *M* denotes materials/intermediate inputs, *L* denotes labor, *K* denotes non-IT capital, *C* denotes computer/IT capital and *O* is a measure of the firms' management/organizational capital that is complementary with IT capital. This specification of the production function in equation (1) is a simple way of capturing the notion that IT (*C*) and management (*O*) are complementary if $\sigma > 0$ (Bresnahan et al, 2002). Equation (1) should be regarded as an approximation to a more flexible production function, such as the translog (we examine more general production functions in the empirical section). We assume that all the exponents on the factor inputs are bounded by zero and unity to make sure the firm's optimization problem is well behaved (i.e. $0 \le \{\alpha^L - \sigma O, \alpha^C + \sigma O, \alpha^K, \alpha^M, \alpha^O\} \le 1$). Note that α^O could be equal to zero, so that increasing *O* would have no direct effect on firm output. Finally, we will generally consider *O* to be fixed in the short run (sub-section D relaxes this assumption).

We use lower case letters to indicate that a variable is transformed into natural logarithms, so $q_{it} \equiv \ln Q_{it}$, etc., and consider parameterizing the establishment-specific efficiency in equation (1) as $a_{it} = a_i + \gamma' z_{it} + \xi_{kt} + u_{it}$ where *z* are other observable factors influencing productivity - establishment age, region and whether the establishment is part of a multi-plant group. The ξ_{kt} are industry-time specific shocks that we will control for with a full set of three-digit industry (*k*) dummies interacted with a full set of time dummies[11]. Under these assumptions, equation (1) can be written:

$$\begin{aligned}(q-l)_{it} &= \alpha^C (c-l)_{it} + \alpha^K (k-l)_{it} + \alpha^M (m-l)_{it} + (\alpha^C + \alpha^L + \alpha^M + \alpha^K - 1) l_{it} \\ &+ \sigma[(c-l)_{it} * O_{it})] + \alpha^O \ln O_{it} + a_i + \gamma' z_{it} + \xi_{kt} + u_{it}\end{aligned} \quad (2)$$

[10] For example, Helpman, Melitz and Yeaple (2004), Burstein and Monge (2007) and Antras, Garicano and Rossi-Hansberg (2008).
[11] We also experimented with year-specific four digit dummies and explicit measures of output prices (up to the five-digit level) which generated very similar results to our baseline model with year-specific three-digit industry dummies.

Another implication of the idea that IT capital is complementary with specific types of management is that, ceteris paribus, firms with higher levels of *O* will have a greater demand for IT capital. We consider the IT intensity equation[12]:

$$(c-l)_{it} = \beta^{O} O_{it} + \varphi_h ' w_{it} + \varsigma_{kt} + e_{it} \tag{3}$$

where w_{it} are controls, ς_{kt} are the industry-time shocks, e_{it} is an error term and we expect β^{O} to be positive under complementarity of IT and *O*. It is worth noting that the estimates of equation (2) and (3) embody alternative identification assumptions. If all factor prices are identical across firms (in an industry-year cell), there are no adjustment costs and firms make no optimization errors then only equation (3) will offer any insight into whether firms with higher levels of *O* have some productivity advantage in IT. On the other hand, if there is some exogenous variation in IT use then the production function of equation (2) will also indicate whether high *O* firms have a productivity advantage in their use of IT.

A key idea in this paper is that $\overline{O}^{USA} > \overline{O}^{MNE} > \overline{O}^{DOM}$, where $\overline{O}^{USA}$ is the mean level of management in US firms, $\overline{O}^{MNE}$, the mean level in non-US multinationals and $\overline{O}^{DOM}$, the mean level in domestic firms. We describe below two different empirical strategies to test this hypothesis, which vary according to the availability of data on *O*.

B. Testing the Model when O is unobserved

Basic Production Function - When *O* is unobserved, given its complementarity with IT, we expect to see systematic differences in the elasticity of output with respect to IT capital in equation (2) between US and other firms. In order to test this hypothesis we estimate the following production function for each sector *h* (e.g. IT intensive and non-IT intensive)[13]

[12] This is a first-order approximation to the non-linear factor demand equation (B7) for IT in Appendix B where the factor prices are common across firms in an industry for a given year. If $\sigma > 0$ then $\beta^{O} > 0$.
[13] We will generally suppress the *h* sub-script for notational simplicity.

$$(q-l)_{it} = \alpha^{C,DOM}(c-l)_{it} + \alpha^{K}(k-l)_{it} + \alpha^{M}(m-l)_{it} + (\alpha^{C,DOM} + \alpha^{L} + \alpha^{M} - 1)l_{it} +$$
$$+ \alpha^{C,USA}[(c-l)*D^{USA})]_{it} + \alpha^{C,MNE}[(c-l)*D^{MNE}]_{it} + a_i + \delta_h^{USA}D_{it}^{USA} + \delta^{MNE}D_{it}^{MNE} + \gamma' z_{it} + \xi_{kt} + u_{it} \quad (4)$$

where D_{it}^{USA} denotes that the establishment is owned by a US firm in year *t* and D_{it}^{MNE} denotes that the establishment is owned by a non-US multinational enterprise (the omitted base is that the establishment belongs to a non-multinational domestic firm denoted "*DOM*"[14]). If our model is correct then empirically when we estimate equation (4) we should find $\hat{\alpha}^{C,USA} > \hat{\alpha}^{C,MNE} > \hat{\alpha}^{C,DOM}$, i.e. a greater productivity effect of IT in US multinationals than non-US multinationals or domestic establishments[15].

Another implication of the idea that US firms have an advantage in the use of IT is that, ceteris paribus, they will have a greater demand for IT capital. Consequently we estimate the IT intensity equation equivalent to equation (3):

$$(c-l)_{it} = \beta^{USA}D_{it}^{USA} + \beta^{MNE}D_{it}^{MNE} + \varphi' w_{it} + \varsigma_{kt} + e_{it} \quad (5)$$

Where w_{it} are controls, ς_{kt} the industry-time shocks and e_{it} is an error term. The hypothesis of interest is, of course, whether $\beta^{USA} > \beta^{MNE}$.

Since the significance of the *US*ln(C/L)* interaction may capture unobservable factors beyond organizational differences, we perform an extensive range of tests to check the robustness of our results. These are detailed below.

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14 We could not reject that UK multinationals had the same productivity and IT elasticity as other non-US multinationals.

15 A more general form of the production function is one where we allow all the factor inputs (x_{it}^{J}) to differ by ownership status:

$$q_{it} = \sum_{M,L,K,C\in J}\alpha^{J,DOM}x_{it}^{J} + \sum_{M,L,K,C\in J}\alpha^{J,USA}D_{it}^{USA}x_{it}^{J} + \sum_{M,L,K,C\in J}\alpha^{J,MNE}D_{it}^{MNE}x_{it}^{J} + a_i + \delta^{USA}D_{it}^{USA} + \delta^{MNE}D_{it}^{MNE} + \gamma' z_{it} + \xi_{kt} + u_{it}$$

Note, that although we will estimate this equation in some specifications, empirically the interactions between the non-IT factor inputs and ownership status are not significantly different from zero. The one interaction that does stand out is between the US ownership dummy and IT capital: the coefficient on IT capital is significantly higher for US

Sub-sample of establishments who are taken over - One concern with our empirical strategy is that US firms may "cherry pick" the establishments with the highest IT productivity. This would generate a higher IT coefficient for American firms, but this would only be due to positive selection. To tackle this issue we focus on a sub-sample of UK establishments that have been taken over at some point in the sample period. Prior to the takeover we find no evidence of differential coefficients on IT in establishments subsequently targeted by US firm versus non-US firms. But after the takeover we find that establishments acquired by US firms have significantly higher IT productivity than those taken over by other firms.

Unobserved Heterogeneity - In all specifications, we choose a general structure of the error term that allows for arbitrary heteroskedasticity and autocorrelation over time. But, there could still be establishment-specific unobserved heterogeneity. So, we also generally include a full set of establishment-level fixed effects (the "within-groups" estimator). The fixed-effects estimators are more demanding, as there may be many unobservable omitted variables correlated with IT that generate an upwards bias for the coefficient on IT capital.

One aspect of unobserved heterogeneity is establishment-specific prices which will not be fully controlled for by the fixed effects and the industry dummies interacted with time dummies (see Foster, Haltiwanger and Syverson, 2008). Empirically, the dependent variable in equation (4) is revenue not physical units, so we are estimating "revenue productivity" equations rather than physical productivity equations and we should interpret the coefficients on the factor inputs as reflecting both the technological parameters and a mark-up term.

To investigate this we will estimate the "revenue productivity function" allowing for monopolistic competition following Klette and Griliches (1996) and de Loecker (2007). Essentially this implies including additional terms for four digit output interacted by ownership type to the empirical analogue of equation (4). Note, however, differential mark-ups for American firms cannot easily explain one of our findings that the coefficient on IT is significantly larger for US firms *but the other factor coefficients appear to be the same across multinationals types*. If US firms are able to command a higher output price for IT capital this is consistent with the idea that IT improves

establishments than for other multinationals or domestic establishments. We also cannot reject the hypothesis that all quality (rather than simply increasing output) by more for American multinationals than other multinationals. This higher IT-related quality would be reflected in a firm-specific higher mark-up for IT-intensive US firms. This is consistent with our theoretical story.

Endogeneity of the Factor Inputs - We take several approaches to check the robustness of our results to the endogeneity issue, accepting that there is no "magic bullet" to this problem which is still an active area of econometric research (see Ackerberg et al, 2008, for a survey). In particular, we present results using a version of the Olley-Pakes estimator (1996) allowing for multiple capital inputs, and the "System GMM" estimator of Blundell and Bond (1998, 2000). In both cases we find a much higher IT coefficient for US firms in the production function. We also present IT intensity equations derived from the first-order conditions of the model and find that US firms have significantly higher IT capital intensities than other firms, especially in the IT intensive sectors.

Heterogeneity in the coefficients by industry - We allow for considerable heterogeneity by including fixed effects and industry effects interacted with time dummies. But the fact that the gap in US-EU productivity growth is so concentrated in the so-called "IT intensive sectors" suggests breaking down the regression estimates along these lines. We follow exactly the same classification as Stiroh (2002) to divide our sample into those which intensively *use* IT versus the rest of the sample (he based these on the flow of IT services in total capital services). These are predominantly service sectors such as wholesale, retail and business services, but also include several manufacturing sectors such as printing and publishing (see Table A1). We interpret this sectoral breakdown as indicating which sectors in Europe have the greatest *potential* (i.e. highest σ) to benefit from IT-enabled innovations if firms are able to adopt the appropriate complementary organizational practices[16]. Blanchard (2004) and Blanchard et al (2002) give many examples of these from various in-depth case studies. One could argue, for example, whether or not Stiroh was correct in classifying retail in the IT intensive sector or not, but this is beside the point - retail is a sector that had fast productivity growth in the US post 1995 and Europe did not. Our hypothesis is that part of this difference was due to different management practices which enabled US retailers to efficiently

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ownership types have the same return to scale parameter so we generally impose this.

[16] We think this division is most appropriate as it does not rely on our subjective judgement. We consider other sectoral breakdowns such as using the industry level IT services share in Europe rather than the US and the IT to value added ratio. We obtain similar results from this. We also looked at a finer level of disaggregation by industry (such as splitting out retail and wholesale – see Section III).

exploit IT-enabled innovations in retail[17]. If that was the case, than estimating equation (4) by different industry sectors should reveal a much stronger *US*ln(C/L)* interaction in the "IT intensive sectors" than the other industries. We also go further estimating the productions functions separately by each two digit sector, in particular breaking down the IT intensive sector into sub-industries such as retail and wholesale.

C. Testing the Model using Direct Measurement of Firm Management practices

A more direct way to test whether US firms have higher levels of *O* (i.e. $\overline{O}^{USA} > \overline{O}^{MNE}$) is to use direct measures of management. For this purpose, we collected our own data on management practices based on the methodology in Bloom and Van Reenen (2007). We empirically measure *O* by an index of the "people management" in the firm which combines indicators of best practice in hiring, promotions, pay, retention and removing under-performers (see below and Appendix A). We focus on these people management aspects of firm organization because the econometric and case-study evidence suggest that these features are particularly important for IT. The successful deployment of IT requires substantial changes in the way that employees work, including the ability to decentralize decision making so employees can experiment. High outcomes on our people management scores will reflect this[18].

We show that this index of people management is higher in US multinationals than in non-US multinationals (and domestic firms). In particular, US firms tend to be more aggressive in promoting and rewarding high performing workers and removing under-performing workers[19]. We combine the measures of people management with firm-level panel data from accounting

[17] Retailing has shifted from a low tech industry focused on shifting boxes from producer to consumer to an industry whose main activity is trading information by matching goods to consumer demand on a near continuous basis, where IT is an integral part of this process.

[18] For example, the organizational measure in Bresnahan et al (2002) covers six measures which relate to the way that employees are managed (three on team-work, two on decentralization over pace and methods of work and one on employee involvement).

[19] The econometric and case-study evidence suggest that these features of people management are particularly important for IT. The successful deployment of IT requires substantial changes in the way that employees' work, which is highly intensive in people management. For example, Hunter, Bernhardt, Hughes and Skuratowicz (2000) describe how IT radically changed the organization of US banks in the 1980s. The introduction of ATMs substantially reduced the need for tellers. At the same time PCs allowed staff to locate on the bank floor and directly sell customers mortgages, loans and insurance, replacing bank managers as the primary sales channel for these products. IT also enabled regional managers to remotely monitor branches. This led to a huge reduction in branch-level management, and an extensive realignment of job responsibilities, major human-resources reorganization for senior bank managers. We discuss in more detail the empirical measures in the Data Section.

information and an alternative source of IT data described below. Using this new European firm-level panel database we estimate an augmented form of equation (4):

$$
\begin{aligned}
(q-l)_{it} &= \alpha^{C,DOM}(c-l)_{it} + \alpha^{K}(k-l)_{it} + \alpha^{M}(m-l)_{it} + \sigma[(c-l)_{it} * O_i)] + \alpha^{O}\ln O_i + \\
&+ (\alpha^{C,DOM} + \alpha^{L} + \alpha^{K} + \alpha^{M} - 1)l_{it} + \alpha^{C,USA}[(c-l) * D^{USA})]_{it} + \alpha^{C,MNE}[(c-l) * D^{MNE}]_{it} + \\
&+ a_i + \delta^{USA} D_{it}^{USA} + \delta^{MNE} D_{it}^{MNE} + \gamma' z_{it} + \xi_{kt} + u_{h,it}
\end{aligned}
\qquad (6)
$$

If our hypotheses is correct that the higher coefficient on IT in the production function for US multinationals is due to their management practices then we would predict that σ >0 and that $\alpha^{C,USA}$, the coefficient on the interaction between IT intensity and the US multinational dummy, $[(c-l) * D^{USA})]_{it}$, would be insignificant once we condition on $[(c-l)_{it} * O_i)]$. We will show that this is indeed the case in our European panel dataset. Note that this does not imply that management is unimportant without IT, nor that management only matters in certain sectors. Rather we are arguing these practices may be particularly important when combined with IT enabled innovations in the high productivity growth sectors of the "productivity miracle" period.

D. Models of adjusting Management Practices

To what extent does *O* change over time at the firm level? There is limited empirical evidence here, but many case studies suggest that management practices are difficult to change for incumbents. Micro-econometric studies of responses to external shocks such as deregulation (e.g. Olley and Pakes, 1996) or trade liberalization (e.g. Pavnik, 2002) suggest that much aggregate change in productivity is driven by reallocation, entry and exit rather than incumbent plants increasing their productivity. Some theoretical models are built on the assumption that the efficiency of establishments is fixed at birth (e.g. Jovanovic, 1982; Melitz, 2003). So, in the short-run, the assumption of quasi-fixed management practices seems plausible and we exploit this in our estimation.

In the longer-run, however, management practices are variable to some degree. Appendix B discusses some formal models where we allow management practices to be endogenously chosen by the firm. The first extension is to allow practices to be transferred when one firm takes over another firm. As with recent trade theory (e.g. Antras et al, 2008) we assume that a multinational can transfer its management practices overseas (subject to some cost). This generates predictions of a distinctive dynamic pattern for the productivity-IT relationship for establishments taken over by US multinationals, which we find in the takeover sub-sample (see sub-section I.B.2 above).

Appendix B also discusses allowing management practices to be adjustable even for establishments which are not taken over (with and without adjustment costs) and shows that the key predictions are robust to this extension. We also discuss how our modelling structure relates to Basu et al (2003) who also consider a formal model of productivity dynamics when there is complementarity between IT and organization[20].

II. Establishment-level panel data from the UK Census

We use two main datasets in the paper which are drawn from several sources. A full description of the datasets appears in Appendix A. Both are original and have not been previously exploited in empirical work. The first is an original UK establishment level panel constructed from combining multiple datasets within the UK Census Bureau. We present results from this data in Section III. The second is a firm-level panel dataset across seven European countries. This combines our own survey of management practices, an establishment-level IT panel and European firm-level accounting data. We describe the data in detail Section IV and present the results in Section V. Both datasets are unbalanced panels – i.e. we do not condition on the sub-sample of firms who are alive throughout the time period.

The basis of the UK data is a panel of establishments covering all sectors of the UK private sector called the Annual Business Inquiry (ABI). It does not include financial services, which is a virtue given the difficulty of measuring productivity in these sectors as the credit crunch has amply demonstrated. It is similar in structure and content to the US Longitudinal Research Database (LRD), which contains detailed information on revenues, investment, employment and material/intermediate inputs. However, unlike the US LRD it also covers the non-manufacturing sector from the mid-1990s onwards. This is important, because the majority of the sectors responsible for the US productivity acceleration are outside manufacturing, such as retailing and

[20] In Appendix B of Bloom et al (2007) we show how IT adjustment costs could help rationalize these TFP dynamics, although this is less elegant than in Basu et al (2003).

wholesaling[21]. We were also able to obtain access to several surveys of establishment-level IT expenditure conducted annually by the UK Census Bureau, which we then matched into the ABI using the establishment's reference number. The dataset is unique in containing such a large sample of establishment-level longitudinal information on IT and productivity.

We build IT capital stocks from IT expenditure flows using the perpetual inventory method and following Jorgenson (2001), keeping to US assumptions about depreciation rates and hedonic prices. We considered several experiments by changing our assumptions concerning the construction of the IT capital stock using alternative assumptions over depreciation rates and initial conditions[22]. Furthermore, we present results using an entirely different measure of IT usage based on the number of workers in the establishment who use computers (taken from a different survey, the E-Commerce Survey). Qualitatively similar results were obtained from all methods.

Our final dataset runs from 1995 through 2003, but there are many more observations after 1999. After cleaning, we are left with 21,746 observations with positive values for all the factor inputs. Note that the panel is unbalanced: we keep all entrants and exiters. The results are robust to conditioning on three continuous time series observations per firms, but are weaker if we start conditioning on many more observations as we induce increasing amounts of selection bias.

There are many small and medium-sized establishments in our sample[23] - the median establishment employs 238 workers. Average IT capital is about 1% of gross output at the unweighted mean (1.5% if weighted by size) or 2.5% of value added. These estimates are similar to the UK economy-wide means in Basu et al (2003).

We have large numbers of multinational establishments in the sample. We can identify ownership using the Annual Foreign Direct Investment registry, which we also use to identify takeovers (from

[21] The new US Longitudinal Business Database includes services but does not have information on IT or non-IT investment (see Davis et al, 2006).
[22] First, because there is uncertainty over the exact depreciation rate for IT capital, we experimented with a number of alternative values. Second, we do not know the initial IT capital stock for ongoing establishments the first time they enter the sample. Our baseline method is to impute the initial year's IT stock using as a weight the establishment's observed IT investment relative to the industry IT investment. An alternative is to assume that the plant's share of the industry IT stock is the same as its share of employment in the industry.
[23] Table A2 sets out the basic summary statistics of the sample.

changes in ownership). About 8% of the establishments are US owned, 31% are owned by non-US multinationals and 61% are purely domestic. Multinationals' share of employment is even higher and their share of output higher still. Table 1 presents some descriptive statistics for the different types of ownership, all relative to the three-digit industry average. Labor productivity, as measured by output per employee, is 24% higher for US multinational establishments and 15% higher for non-US multinational establishments. This suggests a nine percentage point productivity premium for US establishments as compared to other multinationals. But US establishments also look systematically larger and more intensive in their non-labor input usage than other multinationals. US establishments have 14 percentage points more employees, use about 8 percentage points more intermediate inputs per employee and 10 percentage points more non-IT capital per employee than other multinationals. Most interesting for our purposes, though, the largest gap in factor intensity is for IT: US establishments are 32 percentage points more IT intensive than other multinationals. Hence, establishments owned by US multinationals are notably more IT-intensive than other multinationals in the same industry.

III. Results from the UK Establishment Panel

A. Main Results

In Table 2 we examine the output elasticity of IT in the standard production function framework described in Section II (these are all different implementations of equation (4)). Column (1) estimates the basic production function, including dummy variables for whether or not the plant is owned by a US multinational ("USA") or a non-US multinational ("MNE") with domestic establishments being the omitted base. US establishments are 7.1% more productive than UK domestic establishments and non-US multinationals are 3.9% more productive. This 3.2% (= 0.0712 - 0.0392) difference between the US and non-US multinationals coefficients is also significant at the 5% level (p-value = 0.02) as reported at the base of the column[24].

The second column of Table 2 includes the IT capital measure. This enters positively and significantly and reduces the coefficients on the ownership dummies. US establishments are more IT intensive than other establishments, but this only accounts for about 0.2 percentage points of the

[24] This implies that about two-thirds (6 percentage points of the 9 percentage point gap) of the observed labor productivity gap between US and other multinationals shown in Table 1 can be accounted for by our observables, such as greater non-IT capital intensity in the US establishments, but a significant gap remains.

initial 3.2% productivity gap between US and non-US multinational establishments. Column (3) includes two interaction terms: one between IT capital and the US multinational dummy and the other between IT capital and the non-US multinational dummy. These turn out to be very revealing. The interaction between the US dummy and IT capital is positive and significant at conventional levels. According to column (3) doubling the IT stock is associated with an increase in productivity of 6.3% (=0.0428 + 0.0202) for a US multinational but only 4.6% (=0.0428 + 0.0036) for a non-US multinational. Note that non-US multinationals are not significantly different from domestic UK establishments in this respect: we cannot reject the possibility that the coefficients on IT are equal for domestic UK establishments and non-US multinationals. It is the US establishments that are distinctly different. The reported *US*ln(C/L)* interaction tests for significant differences in the output-IT elasticity between US multinationals and UK domestic establishments. The key test, however, is whether the IT coefficient for US multinationals is significantly different from the IT coefficient for other multinationals. The row at the bottom of Table 3 reports the p-value of tests on the equality between the *US*ln(C/L)* and the *MNE*ln(C/L)* coefficient (i.e. Ho: $\alpha^{C,USA} = \alpha^{C,MNE}$), showing that the coefficients are significantly different at the 5% level.

To investigate the industries that appear to account for the majority of the productivity acceleration in the US we split the sample into "IT using intensive sectors" in column (4) and "Other sectors" in column (5). Sectors that use IT intensively account for most of the US productivity growth between 1995 and 2003. These include retail, wholesale, business services and hi-tech manufacturing like printing/publishing. The US interaction with IT capital is much stronger in the IT-using sectors, and it is not significantly different from zero in the other sectors (even though we have twice as many observations in those industries). The final three columns include a full set of establishment fixed effects. The earlier pattern of results is repeated; in particular, column (7) demonstrates that US establishments appear to have a significantly higher coefficient on their IT capital stocks than other multinationals (and domestic firms)[25]. A doubling of the IT capital stock is associated with 1.2% higher productivity for a domestic or non-US multinational, but 4.9% higher productivity for an establishment owned by a US multinational.

[25] We were also concerned that the IT interaction could be driven by the presence of labor in the denominator of both the dependent variable and the interaction so we re-estimated without normalizing any of the variables by labor. The US interaction with IT was still significantly different from the non-US multinational interaction with IT (p-value = 0.040). See also the results in Bloom et al (2007).

Quantification - The results in column (7) of Table 2 reports a US coefficient on IT capital stock that is about 3.7% higher than for domestic firms or non-US multinationals. Given that IT intensity over the period of 1995 to 2004 was rising at about 22% per year in both the US and EU (Timmer and Van Ark, 2005), this implies a faster growth rate of labor productivity of US establishment in the IT intensive sector of about 0.81 percentage points per year (=0.22×3.7%). IT intensive industries account for about half of aggregate employment so that this higher coefficient – if applied to the US economy – would imply that aggregate US labor productivity would rise at about 0.4% a year faster than in Europe (= 0.5×0.81) between 1995 and 2004. Since actual US labor productivity growth over this period was at least 0.8% higher than in Europe, this coefficient would suggest that about half of the US productivity miracle was related to the stronger relationship between productivity and IT in the US than Europe.

B. Robustness Tests of the production function results

Table 3 presents a series of tests showing the robustness of the main results - we focus on the fixed effects specification, which is the most demanding, and on the IT intensive sectors, which we have shown to be crucial in driving our result. The first column represents our baseline production function results from column (7) in Table 2. The results were similar if we use value-added-based specifications (see column (2)), so we stay with the more general specification using gross output as the dependent variable.

Transfer Pricing and mark-ups - Since we are using multinational data, could transfer pricing be a reason for the results we obtain? If US firms shifted more of their accounting profits to the UK than other multinationals this could cause us to over-estimate their productivity. But this would suggest that the factor coefficients on other inputs, particularly on materials, would also be systematically different for US establishments (see the discussion on establishment-specific prices above). To test this, column (3) estimates the production function with a full set of interactions between the US multinational dummy and *all* the factor inputs (and the non-US multinational dummy and all the factor inputs). None of the additional non-IT factor input interactions are individually significant, and the joint test at the bottom of the column of the additional interactions shows that they are jointly insignificant[26]. We cannot reject the specification of equation (4) in column (1) as a good representation of the data versus the more general interactive models of column (3)[27]. This experiment also rejects the general idea that the productivity advantage of the US is attributable to differential mark-ups, because then we would expect to see significantly different coefficients on *all* the factor inputs, not just on the IT variable.

As a second test of differential mark-ups we follow Klette and Griliches (1996) and de Loecker (2007) by controlling for four-digit industry output (disaggregated by ownership type). The estimated mark-ups (inverse elasticities of demand) were significantly higher for multinationals than domestic firms, but the US multinationals did not have significantly higher mark-ups than non-multinationals (p-value of difference = 0.404). More importantly, the US IT coefficient remained significantly greater than the non-US multinational coefficient (p-value of difference = 0.009).

Mismeasurement of IT capital stock? - One concern is that we may be underestimating the true IT stock of US multinationals and this could generate a positive coefficient on the interaction term, because of greater measurement error for the US establishments. For example, US multinationals pay lower prices for IT than non-US multinationals. To tackle this issue we turn to an alternative IT survey (the E-commerce Survey, see Appendix A) that has data on the proportion of workers in the establishment who are using computers. This is a pure "stock" measure so it is unaffected by the initial conditions concern[28]. In column (4) we replace our IT capital stock measure with a measure of the computers per worker. Reassuringly, we still find a positive and significant coefficient on the US interaction with computer usage.

Functional Forms - We tried including a much broader set of interactions and higher order terms (a "translog" specification) but these were generally individually insignificant. Column (5) shows the results of including all the pair-wise interactions of materials, labor, IT capital, and non-IT capital

[26] For example, the joint test of the all the US interactions except the IT interaction has a p-value of 0.62.
[27] The p-value = 0.38 on this test. We also investigated whether the coefficients in the production function regressions differ by ownership type and sector (IT intensive or not). Running the six separate regressions (three ownership types by two sectors) we found that the F-test rejected at the 1% level the pooling of the US multinationals with the other firms in the IT intensive sectors. In the non-IT intensive sectors, by contrast, the pooling restrictions were not rejected. Details are available from the authors on request.
[28] Our IT capital stock measure is theoretically more appropriate as it is built analogously to the non-IT stock and is comparable to best practice existing work. The E-Commerce Survey is available for three years (2001 to 2003), but the vast majority of the sample is observed only for one period, so we do not control for fixed effects.

and the square of each of these factors. The additional terms are jointly significant but the key US interaction with the IT term remains basically unchanged (it falls slightly from 0.0368 in the baseline specification to 0.0334) and remains significant.

Stronger selection effects for US multinationals because of greater distance from the UK? - A further issue is that US firms may be more productive in the UK because the US is geographically further away than the average non-US multinational (in our data most foreign multinationals are European if they are not American). This would generate a strong US selection bias if only the most productive firms are able to overcome the greater fixed costs of distance. To test this we divide the non-US multinational dummy into European versus non-European firms. Under the distance argument, the non-European firms would have to be more productive to be able to set up greenfield establishments in the UK. According to column (6) however, the IT coefficient for the US multinationals is significantly higher than the IT coefficient for the non-European multinationals (p-value = 0.012), as well as higher than the IT coefficient on the European multinationals. Again, it is the US multinationals that appear to be different.

Industry heterogeneity - We allow for industry heterogeneity by including fixed effects, industry dummies interacted with time dummies and estimating separately for IT using sectors. We also considered further heterogeneity of the IT coefficients by estimating the production functions separately by each industry, but did not find much further systematic heterogeneity. For example, 70% of the IT using sectors (and 63% of the IT producing sectors) had positive US IT interactions compared to and only 42% of the “non-IT sectors”[29].

One experiment was to estimate separately for the retail and wholesale sector which have been large contributors to faster US productivity growth since 1995. For these 3,838 observations, the coefficient on the *US*ln(C/L)* interaction is 0.0347 with a standard error of 0.0181[30]. In the remaining IT intensive sectors outside retail/wholesale the coefficient on the *US*ln(C/L)* interaction

[29] Furthermore, the only significantly negative interactions between IT and the US multinational dummy were for these non-IT sectors.
[30] This is reassuring as manipulating the transfer prices of intermediate inputs is more difficult in retail/wholesale than in manufacturing, as intermediate inputs generally are purchased from independent suppliers.

is 0.0413 with a standard error of 0.0208. Consequently, our results are not simply driven by the retail and wholesale sector[31].

Controlling for endogenous inputs – We are also concerned about the endogeneity of the factor inputs attributable to unobserved transitory shocks. It is worth noting, however, that for endogeneity to rationalize our empirical results this would need to arise: (i) *only* for IT capital and not the other factor inputs; (ii) *only* for US multinationals; and (iii) *only* in the sectors responsible for the US productivity miracle. Such a bias is possible, of course, but it is not obvious what the alternative hypothesis would be that would induce exactly these types of bias.

Nevertheless, we re-estimated the production functions using a version of the Olley-Pakes estimator (1996) that allows for two observable capital stocks, IT and non-IT (a straightforward extension of the basic model as discussed in Ackerberg et al, 2008). We also used the "System GMM" estimator of Blundell and Bond (1998, 2000) which relies on a different set of identification assumptions to address the endogeneity of the factor inputs. These estimators are discussed in Appendix C with the results presented in Appendix Table A4. In both cases the main finding - that the output-elasticity of IT for US multinationals is much larger than the output-elasticity of IT for non-US multinationals - is robust, even though the coefficients are estimated less precisely than under our baseline within-groups estimates[32].

Unmeasured software inputs for US establishments - Could the *US*ln(C/L)* interaction reflect greater unmeasured software inputs for US establishments? Although this is certainly possible when we compare US multinationals with domestic establishments it is less likely when we compare US multinationals with non-US multinationals because *a priori* there is no reason to believe that they

[31] Another possible explanation for the apparently higher productivity of IT is that US multinationals may be disproportionately represented in specific industries in which the output elasticity of IT is particularly high. The interaction of IT capital with the US dummy then would capture omitted industry characteristics rather than a "true" effect linked to US ownership. To test for this, we include in our regression as an additional control the percentage of US multinationals in the specific four-digit industry and its interaction with IT. The interaction was positive and statistically significant but the coefficient on the IT*US interaction remains significant and largely unchanged.

[32] The coefficient on the *US*ln(C/L)* interaction in the GMM system estimator is 0.0524 with a standard error of 0.0192 and this is significantly different from the non-US multinational interaction at the 10% level. The underlying theoretical model of Olley-Pakes does not allow us to simply include interactions, so we estimated the production function

have higher levels of software. It could, however, be a problem if US firms were globally larger than other multinationals (software has a large fixed cost component so will be cheaper per unit for larger firms than smaller firms). To address this issue, we included a measure of the "global size" of the multinational parent of our establishments. In our UK ABI data, US and non-US multinationals are similar in their median global employment size. As a more direct test, we introduce an explicit interaction term between the global size of the parent firm (defined as the log of the total number of worldwide employees) and IT capital in a specification identical to baseline specification in column (1) of Table 4. The interaction between global size and IT is insignificant and the US interaction with IT remained significant (at the 1% level) and significantly different from the non-US multinational interaction with IT at the 10% level[33]. So this does not appear to support a large role for software inputs driving the superior US productivity of IT[34]. Nevertheless, to address this issue more directly we will use explicit measures of management practices in Section IV.

C. Estimation of the IT intensity equation

Table 4 examines the regressions where the dependent variable is IT intensity (IT capital stock per worker). Column (1) shows that IT intensity is significantly higher in US firms than in both domestic firms and non-US multinationals as was already suggested by Table 1. Column (2) presents the same regression for the sectors which intensively use IT and column (3) for the other sectors. The difference between US and non-US multinationals is significant at the 10% level for the IT using industries, but insignificant for the other sectors. The last four columns repeat the specifications but include a longer list of controls. The same pattern emerges: US firms are more IT intensive, especially in the IT using sectors.

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separately for the three ownership types (US multinationals, non-US multinationals and domestic UK establishments). The output-IT elasticity for US multinationals is twice as large as that of non-US multinationals.

[33] The global size variable was only available for a sub-sample of 2,205 observations (from the baseline sample of 7,784). When we re-ran the baseline specification on this smaller sub-sample, the US interaction with IT was 0.042 (instead of 0.037 in the baseline) and significant at the 1% level. When we include the global size term the point estimate rose to 0.043 (the point estimate on the global size*IT interaction was -0.0015, insignificant at conventional levels). We are very grateful to Ralf Martin and Chiara Criscuolo for matching in the data.

[34] We also used a measure of software capital constructed analogously to our main IT capital variable (see Appendix B). In our data, software expenditure includes a charge for software acquired from the multinational's parent. The IT capital interaction is robust to the inclusion of this measure of software capital (and its interaction with ownership status). For example, when we added software capital to a specification identical to column (1) of Table 4 the standard IT interaction with the US remained positive and significant. In the pan-European database in the next section we have explicit measures of software applications such as ERP and Databases and also find our results robust to using these measures of software.

Our implementation of the production function and IT demand equation generates the same finding – US firms appear to have some advantage in their use of IT as revealed both by the higher coefficient on IT in the production function and their greater usage of IT capital.

D. US Multinational Takeovers of UK establishments

One concern with our empirical strategy is that US firms may "cherry pick" the best UK establishments. In other words, it is not the US multinational's management that generates a higher IT coefficient but rather that American firms systematically take over UK establishments with higher output-IT elasticities. To look at this issue, we examined the sub-sample of establishments that were, at some point in our sample period, taken over by another firm in the IT-intensive sectors. We considered both US and non-US acquirers[35].

Note that the identification assumption here is not that establishments that are taken over are the same as establishments that are not taken over. We condition on a sample of establishments who are all taken over at some point in the sample period. Thus, we assume that US multinationals are not systematically taking over establishments that are more productive in their use of IT than non-US multinationals. We can empirically test this assumption by examining the characteristics - such as the IT level, IT growth and IT productivity - of establishments who will be taken over by US multinationals in the pre-takeover period relative to non-US multinationals. We will show that there is no evidence of such positive selection[36].

In column (1) of Table 5, we start by estimating our standard production functions, for all establishments that are eventually taken over in their *pre-takeover* years (this is labelled "before takeover"). The coefficients on the observable factor inputs are similar to those for the whole sample in column (2) of Table 3. Unlike the full sample, though, the US and non-US ownership

[35] We have a larger number of observations "post-takeover" than "pre-takeover" as there was a takeover wave at the beginning of our sample in the late 1990s associated with the stock market bubble and high tech boom. For these establishments, we necessarily have a lot more post takeover information than pre-takeover information. We drop takeovers which resulted in no change of ownership status (e.g. a US multinational taking over another US multinational subsidiary – see Appendix A).

[36] If US multinationals have higher IT productivity why do we not observe some systematic selection of US firms taking over particular UK establishments? We show there is some weak evidence of negative selection which is consistent with a simple model (discussed below and in Appendix B) of international transfer of management practices with a fixed costs. It is likely this incentive is small in magnitude compared to the many other causes of international merger and

dummies are insignificant, suggesting that the establishments taken over by multinationals are not *ex ante* more productive than those acquired by domestic UK firms.

In column (2) of Table 5 we interact the IT capital stock with a US and a non-US multinational ownership dummy, again estimated on the *pre-takeover* data. We see that neither interaction is significant – that is *before* establishments are taken over by US firms they do not have unusually high IT coefficients. So, US firms also do not appear to be selecting establishments that already provide higher IT productivity. In column (3) we estimate production function specifications identical to columns (1) but on the *post-takeover* sample. The US multinational ownership coefficient has moved from being negative in the pre-takeover period to being positive, implying a change of 10.1%. By contrast the non-US multinational coefficient hardly changes (it actually falls by 2%).

Column (4) is the post-takeover version of column (2) where we allow the coefficient on IT to differ by ownership status. As in the earlier results of Table 2, the interaction between IT and US ownership is positive and significant at the 5% level (and is significantly different than the non-US multinational's IT coefficient at the 10% level). The test of the difference of the *US*ln(C/L)* interaction before and after the takeover is significant at the 10% level (p-value=0.097)[37].

The fifth column of Table 5 breaks down the post takeover period into the first year after the takeover and the subsequent years[38]. The greater productivity of IT capital in establishments taken over by US multinationals is revealed only two and three years after takeover (this interaction is significant at the 5% level whereas the interaction in the first year is insignificant). This is consistent with the idea that US firms take some time to reorganize before obtaining higher productivity gains from IT. Domestic and other multinationals again reveal no pattern, with all the dummies and interactions remaining insignificant.

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acquisitions. Statistically, the only variable which was significant in a takeover model was size: US multinationals were more likely to take over larger plants than non-US multinationals. IT and other factors were insignificant.

[37] We examined whether the US productivity advantage was because they were more aggressive at closing down less efficient establishments. Foster, Haltiwanger and Krizan (2006), show that almost all aggregate US retail labor productivity growth in their sample is through this type of restructuring. In our data, although multinationals did close down more establishments post-takeover than domestic takeovers, American firms did not seem to do this significantly more than other multinationals.

[38] Note that throughout the table we drop the takeover year itself as we cannot determine the exact timing within the year when the takeover occurred.

The sample in Table 5 includes some multinational firms that are taken over by domestic UK firms, so a stronger test is to drop these observations and consider only takeovers by multinational firms. In column (6) we replicate the specification of column (5) for this smaller sample and again find that establishments taken over by US multinationals have a significantly higher coefficient on IT capital after two or more years than non-multinational takeovers.

Although there is no evidence that US firms are "cherry picking" the better UK establishments, it is noticeable that the point estimates in column (1) and (2) are consistent with the idea that US firms may select the UK establishments that have *lower* IT coefficients in the production function, a form of negative selection. Although these point estimates are statistically insignificant, negative selection is consistent with a model where US firms are able to transfer their management practices to the plants they acquire. If this transfer has an element of fixed disruption cost, US firms will have a greater incentive to reorganize firms after takeover and so will be more willing to purchase badly managed firms that they can "turnaround". Appendix B discusses an extension to our basic model that has this feature.

IV. Firm-level Panel data from seven European countries

A disadvantage of the UK establishment level panel is that it does not contain direct information on management practices. To remedy this we constructed a second panel dataset across seven European countries that combined three main sources: the Center for Economic Performance (CEP) management survey, the Harte-Hanks IT panel and the Amadeus database of firm accounts.

The CEP management survey - In the summer of 2006 a team of 51 interviewers ran a management practices survey from the CEP in London on 4,003 firms across Europe, the US and Asia. In this paper we use data on the 1,633 firms from seven European countries (France, Germany, Italy, Poland, Portugal, Sweden and the UK). Appendix A provides a detailed data description for the full sample, but we summarize relevant details here.

The management data was collected using the survey tool developed in Bloom and Van Reenen (2007). This survey collects information on 18 questions grouped into four broad areas of management practices. In this paper we focus on the four *people management* questions covering promotions, rewards, hiring and fixing/firing bad performers. The reason for this focus is because of the case study and econometric evidence that effective use of IT requires changing several elements of the way that people are managed. First, there is an abundance of empirical evidence that IT is on average skill biased and requires shedding less skilled workers, hiring more skilled workers and re-training incumbent workers. In addition to this skill upgrading, IT-enabled improvements usually require more worker flexibility inside the firm with workers taking on new roles. Secondly, some theoretical work emphasizes that when there is uncertainty over how best to use a new technology, giving more discretion to employees with higher powered rewards may be a way to efficiently exploit their private knowledge. Prendergast (2002) emphasized that higher powered incentives (such as output-based remuneration rather than flat-rate salary) may be more common when the principal has uncertainty over what tasks an agent should be performing. Acemoglu et al, (2007) argue that delegation becomes more attractive when there is uncertainty about the best way to use a new technology.

To operationalize these ideas we focus on four questions designed to pick up managerial attention to fixing/firing under-performers, aggressively promoting higher effort/ability employees (rather than just using tenure), offering higher powered incentives to employees and management effort in hiring talent. Like the questions used by Bresnahan et al (2002), they emphasize the management of human capital. We also present robustness tests looking at other forms of management and organization (such as lean techniques, target-setting and monitoring) and show that it is really people management that seems to matter for IT.

Firms are scored from a 1 to 5 basis on each question, with the scores then normalized into z-scores using the complete sample[39] so the questions can be aggregated together. Although it is plausible that higher scores reflect "better" management, we do not assume this. All we claim is that American firms have, on average, *different* people management practices than European firms, and these types of practices are complementary with IT. The survey uses a *double-blind* technique to try and obtain unbiased accurate responses to the management survey questions. One part of this double-blind methodology is that managers were not told they were being scored during the

[39] The scores are normalized to have a mean of zero and a standard deviation of one across the sample of 4,003 firms.

telephone survey. This enabled scoring to be based on the interviewer's evaluation of the firm's actual practices, rather than their aspirations, the manager's perceptions or the interviewer's impressions. To run this "blind" scoring we introduced the exercise as an interview about management practices, using open questions (i.e. "can you tell me how you promote your employees"), rather than closed questions (i.e. "do you promote your employees on tenure [yes/no]?"). Furthermore, these questions target actual practices and examples, with the discussion continuing until the interviewer can make an accurate assessment of the firm's typical practices based on these examples. Bloom and Van Reenen (2007) present extensive tests of the reliability of these management measures and their robustness to many different forms of psychological bias.

The Harte-Hanks establishment level IT Panel - We use an establishment level IT data panel that comes from the European Ci Technology Database (CiDB) produced by the marketing and information company Harte-Hanks (H-H)[40]. The H-H data has been collected annually for over 160,000 establishments across 14 European countries since the mid-1990s. They target all firms with 100 or more employees, obtaining about a 45% response rate. We use the data only for the firms we matched to those in the management survey (i.e. in France, Germany, Italy, Poland, Portugal, Sweden and the UK). Bresnahan et al (2002), Brynjolfsson and Hitt (2003) and Forman, Goldfarb and Greenstein (2009) among others have also previously used the US H-H data, typically matching the US data to a sub-sample of large publicly quoted firms in Compustat.

The H-H survey contains detailed hardware, equipment and software information at the establishment level. We focus on using PCs per worker as our key measure of IT intensity because this is available for all the establishments and is measured in a comparable way across time and countries. This PC per worker measure of IT has also been used by other papers in the micro-literature on technological change (e.g. Beaudry, Doms and Lewis, 2006) and is highly correlated with other measures of IT use like the firm's total IT capital stock per worker[41]. We aggregate across establishments to form an estimate of the firm-level number of PCs per worker.

[40] H-H is a multinational that collects IT data primarily for the purpose of selling on to large producers and suppliers of IT. The fact that H-H sells this data on to major firms like IBM and Cisco exerts a strong market discipline on the data quality. Major discrepancies in the data are likely to be rapidly picked up when H-H customers' sales force placed calls using the survey data.

The AMADEUS firm-level Accounts Panel - The AMADEUS accounts database, which provides company accounts on essentially the population of public and private firms in Europe. It has information for most companies on sales, employment and fixed-assets, and has been used in previous papers to estimate production functions (e.g. Bloom and Van Reenen, 2007 and de Loecker, 2007). AMADEUS is constructed primarily from the mandatory national registries of companies.

The combined European firm-level panel dataset

We match 43% of the 1,633 EU firms in our management survey to the H-H data and accounting data leaving us with a total of 719 companies. We estimate our regressions over the years 1999 to 2006. Panel C of Table A2 presents some descriptive statistics. As with the UK establishment database, compared to other multinationals, US multinationals are larger, more productive and have higher IT intensity. They also tend to have better people management (see next section). We also have information on the proportion of college educated workers which is also higher in the US than elsewhere. Consequently, as a robustness check for technology-skill complementarity we control for human capital and its interaction with IT in some regressions.

V. Results from a cross-European firm-level panel

The results so far suggest that US owned establishments have a higher elasticity of productivity with respect to IT intensity, even after taking over existing establishments. This implies there may be an unobserved factor that is more abundant in American firms and that is complementary with IT. In this section we explore the idea that people management practices constitute this previously unobserved factor and use our survey instrument to measure it. In the first sub-section we discuss some descriptive statistics and in the second sub-section we offer some econometric results consistent with our key hypothesis.

A. People Management in US firms compared to other countries

Before we present the results it is worth considering some supporting evidence on the different internal management of American firms compared to those in Europe and Asia. Remember that we choose these people management aspects because the econometric and case-study evidence suggest

[41] For example, in our establishment level data a regression of ln(IT capital stock per employee) on the ln(proportion of employees using computers) gives a coefficient of 0.63.

that these features of the firm are particularly important for effectively using IT, which frequently requires substantial changes in the way that employees work.

In Figure 3, panels 3a and 3b provide new evidence we collected on the people management scores of 4,003 firms in the US, Asia and Europe. In Figure 3a, we see that firms based in the US have much higher scores than firms in other countries – about half a standard deviation on average. In Figure 3b we examine a sub-sample of the data, plotting the average people management scores of subsidiaries located in our seven European countries by multinational origin[42]. Interestingly, the affiliates of US multinationals in Europe tend to have much higher people management scores than other countries. This is consistent with the idea that US firms are able to transfer some of their practices overseas to their subsidiary operations[43]. Local labor market regulations influence people management practices, but do not completely determine them. If they did, there would be no systematic difference in the management practices of US subsidiaries in Europe compared to other firms.

B. Results

Basic results- Table 6 contains the results from the European panel. In columns (1) to (7) we estimate the production function and in the final two columns the IT intensity equation. Column (1) estimates a basic productivity equation controlling only for capital, labor, ownership status and some basic controls (country dummies interacted with time dummies, three digit industry dummies and listing status). As with the UK establishment data, US multinational subsidiaries have higher measured total factor productivity than other multinationals (and domestic firms). As before, the data is consistent with constant returns to scale (i.e. the coefficient on labor is insignificant). The point estimates are much larger than for the establishment level data because materials is not included as an explanatory variable as this is not available in most company accounts. If materials are included the point estimates on the sub-sample look very similar to those for the establishment level data[44].

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[42] A multinational source country had to have at least 25 subsidiaries in the sample to be included in the graph.

[43] The high people management ratings for some countries such as Germany may appear surprising given their high degree of labor market regulation. This arises because the average scores for management practices as a whole in Germany are high (although relatively stronger in operations). Bloom and Van Reenen (2007) relate this to a combination of relatively high skill levels and few primo geniture family firms.

[44] For example, including materials in column (1) specification reduces the sample size to 3,403 observations, delivering point estimates (standard-errors) on capital, US and non-US multinational ownership, and materials of 0.1110 (0.0154),

The second column of Table 6 uses the sub-sample of the data where we observe IT (i.e. the sample that overlaps with the H-H dataset). First we follow Table 2 and simply interact the ownership dummies with the IT measure. Exactly as we saw in the UK establishment panel the coefficient on IT is significantly higher for US multinationals compared to non-US multinationals (and also to domestic firms). Column (3) replaces the multinational interactions with IT with our measures of people management practices and their interaction with IT intensity. As the model predicts, there is a positive and significant interaction between people management and IT intensity. Column (4) is the key column which includes both sets of interactions. We find that conditional on the management interactions, the coefficient on the interaction of IT and US ownership has dropped by more than half in magnitude and is now insignificantly different from zero. This is a key result: it suggests that the reason that we observed a higher coefficient on IT for US multinationals in column (2) was because: (i) they have higher levels of people management and (ii) there is a complementarity between IT and people management[45].

Column (5) of Table 6 repeats the specification from column (4) but now includes a full set of firm fixed effects. The pattern is broadly the same, although the precision of the estimates has fallen, as would be expected when we rely solely on within-firm variation[46]. The interaction between IT and people management remains significant at the 10% level, whereas the coefficient on the interaction between IT and US ownership is now only 0.019 and completely insignificant. In the management survey we also collected information of the proportion of the workforce who held college degrees. In all of the regressions this has a positive and significant association with productivity, as we would expect from basic human capital theory.

The final two columns of Table 7 present the regressions where IT intensity is the dependent variable. Column (7) shows that US firms are much more IT intensive than other multinationals and domestic firms. The people management variable also has a strong and positive correlation with IT intensity as shown in the column (8). In this final column the US coefficient falls from 0.260 to

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0.1419 (0.0490), 0.0485 (0.0256) and 0.5214 (0.0267) respectively. If computers are included, the point estimate (standard error) is 0.0435 (0.0174).

[45] If we drop the interactions and ownership variable, the people management score in levels is positively and significantly related to productivity at the 10% level: a coefficient of 0.028 with a standard error of 0.016.

0.215, indicating that part of the higher IT intensity in US multinationals is due to the higher levels of people management.

Technology-skill complementarity - There is a large literature showing that new technologies are complementary with skills (e.g. Autor, Katz and Krueger, 1998). If US firms have higher levels of skills, could this simply explain our results? Fortunately, the CEP management survey contained a measure of the proportion of employees with college degrees. We include this variable throughout Table 6 and find it to be consistently positive in the production function. In column (6) we also include the interaction of this human capital measure with IT. The IT*skills interaction enters with a positive but insignificant coefficient, but the management interaction with IT remains robust to this extra interaction.

In the UK establishment panel the main control for labor quality is the inclusion of establishment-specific fixed effects as we have no direct measure of skill. As an alternative, we assume that wages reflect marginal products of workers, so that conditioning on the average wage in the establishment is sufficient to control for human capital[47]. When entered into a specification identical to that of column (1) of Table 3, the average wage is highly significant and the interaction between the average wage and IT capital is positive and significant at the 10% level, consistent with technology-skill complementarity. The interaction between the US dummy and average wages in the establishment is significant at the 10% level (a coefficient of 0.0119 and a standard error of 0.0063). Nevertheless, even in the presence of these skills controls, the coefficient on the US ownership and IT interaction remains significantly positive (0.0279 with a standard error of 0.0133). Consequently we do not believe that our results only reflect technology-skill complementarity.

Other dimensions of management practice - Table A5 presents further examination of these effects. We argued on *ex ante* grounds that people management was likely to be an organizational feature complementary to IT. In this table we examine the interactions of IT with other aspects of management such as shopfloor operations, targets, monitoring and combinations across all 18

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[46] Note that the management and ownership status variables are cross sectional so the linear terms are absorbed by the fixed effects, even though their interaction with IT is still identified.

[47] The problem is that wages may control for "too much", as some proportion of wages may be related to non-human capital variables. For example, in many bargaining models, firms with high productivity will reward even homogenous workers with higher wages (for example, see Van Reenen, 1996, on sharing the quasi-rents from new technologies).

questions. Although these interactions are positive, none are significant or as strong as the people management interaction.

Other confounding factors – We checked for a large number of other confounding factors that could be correlated with management practices and be driving the results on the interaction with IT. These included average hours worked, union strength, different types of software (e.g. Enterprise Resource Planning). Although these were systematically different in European and US firms, they did not change the IT and management results.

So in summary, the evidence from the European panel has the same basic pattern of results we saw in the UK establishment panel. US firms appear to have some advantage in IT. The new piece of information is that this advantage appears to be linked with their superior people management practices that are complementary with IT and this explains, at least in an accounting sense, the higher coefficient on IT for US firms observed in the earlier tables.

VI. Conclusions

Why did Europe not follow the American IT-led productivity acceleration after 1995? We provide econometric evidence in line with the hypothesis that US people management practices were a reason for this difference as has been suggested by Blanchard (2004) and others. Using two rich micro-panels, we show robust evidence that US multinationals obtain higher productivity from IT than non-US multinationals (or domestic firms) in Europe. In the first dataset (of UK establishments), we found that the stronger association of IT with productivity for US firms is focused in the same "IT using intensive" industries that largely accounted for the US productivity acceleration since the mid 1990s. These results were robust to examining establishments that were taken over by other firms: US firms who took over establishments have significantly greater IT productivity relative to non-US multinationals who took over statistically similar establishments. In the second dataset of firms across seven European countries, we showed that US firms had higher levels of people management (which was complementary with IT) and this accounted for the American advantage in IT use.

Taken together, this suggests that part of the IT-related productivity gains underlying the post-1995 period is related to the management practices of US firms rather than simple natural advantage (geographical, institutional or otherwise) of being located in the US environment. US firms appear to have transplanted these management practices abroad, so that their overseas subsidiaries also enjoyed a productivity miracle.

There remain many outstanding issues and research questions. First, understanding what are the determinants of the heterogeneous management practices between firms, industries and nations is a vitally important question. Theory has out-run econometric work here, but this is currently an area of active research (e.g. Bloom et al, 2009; Acemoglu et al, 2007).

A second and related question is why do US firms have different people management practices from Europe? One result from Bloom and Van Reenen (2007) is that US firms are "better managed" in general, because of the higher levels of competition in their domestic markets and the more limited involvement of *primo geniture* family firms. But US firms also appear to be particularly strong on people management. One reason seems to be the greater supply of human capital in the US. Across firms and industries the intensity of graduate-level employees is strongly associated with better people-management practices. Another reason seems to be lower levels of labor market regulation in the US: labor flexibility is significantly and positively correlated with better people-management across countries in our data.[48]

This management gap also appears to be a long-standing phenomenon. For example, the Marshall Plan productivity mission of 1947 wrote: "*Efficient management is the single most significant factor in the American productivity advantage*". This implies the US productivity surge was the effect of a rapid increase in IT intensity, driven by the accelerating fall in IT prices since 1995, which better people managed US firms at home and abroad have been able to exploit. The rate of decline of IT prices appears to have slowed since 2005 and this may have brought an end to the US productivity miracle. If this period is historically specific, then the wave of US takeovers in Europe may slow down or be reversed. Alternatively, if another wave of rapid technological change occurs then our

[48] See Botero et al (2004) or Gust and Marquez (2004) on cross-country labor regulations. In our data we find a cross-country correlation of 0.71 between the World Bank index of employment flexibility and people management practices.

results suggest that US firms may once again enjoy a period of accelerated productivity growth as their people management practices allow them to better exploit new technologies.

A final remark is that our framework has implications for firms outside Europe. For example, we would expect to see the same US productivity advantage in IT for American multinationals in the US (or indeed Asia) compared to non-US multinationals.

Despite this need for further research we believe our paper has made some inroads into one of the most puzzling episodes in the last decade: the explanation of the US “productivity miracle”.

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TABLE 1 – UK DESCRIPTIVE STATISTICS BROKEN DOWN BY MULTINATIONAL STATUS
(Normalized to 100 for the 3-digit SIC and year average)

		Employment	Value added per Employee	Gross output per Employee	Non IT Capital per Employee	Materials per Employee	IT Capital per Employee
US Multinationals							
	Mean	162.26	127.96	123.63	129.61	123.81	152.13
	St. Deviation	297.58	163.17	104.81	133.91	123.35	234.41
	Observations	569	569	569	569	569	569
Other Multinationals							
	Mean	148.58	113.71	115.22	120.65	116.02	119.58
	St. Deviation	246.35	107.87	86.50	126.83	107.63	180.34
	Observations	2,119	2,119	2,119	2,119	2,119	2,119
UK domestic							
	Mean	68.78	89.86	89.69	86.33	89.29	83.95
	St. Deviation	137.72	104.50	102.09	127.16	129.37	188.30
	Observations	4,433	4,433	4,433	4,433	4,433	4,433

Notes: These are 2001 values from our sample of 7,121 establishments

TABLE 2 – ESTIMATES OF THE UK PRODUCTION FUNCTION ALLOWING THE I.T. COEFFICIENT TO DIFFER BY OWNERSHIP STATUS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable: ln(Output/L)	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**
Sectors	All Sectors	All Sectors	All Sectors	IT Using Intensive Sectors	Other Sectors	All Sectors	IT Using Intensive Sectors	Other Sectors
Fixed effects	**NO**	**NO**	**NO**	**NO**	**NO**	**YES**	**YES**	**YES**
USA*ln(C/L)	-	-	0.0202***	0.0380***	0.0120	0.0093	0.0368**	-0.0060
USA ownership*IT capital per employee			(0.0072)	(0.0128)	(0.0084)	(0.0085)	(0.0144)	(0.0098)
MNE*ln(C/L)	-	-	0.0036	-0.0011	0.0062	0.0010	-0.0003	0.0008
Non-US multinational *IT capital per employee			(0.0045)	(0.0062)	(0.0060)	(0.0042)	(0.0064)	(0.0053)
ln(C/L)	-	0.0457***	0.0428***	0.0373***	0.0457***	0.0152***	0.0123**	0.0157***
IT capital per employee		(0.0024)	(0.0029)	(0.0038)	(0.0039)	(0.0030)	(0.0051)	(0.0036)
ln(M/L)	0.5575***	0.5474***	0.5477***	0.6216***	0.5067***	0.4031***	0.5018***	0.3606***
Materials per employee	(0.0084)	(0.0083)	(0.0083)	(0.0142)	(0.0104)	(0.0178)	(0.0279)	(0.0210)
ln(K/L)	0.1388***	0.1268***	0.1268***	0.1106***	0.1459***	0.0900***	0.1056***	0.0666***
Non-IT Capital per employee	(0.0071)	(0.0068)	(0.0068)	(0.0093)	(0.0092)	(0.0159)	(0.0228)	(0.0209)
ln(L)	-0.0052*	-0.0112***	-0.0111***	-0.0094**	-0.0121***	-0.1986***	-0.1279***	-0.2466***
Labor	(0.0027)	(0.0027)	(0.0027)	(0.0037)	(0.0036)	(0.0217)	(0.0319)	(0.0279)
USA	0.0711***	0.0641***	0.0733***	0.0440**	0.0892***	0.0214	0.0451	-0.0070
USA Ownership	(0.0140)	(0.0135)	(0.0144)	(0.0213)	(0.0189)	(0.0224)	(0.0366)	(0.0242)
MNE	0.0392***	0.0339***	0.0372***	0.0149	0.0441***	0.0081	0.0173	-0.0008
Non-US multinational	(0.0079)	(0.0078)	(0.0093)	(0.0134)	(0.0124)	(0.0103)	(0.0172)	(0.0126)
Observations	21,746	21,746	21,746	7,784	13,962	21,746	7,784	13,962
Test USA*ln(C/L)=MNE*ln(C/L), p-value		-	0.0320	0.0035	0.5272	0.3622	0.0094	0.5210
Test USA=MNE, p-value	0.0206	0.0232	0.0113	0.1755	0.0151	0.5545	0.4301	0.8145

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns is the log of gross output per employee. The time period is 1995-2003. The estimation method in all columns is OLS. Columns (6) to (8) include establishment level fixed effects. Standard errors in brackets under coefficients in all columns are clustered by establishment (i.e. robust to heteroskedasticity and autocorrelation of unknown form). All columns include a full set of three digit industry dummies interacted with a full set of time dummies and as additional controls: dummies for establishment age (interacted with a manufacturing dummy), region, multi-establishment group (interacted with ownership type) and IT survey. See Appendix Table A1 for definition of IT using intensive sectors. "Test USA*ln(C/L)=MNE*ln(C/L)" is test of whether the coefficient on USA*ln(C/L) is significantly different from the coefficient on MNE*ln(C/L), etc.

TABLE 3 – ROBUSTNESS TESTS OF THE UK PRODUCTION FUNCTION

Experiment	(1) Baseline Specification	(2) Value Added	(3) All Inputs Interacted	(4) Alternative IT measure	(5) Full "Translog" interactions	(6) EU and Non EU MNEs
ln(Output per employee)	**ln(Q/L)**	**ln(VA/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**
USA*ln(C/L)	0.0368**	0.0681**	0.0328**	0.0647**	0.0334**	0.0376***
USA ownership*IT capital per employee	(0.0144)	(0.0319)	(0.0141)	(0.0258)	(0.0140)	(0.0145)
MNE*ln(C/L)	-0.0003	-0.0179	0.0002	0.0034	-0.0012	
Non-US multinational*IT capital per employee	(0.0064)	(0.0166)	(0.0065)	(0.0127)	(0.0062)	
Ln(C/L)	0.0123**	0.0290***	0.0126**	0.0292***	0.0330	0.0120**
IT capital per employee	(0.0051)	(0.0110)	(0.0050)	(0.0081)	(0.0460)	(0.0051)
USA*ln(M/L)			0.0334			
USA ownership*materials per employee			(0.0376)			
MNE*ln(M/L)			0.0080			
Non-US multinational *materials per employee			(0.0236)			
USA*ln(K/L)			0.0241			
USA ownership*Non IT capital per employee			(0.0368)			
MNE*ln(K/L)			-0.0142			
Non-US *Non IT capital per employee			(0.0134)			
EU MNE						0.0063
EU ownership						(0.0198)
NON-EU MNE						-0.0603
Non EU-NON USA Ownership						(0.0489)
EU MNE*ln(C/L)						0.0016
EU ownership*IT Capital per employee						(0.0064)
NON EU MNE*ln(C/L)						-0.0140
Non EU-NON USA *IT capital per employee						(0.0157)
Observations	7,784	7,784	7,784	2,196	7,784	7,784
Test USA*ln(C)=MNE*ln(C), p-value	0.0094	0.0103	0.0224	0.0196	0.0138	
Test USA=MNE, p-value	0.4301	0.9638	0.3620	0.1869	0.3852	
Test on joint significance of all the interaction terms, excluding IT interactions (p-value)			0.3752			
Test on joint significance of all the US interaction terms, excluding IT per employee (p-value)			0.6216			
Test on all the other MNE's interaction terms, excluding IT per employee (p-value)			0.2723			
Test on additional "translog" terms, p-value					0.0000	
Test USA=EU, p-value						0.3216
Test USA=NON EU, p-value						0.0815
Test [USA*ln(C/L)] = [EU*ln(C/L)], p-value						0.0120
Test [USA*ln(C/L)] = [NON EU*ln(C/L)], p-value						0.0123

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns is the log of gross output per employee. All columns are for the sectors that use IT intensively only. The time period is 1995-2003. The estimation method is OLS. All columns include (the log of) non-IT capital per worker (K/L), materials per worker (M/L) and labor (L). All columns except (4) include establishment fixed effects. Standard errors in brackets under coefficients are clustered by establishment (i.e. robust to heteroskedasticity and autocorrelation of unknown form). All columns include a full set of three digit industry dummies interacted with a full set of time dummies and as additional controls: dummies for establishment age (interacted with a manufacturing sector dummy), region, multi-establishment group (interacted with ownership type) and IT survey (except column (4)). The IT measure in column (4) is the ln(fraction of workers using computers). Column (5) includes all the pair-wise interactions of materials, labor, IT capital, and non-IT capital and the square of each of these factors. "Test USA*ln(C/L) =MNE*ln(C/L)" is test of whether the coefficient on USA*ln(C/L) is significantly different from the coefficient on MNE*ln(C/L), etc.

TABLE 4 – UK IT INTENSITY EQUATIONS

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: ln(IT capital per employee)	**ln(C/L)**	**ln(C/L)**	**ln(C/L)**	**ln(C/L)**	**ln(C/L)**	**ln(C/L)**
Sectors	**All Sectors**	**IT Using Intensive Sectors**	**Other Sectors**	**All Sectors**	**IT Using Intensive Sectors**	**Other Sectors**
USA	0.2629***	0.3393***	0.2085***	0.2406***	0.3129***	0.1927***
USA Ownership	(0.0461)	(0.0717)	(0.0600)	(0.0463)	(0.0717)	(0.0604)
MNE	0.1632***	0.2117***	0.1332***	0.1506***	0.1939***	0.1228***
Non-US multinational	(0.0287)	(0.0440)	(0.0375)	(0.0291)	(0.0452)	(0.0380)
Additional controls	**NO**	**NO**	**NO**	**YES**	**YES**	**YES**
Observations	21,746	7,784	13,962	21,746	7,784	13,962
Test USA=MNE, p-value	0.0310	0.0758	0.2108	0.0528	0.0970	0.2508

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns is the log of IT capital per employee. The time period is 1995-2003. The estimation method in all columns is OLS. Standard errors in brackets under coefficients in all columns are clustered by establishment (i.e. robust to heteroskedasticity and autocorrelation of unknown form). All columns include a full set of three digit industry dummies interacted with a full set of time dummies and the log of gross output. Additional controls include dummies for establishment age (interacted with a manufacturing dummy), region, multi-establishment group (interacted with ownership type) and IT survey. See Appendix Table A1 for definition of IT using intensive sectors. "Test USA=MNE" is test of whether the coefficient on USA is significantly different from the coefficient on MNE.

TABLE 5 – UK PRODUCTION FUNCTIONS BEFORE AND AFTER TAKEOVERS

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	**Before Takeover**	**Before Takeover**	**After Takeover**	**After Takeover**	**After Takeover**	**After Takeover (drop UK domestic acquirers)**
Dependent Variable: ln(Output per employee)	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**	**ln(Q/L)**
USA*ln(C/L)		-0.0672		0.0541**		
USA Takeover*IT capital per employee		(0.0749)		(0.0273)		
MNE*ln(C/L)		-0.0432		0.0073		
Non-US multinational Takeover*IT capital per employee		(0.0463)		(0.0150)		
USA	-0.0661	-0.1055	0.0353	0.0619		
USA Takeover	(0.0663)	(0.0863)	(0.0402)	(0.0461)		
MNE	0.0321	-0.0009	0.0117	0.0205		
Non-US multinational Takeover	(0.0565)	(0.0710)	(0.0298)	(0.0342)		
USA*ln(C/L) one year after takeover					0.0192	0.0191
					(0.0378)	(0.0562)
USA*ln(C/L) two and three years after takeover					0.0661**	0.1303**
					(0.0294)	(0.0573)
MNE*ln(C/L) one year after takeover					-0.0091	
					(0.0197)	
MNE*ln(C/L) two and three years after takeover					0.0115	
					(0.0162)	
USA one year after takeover					0.0019	0.0014
					(0.0542)	(0.0716)
USA two and three years after takeover					0.0934*	0.0942
					(0.0485)	(0.0856)
MNE one year after takeover					-0.0178	
					(0.0411)	
MNE two and three years after takeover					0.0327	
					(0.0361)	
ln(C/L)	0.0744**	0.0935**	0.0395***	0.0287***	0.0288***	0.0282
IT capital per employee	(0.0299)	(0.0432)	(0.0079)	(0.0088)	(0.0088)	(0.0224)
ln(M/L)	0.5486***	0.5487***	0.6871***	0.6892***	0.6886***	0.7323***
Materials per employee	(0.0489)	(0.0481)	(0.0173)	(0.0173)	(0.0172)	(0.0292)
ln(K/L)	0.1759***	0.1718***	0.0350**	0.0350**	0.0353**	-0.0108
Non-IT Capital per employee	(0.0343)	(0.0335)	(0.0160)	(0.0159)	(0.0159)	(0.0431)
ln(L)	-0.0185	-0.0215	-0.0117	-0.0111	-0.0112	-0.0358*
Labor	(0.0292)	(0.0276)	(0.0108)	(0.0108)	(0.0107)	(0.0213)
Observations	261	261	1,006	1,006	1,006	241
Test USA*ln(C/L) = MNE*ln(C/L), p-value		0.7037		0.0965		
Test USA = MNE, p-value	0.1637	0.1773	0.5979	0.4056		
Test (USA one year)*ln(C/L) = (MNE one year)*ln(C/L), p-value					0.4948	
Test (USA two plus years)*ln(C/L) = (MNE two plus years)*ln(C/L), p-value					0.0734	
Test USA one year = MNE one year, p-value					0.7463	
Test USA two plus years = MNE two plus years, p-value					0.2481	

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The sample is of all establishments in the IT intensive sectors who were taken over at some point (the omitted base is “domestic takeovers” – a UK firms taking other another firms). We drop takeovers that do not result in a change of ownership category (e.g. US takeovers of US firms, non-US MNE takeovers of non-US MNEs and domestic takeovers of domestic firms). The dependent variable in all columns is the log of gross output per employee. The time period is 1995-2003. The estimation method is OLS. Standard errors in brackets under coefficients are clustered by establishment. A takeover is defined as a change in the establishment foreign ownership marker or - for UK domestic establishment - as a change in the enterprise group marker. The "before" period is defined as the interval between one and three years before the takeover takes place. The "after" period is defined as the interval between one and three years after the takeover takes place. The year in which the takeover takes place is excluded from the sample. All columns include a full set of two digit industry dummies interacted with time dummies and as additional controls: age, region dummies, a multi-establishment group dummy and an IT survey dummy. “Test USA*ln(C/L) =MNE*ln(C/L)” is test of whether the coefficient on USA*ln(C/L) is significantly different from the coefficient on MNE*ln(C/L), etc.

TABLE 6 –
EUROPEAN FIRM-LEVEL PANEL DATA WITH DIRECT MEASURES OF MANAGEMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	**Ln(Q/L)**	**Ln(Q/L)**	**Ln(Q/L)**	**Ln(Q/L)**	**Ln(Q/L)**	**Ln(Q/L)**	**Ln(C/L)**	**Ln(C/L)**
Fixed Effects	NO	NO	NO	NO	YES	YES	NO	NO
USA*ln(C/L) USA ownership*Computers per employee		0.1790** (0.0733)		0.0784 (0.0720)	0.0518 (0.0713)	0.0192 (0.0785)		
MNE*ln(C/L) Non-US multinational*Computers per employee		-0.0263 (0.0586)		-0.0235 (0.0553)	0.0218 (0.0547)	0.0235 (0.0550)		
People Management People management			0.0188 (0.0153)	0.0189 (0.0152)				0.0882*** (0.0246)
People Management*ln(C/L) People management*Computers per employee			0.1451*** (0.0331)	0.1404*** (0.0344)	0.1284* (0.0773)	0.0994* (0.0581)		
ln (K/L) Non-IT Capital per employee	0.2355*** (0.0180)	0.1838*** (0.0284)	0.1782*** (0.0276)	0.1791*** (0.0276)	0.2347** (0.0926)	0.2316*** (0.0882)		
ln(L) Labor	-0.0257 (0.0182)	0.0421 (0.0360)	0.0421 (0.0344)	0.0409 (0.0349)	-0.2182 (0.2600)	-0.2347 (0.2497)		
ln(C/L) Computers per employee		0.1256*** (0.031)	0.1430*** (0.0284)	0.1463*** (0.0303)	-0.0493 (0.0596)	-0.2282 (0.1738)		
USA USA Ownership	0.2699*** (0.0476)	0.0779 (0.0481)	0.1111** (0.0446)	0.0837* (0.046)			0.2601*** (0.0742)	0.2150*** (0.0732)
MNE Non-US multinational	0.1927*** (0.0340)	0.1597*** (0.0363)	0.1604*** (0.0355)	0.1618*** (0.0357)			0.0492 (0.0596)	0.0367 (0.0591)
ln(Degree) Percentage employees with a college degree		0.0433** (0.0183)	0.0375** (0.0184)	0.0370** (0.0184)			0.0585** (0.0293)	0.0359 (0.0296)
ln(Degree)*ln(C/L) Percentage employees with a college degree*Computers per employee						0.0700 (0.0484)		
Observations	7,420	2,555	2,555	2,555	2,555	2,555	2,555	2,555
Test USA=MNE, p-value	0.1410	0.1206	0.3094	0.1264				
Test USA*ln(C/L)= MNE*ln(C/L), p-value		0.0189		0.2419	0.6360	0.9565	0.0095	0.0253

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns (1) to (6) is the log of sales per employee, and in columns (7) and (8) is the log of computers per employee. The time period is 1999-2006, containing data from France, Germany, Italy, Poland, Portugal, Sweden and the UK. The estimation method in all columns is OLS. Columns (5) to (7) include firm level fixed effects. Standard errors in brackets under coefficients in all columns are clustered by firm (i.e. robust to heteroskedasticity and autocorrelation of unknown form). All columns include a full set of three digit industry dummies, country dummies interacted with a full set of time dummies and a public listing indicator. Columns (2) to (9) are weighted by the survey coverage rate in the Harte-Hanks data, plus include a 5th order Taylor expansion for the coverage ratio to control for any potential survey bias. "Test USA*ln(C/L)=MNE*ln(C/L)" is test of whether the coefficient on USA*ln(C/L) is significantly different from the coefficient on MNE*ln(C/L), etc. 719 firms in all columns except column (1) where there are 1,633 firms.

NOTE: THESE APPENDICES ARE FOR REFEREES ONLY (UNLESS THE EDITOR PREFERS OTHERWISE). THEY WILL BE MADE AVAILABLE ON THE WEB.

APPENDIX A: DATA

I UK Establishment level Data

A1 THE ANNUAL BUSINESS INQUIRY

The Annual Business Inquiry (ABI) is the major source of establishment level data in the UK. It underlies the construction of aggregate output and investment in the national accounts and is conducted by the Office of National Statistics (ONS) the UK equivalent of the US Census Bureau. The ABI is similar in structure and content to the US Longitudinal Research Database except that it covers non-manufacturing as well as manufacturing. The recently constructed US Longitudinal Business Database covers non-manufacturing but it does not have output or investment – items that are necessary to estimate production functions.

The ABI is a stratified random sample: sampling probabilities are higher for large establishments (e.g. 100% for all establishments with more than 250 employees). Each establishment has a unique "reporting unit reference number" (RUREF) which does not change when an establishment is taken over by a new firm. Data on the production sector (manufacturing, extraction and utilities) is in the ABI which has a long time series element (from 1980 and before in some cases). Data on the non-production sector (services) is available for a much shorter time period (from 1997 onwards). The sample is large: in 1998 there are 28,765 plants in the production sector alone. The regression sample used in this paper consists of 11,064 establishments, of which 4,059 are classified in IT Intensive using industries.

The questionnaire sent out on the ABI is extensive and covers all the variables needed to estimate basic production functions. The response rates to the ABI are high because it is illegal not to return the forms to the Office of National Statistics. The ABI includes data on gross output, value added, employment, the wage bill, investment and "total materials" (this includes all purchased intermediate inputs – services, energy, material goods, etc.)[49]. Value added is gross output minus purchases. The construction of the IT and non-IT capital stocks are described in the next section[50]. We condition on a sample that has positive values of all the factor inputs, so we drop establishments that have zero IT capital stocks.

A2 INFORMATION TECHNOLOGY DATASETS

Working closely with statisticians and data collectors at the ONS we combined five major IT surveys and matched this into the ABI establishment data using the common establishment code (RUREF). The main IT surveys include the Business Survey into Capitalized Items (BSCI), the Quarterly Inquiry into Capital Expenditure (QICE) and the Fixed Asset Register (FAR). We used information on hardware from the BSCI, QICE and FAR in the main part of the paper, one survey of computer use by workers (the E-Commerce Survey) and one software survey (ABI supplement). Of these, only the software survey was designed to cover exactly the same establishments as contained in the ABI survey, but because there is over-sampling of the larger establishments in all surveys the overlap is substantial, especially for the larger establishments. These surveys contain information on the value (in thousands of pounds) of software and hardware acquisitions and disposals. Once the stocks are built within each different survey, we combine them across surveys and, for hardware and software separately, we build across-surveys stocks[51]. In the following paragraphs we first describe the different surveys; we then illustrate the details of the Perpetual Inventory Method used for the construction of the capital stocks and the procedure followed to build across-surveys variables.

<u>A2.1 Data Sources</u>

Business Survey into Capitalized Items (*BSCI).* The BSCI asks for detail of acquisitions and disposals of capital in more than 100 categories, including computer hardware and software. The survey is annual and runs between 1998 and 2003; we dropped the 1998 cross section due to concerns over reliability expressed by the data collectors. There is a 100% sampling frame for businesses with more than 750 employees and a stratified random sample of businesses with between 100 and 750 workers. The BSCI contributes about 1,500 to 2,000 observations for each year between 1999 and

[49] We examined whether breaking down intermediate inputs into bought in services ("service outsourcing") and goods made a difference. In particular we interacted the proportion of outsourced services with IT capital as in Abramovsky and Griffith (2007). Although this was significant in levels, it became insignificant when we included fixed effects.

[50] The ONS defines gross output as the sum of sales (turnover), net inventories (variation of total stocks), work of capital nature by own staff and insurance claims received.

[51] We are careful to check for differences in coefficients due to the IT measures coming from different surveys. We could not reject the assumption that there were no significant differences in the IT coefficients arising from the fact that the IT stocks were built from different surveys.

2003. We use the SIC92 code 30020 defined as “Computers and other information processing equipment”. Notes to this category specify “Microcomputers, printers, terminals, optical and magnetic readers (including operating systems and software bundled with microcomputer purchase).”

Quarterly Inquiry into Capital Expenditure (QICE). The QICE provides information on hardware and software investments from 2000Q1 until 2003Q4. The inquiry selects 32,000 establishments each quarter. Establishments with over 300 employees are selected every quarter. Businesses with fewer employees are selected for the inquiry randomly. Each quarter one fifth of the random sample is rotated out of the sample and a new fifth is rotated in. The quarterly data have been annualized in several alternative ways and we checked the robustness of the results across these methods. First, we extrapolated within year for establishments with missing quarters[52]. As a second alternative, we constructed an indicator that gives the number of non-missing values that exist for each year and establishment and included this as an additional control in the regressions. Third, we dropped observations constructed from less than four full quarters. The results were robust across all three methods and the tables report results based on the first method.

Fixed Asset Register (FAR). The FAR asks for the historic cost (gross book value) of the fixed assets held on the firms' asset register, broken down by the years of acquisition. The survey provides information on IT hardware assets only, and covers the years 1995 up to 2000. The survey provides information for about 1,000 hardware observations.

E-Commerce Survey. The E-Commerce Survey was conducted in 2001, 2002 and 2003 with around 2,500 establishments in each cross section. Unfortunately these were random cross-sections so the overlap between years is minimal (preventing us from performing serious panel data analysis). Plant managers were directly asked “What proportion of your employees uses a computer, workstation or terminal”. To construct an estimate of the number of employees using IT we multiplied this proportion by the number of workers in the establishment. Although this is conceptually much cruder than the IT capital stock, it has the advantage that we do not have to rely so much on assumptions concerning the initial conditions. In Table 4 we discuss the results from this measure, showing very similar results to those obtained from using the IT capital measure.

Software questions in the Annual Business Inquiry (ABI). The ABI contains a question on software expenditures from 2000 onwards. There are approximately 20,000 non-zero returned values for software investments in each year. We had some concerns about the accuracy of the establishment reports of software expenditure[53] so we focus in the main part of the paper on the IT hardware stocks.

<u>*A2.2 Estimation of IT capital stocks*</u>

We build stocks of IT capital applying the Perpetual Inventory Method (PIM) to the IT investment data (and the non-IT investment data) described above. The basic PIM equation for IT capital is:

$$C_{it} = I_{it}^{c} + \left(1 - \delta^{c}\right)C_{it-1}$$

where I_t^c represents real investment in IT and δ_t^c is the depreciation rate. To construct real investment we deflate nominal investments using the economy-wide hedonic price indices for IT hardware provided by the National Institute of Economic and Social Research (which are based on Jorgensen's US price deflators). We rebased to the year 2000 for consistency with the other PPI deflators (see below). Non-IT capital stock is built in an analogous way.

<u>*Zeros*</u>*;* Both the BSCI and the QICE code missing values as zeros. While in the BSCI we are able to identify actual zero investments through a specific coding, for the QICE this is not possible. In the construction of the capital stocks we treated the zero investments observations as actual absence of IT investments. In the regressions we drop observations with zero IT capital stocks

<u>*Interpolations*</u>: In order to maximize the number of observations over which we could apply the PIM, we interpolated net investment observations for a single year of data if we observed investment the year before and the year afterwards. This affected only 2.8% of the observations in the regression sample and results are robust to dropping these observations.

<u>*Initial Conditions*</u>*:* In order to apply the PIM methodology, we need to approximate a starting value to start the recursion. We construct establishment level capital stocks in the ARD by building two digit industry-specific IT Investment/Capital ratios using the NISEC02 industry level data-set provided by the National Institute of Economic and Social Research, which contains separate time-series data on IT capital stocks and runs up to 2001 (these are based on the input-output tables starting in 1975). We then use the ratio of the establishment's IT investment flow to the industry investment flow to impute the IT capital stock (i.e. we are assuming that the establishment's share of the IT capital

[52] The extrapolation was done by simple averaging, but we also tried more sophisticated quarterly models taking into account the quarter surveyed. This made practically no difference.

[53] For example, many software values are imputed and the coding for the imputation does not make it clear how the imputation took place and for which establishments.

stock in the industry is equal to the establishment's share of IT investment in the industry in the initial year). More precisely, we assume that for $t = 0$ only the initial establishment level IT capital stock C_{i0} is: $C_{i0} = (I^C_{it} / I^C_{jt})C_{jt}\ \forall\ i \in j$ where j represents an industry so a j sub-script represents an industry total – i.e. I^C_{jt} is total industry IT investment and C_{jt} is the total IT capital stock in time t. We apply this approximation to determine our initial condition in the first year that the establishment appears in our sample. For greenfield sites this is not an issue as their capital stock is zero. After the first year, we simply apply the Perpetual Inventory Method.

Some of the establishments that we observe only for the first time may be investing systematically at a different rate from the industry average. To check whether our results were driven by the methodology used to build the initial conditions, we considered an alternative methodology based on employment weights to calculate the starting value, C^*_{i0} : $C^*_{i0} = (L_{it-1} / L_{jt-1})C_{jt-1}(1-\delta) + I^C_{it}$. So this is assuming that the establishment's share of the industry IT stock in the initial period is equal to the establishment's lagged share of employment.

Depreciation: For all IT capital we chose a depreciation rate of 36%. This choice is consistent with the analysis by methodology followed by the BEA which, in turn, derives from the study by Doms, Dunn, Oliner and Sichel (2004). In this study, the depreciation rate for PCs is estimated at approximately 50%, this value including both obsolescence and revaluation effects. Since – as the BEA - we use real IT investments we have to use a lower depreciation rate to avoid double counting of the revaluation effect, included in the price deflators. Basu et al (2003) argue that the true geometric rate of depreciation should be, in fact, approximately 30%. The significance and the magnitude of the coefficient obtained for IT capital is not affected by the exact choice of the alternative depreciation rate.

Across-Survey Stocks: Following the steps described above, we obtain hardware and software stocks within each different survey. We then matched our constructed IT dataset with the ABI sample. In order to simplify the empirical analysis, we combined all the information of the different surveys constructing overall across-surveys IT stocks for both hardware and software. Our strategy is to use the BSCI measure as the most reliable observation (as recommended by the data collectors). We then build our synthetic measure using the QICE stocks if the BSCI observation is missing or equal to zero and the QICE is different from zero. We finally use the FAR if both QICE and BSCI are missing and/or equal to zero and the FAR is not.

In order to keep track of the possible measurement error introduced using this procedure, we introduce in all the IT regressions a dummy that identifies the provenance of the observation for both the hardware and the software stocks. These dummies and their interactions with the IT coefficients are not significantly different from zero. A small portion of the firms included in our dataset responded to more than one survey. We use some of this overlapping sample to get a better understanding of the measurement error in the data. By comparing the reports from the same establishments we calculate that there is much more measurement error for software than for hardware, which is one reason why we focus on hardware. We did not find any evidence that the measurement error for IT capital was different for US firms than other firms.

A3 DEFINITION OF I.T. INTENSIVE USING INDUSTRIES

We focus on "IT intensive" sectors that are defined to be those that use IT intensively and are not producers of information or communication technologies. The definitions of IT usage and IT producers are based on O'Mahony and Van Ark (2003) who base their definitions on Kevin Stiroh (2002). They use US data to calculate the capital service flows and define IT use intensity as the ratio of IT capital services to total capital services. IT intensive using sectors are those where (a) the industries has above median IT capital service flows to total capital service flows and (b) the industry is not an IT producing industry. All industries are based on ISIC Revision 3. The industry definitions are detailed in Table A1.

A4 CLEANING

We used standard procedures to clean the ABI and the IT data. First, we dropped all observations with negative value added and/or capital stock. Secondly we dropped the top and bottom percentile of the distribution of the growth of employment and gross value added. Thirdly, we dropped top and bottom percentile of the distribution of total capital stock per employee and gross value added per employee. This step of the cleaning procedure was performed on the overall ABI sample. We applied a similar cleaning procedure also to our across surveys IT variables. We dropped the top and bottom percentiles of the ratio of the IT capital (and expenditure) relative to gross value added[54].

[54] The results of the regression are qualitatively similar if the IT data are cleaned using the ratio of investments per employee or stocks per employee.

A5 DEFINITION OF FOREIGN OWNERSHIP AND UK MULTINATIONALS
The country of ownership of a foreign firm operating in the UK is provided in the ABI and is based on information from Dun and Bradstreet's Global "Who Owns Whom" database. Dun and Bradstreet define the nationality of an establishment by the country of residence of the global ultimate parent, i.e. the topmost company of a world-wide hierarchical relationship identified "bottom-to-top" using any company which owns more than 50% of the control (voting stock, ownership shares) of another business entity. UK Multinationals are identified via the matching of the ABI with the Annual Foreign Direct Investment (AFDI) register made by Criscuolo and Martin (2004). The AFDI identifies the population of UK firms which are engaging in or receiving foreign direct investment (FDI)[55]. Each establishment in the ABI that is owned by a firm which appears in the AFDI register can consequently be defined as a multinational. UK multinationals are thus UK-owned firms which appear in the AFDI.

A6 TAKEOVERS
The identification of takeovers consists of three basic steps. First, for all the available years (1980-2003 for manufacturing and 1997-2003 for services) we use all the raw ABI data (including "non-selected" establishments where we know employment but not output or capital). We thus create a register file that allows us to keep track of the whole history of each firm, and exploit the uniqueness of the reporting unit reference number (RUREF) to correct for obvious reporting problems (i.e. establishments that disappear in one year, and appear again after some time). Second, for each establishment we keep track of changes in the foreign ownership information and the enterprise group reference number (this is a collection of RUREFs owned by a single group) to identify foreign and domestic takeovers[56]. Third, to control for measurement error in the takeover identification, we drop from the sample some ambiguous establishment observations: (a) establishments that are subject to more than three takeovers during their history; (b) for the establishments with two or three takeovers, we dropped observations where a time period could be simultaneously as "pre" and "post" takeover. We use up to three years prior to the takeovers in the "pre-takeover" regressions and up to three years after the takeover in the "post takeover" regressions. The year when the takeover occurred is dropped because it is unclear when in the year the establishment switched.

We have three types of takeover: by a US multinational, by a non-US multinational and by a domestic firm. When a US multinational takes over an establishment already owned by another US multinational this does not represent a change in its status, even though it is coded as a US takeover. Consequently we excluded from the sample all takeovers where an establishment did not change multinational ownership status (i.e. we dropped US takeovers of US firms, non-US multinationals takeovers of non-US multinational firms and domestic takeovers of purely domestic firms). This is quite a conservative approach. Bloom, Sadun and Van Reenen (2007) present results where we do not drop these establishments and show qualitatively similar results.

A7 DESCRIPTIVE STATISTICS
Panel A of Table A2 gives some descriptive statistics for our key variables. Note that median employment in the establishment is 238 which are larger than the ABI median because the IT surveys tend to focus on the larger establishments. Average IT stock is just over £1m ($2m) and value added per worker is just under £40,000 ($80,000). On average labor costs account for 30% of revenues and materials costs account for 57%. IT capital services are 1% of revenues and non-IT capital services is estimated at 12% of revenues (both at rental prices).

Panel B of Table A3 breaks down mean values of the IT capital - output ratio and ln(IT capital) by ownership type and whether or not the sector is IT intensive. US multinationals have a higher IT capital-output ratio than non-US multinationals in all sectors, especially so in IT intensive sectors. The levels of IT capital show much higher values for US establishments than non-US multinationals (especially in the IT intensive sectors).

II. European Firm-level Panel
As noted in the text this is constructed from three main data sources: the CEP Management Survey, the Harte-Hanks IT database and the Amadeus database. Descriptive statistics are contained in Table A2 Panel C.

CEP Management Survey
In the summer of 2006 we used a team of 51 MBA-type students to collect data on management practices on 4,003 firms in 12 countries (see Bloom, Sadun and Van Reenen, 2009, for a full description). Following the methodology in Bloom and Van Reenen (2007) we used a survey grid of 18 questions which relate to key aspects of workplace management. Four of these questions relate to "people" management and these are the questions we have focused on in

[55] The working definition of Foreign Direct Investment for this purpose is that the investment must give the investing firm a significant amount of control over the recipient firm. The ONS considers this to be the case if the investment gives the investor a share of at least ten per cent of the recipient firm's capital.
[56] Foreign takeovers are observed if a firm experiences a change in the foreign ownership marker. Domestic takeovers are observed if a UK firm changes its enterprise reference number.

the paper. The questions are open rather than tick box and the interviewers are trained to probe with follow up questions in order to ascertain what is actually going on in the firm. Table A3 gives an example of the questions we used to probe managers and the overall grid. They relate to the promotion system, the fixing/firing of poor performers, the rewarding of high performers and the incentives and importance given to attracting and retaining talented workers. Each question is scored on a scale of 1 ("worst practice") to 5 ("best practice") and our basic composite measure z-scores each individual question, averages across the four questions and then z-scores this average[57]. For example, on the promotion question a low score indicates that employees are promoted solely on the basis of tenure, whereas a high score reflects firms who promote on the basis of effort and ability. The other management practice data we collected related to shop-floor operations (lean manufacturing techniques), monitoring (tracking and reviewing of individual and factory performance) and targets (the breadth, realism and interconnection of goals).

Although high scores on these practices are *a priori* likely to be related to higher productivity, we do not need to take a stance in this paper on whether a high score necessarily corresponds to something which will be in and of itself beneficial to productivity. The scores simply reveal whether the firm devotes much effort to promoting, rewarding and retaining its most talented workers and we investigate whether such practices are complementary with IT capital.

We use a "double blind" method where the interviewees did not know that they were being scored. This is to avoid the well known sample bias arising from the psychological reflex to give an answer that the interviewee thinks the interviewer wants to hear. The other part of the double-blind methodology is that the interviewers did not know anything about the firm's performance in advance of the interview. This was achieved by selecting medium sized manufacturing firms and by providing only firm names and contact details to the interviewers (but no financial details). These smaller firms (the median size was 270 employees) would not be known by name and are rarely reported in the business media.

The survey is targeted at plant managers in firms randomly drawn from the population of all public and private firms with between 100 and 5000 employees in the manufacturing sector. We had a response rate of 45% and the response rate was uncorrelated with firm performance[58]. The interviews took an average of 50 minutes with the interviewers running an average of 78.5 interviews each, over a median of 3 countries, allowing us to remove interviewer fixed effects. We also collected detailed information on the interview process including the interview duration, date, time of day, day of the week, and self-assessed reliability score, plus information on the interviewees' tenure in the company, tenure in the post, seniority and gender. We run robustness tests including these plus interviewer fixed-effects as 'noise-controls' to help control for any potential measurement error, and found that the results are extremely similar to those reported here.

Harte Hanks IT Data

We use an establishment level IT data panel taken from the European Ci Technology Database (CiDB) produced by the international marketing and information company Harte-Hanks (H-H). H-H is a multinational that collects IT data primarily for the purpose of selling on to large producers and suppliers of IT. The fact that H-H sells this data on to major firms like IBM and Cisco exerts a strong market discipline on the data quality. Major discrepancies in the data are likely to be rapidly picked up when H-H customers' sales force placed calls using the survey data. Because of this H-H conducts extensive internal random quality checks on its own data, enabling them to ensure high levels of data accuracy.

The H-H data has been collected annually for over 160,000 establishments across 14 European countries since the mid-1990s. They target all firms with 100 or more employees, obtaining about a 45% success rate. Response rates do not seem to be systematically related to performance. The data for Europe is collected via one call centre in Dublin, so that all variables are defined on an identical basis across countries. In this paper we use the data only for the firms we matched to those we collected management data on in the France, Germany, Italy, Poland, Portugal, Sweden and the UK[59]. The papers by Bresnahan et al (2002) and Brynjolfsson and Hitt (2003) have also previously used the US H-H data, matching the US data to some of the larger firms in Compustat (all publicly listed).

The H-H survey contains detailed hardware, equipment and software information at the establishment level. We focus on using PCs per worker as our key measure of IT intensity because this is available for all the establishments and is measured in a comparable way across time and countries. This PC per worker measure of IT has also been used by

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[57] We investigated other weighting schemes such as factor analysis which gave similar results to those reported here.

[58] The high response rate was achieved by a number of steps. First, we obtained 22 letters of endorsement from Governments, Central Banks and Employers Federations across the 12 countries. Second, the survey is confidential and does not discuss financial data (which we can obtain from AMADEUS). Third, we called the survey "*a piece of work*", since the word "*survey*" typically leads to switchboard rejections. Finally, we rewarded interviewers for high response rates, so they persisted in chasing firms for interviews, contacting them 5.2 times each on average.

[59] In Bloom, Draca and Van Reenen (2008) we use the full 14 country data-set on all establishments to analyze the impact of Chinese trade-competition on European firms. There is an extensive description of the data in that paper.

other papers in the micro-literature on technological change (see, for example, Beaudry, Doms and Lewis, 2006) and is highly correlated with other measures of IT use like the firm's total IT capital stock per worker[60].

BVD Amadeus Accounting Data
Bureau Van Dijk (BVD) is a private sector supplier of the AMADEUS database. This contains company-level data on private and public firms from all over Europe. The data are taken from company registries so, in principle, cover the entire population of incorporated firms. Unlike the US, most European countries insist that basic firm accounts are lodged centrally even for unlisted firms (e.g. there are about 2.1m firms per year in UK Company House in the Amadeus data). BVD obtains these accounts data in electronic form and sells it as the Amadeus database. Reporting is generally good for firms over 100 employees, but legal requirements on reporting every data item do vary from country to country (for example there are many missing values on capital in Germany for smaller firms).

For the management survey our sampling frame was taken from Amadeus so we have some data for all seven European countries – France, Germany, Italy, Poland, Portugal, Sweden and the UK (1,633 firms). We lose 914 firms because we need to match this to H-H which is also a random sample. We match to H-H by name cross checking the information on size, address and industry.

An additional problem is that H-H surveys establishments within the firm, so do not always cover 100% of all workers in the firm. We aggregate across establishments using employment weights to form an estimate of the firm-level number of PCs per worker. We use this coverage ratio to weight the regressions. We also include a fifth order polynomial expansion of this coverage ratio as a "noise" control in the regression. The sample mean of coverage is 73%, reflecting the fact in most firms all the workers are covered by the H-H survey. All results are robust to dropping the 12% of observations with less than 25% coverage.

APPENDIX B: MODELS OF MANAGERIAL PRACTICES

In this section we look at our model more formally. In the first sub-section we present the basic model. In the short-run we consider fixed management practices (*O*) and in the long-run we allow them to vary. In the second sub-section we consider some extensions to the model allowing for the in-between case where there are costs of adjustment.

I. Basic Set-Up
The model is very simple and has three key features. First, IT and people management (*O*) are complements. Second, the US has a lower cost of people management. Third, when a multinational takes over a plant it is able to transfer its management after one period when it pays a fixed "disruption" which is independent of the plant's initial level of *O*. Using this model we consider what happens during a period of rapidly falling IT prices. This model generates predictions that are consistent with the micro and macro stylized facts we observe in the data:

1. US firms will have higher levels of *O*
2. US firms will have a higher observed elasticity of output respect to *C*
3. As IT prices fall US labor productivity growth will initially exceed that of the EU

Consider two representative firms, one in the US and one in the EU. To keep things as simple as possible we assume that all parameters are common in the two regions, except that the US has a lower "price" (ρ^O) for people management practices (*O*). This could arise for a wide variety of reasons such as lighter labor market regulations in the US, for example. The firms produce output (*Q*) by combining IT (*C*) inputs, labor inputs (*L*) and "people management" inputs with all other inputs (non-IT capital, *K*, and materials, *M*) assumed to be zero for simplicity. Define the production relationship as:

$$Q = AO^{\alpha^O} C^{\alpha^C + \sigma O} L^{\alpha^L - \sigma O} \qquad \text{(B1)}$$

This specification of the production function is a simple way of capturing the notion that IT and management are complementary when $\sigma > 0$. This implies that the IT per worker ratio is increasing in the level of *O*. If *O* is quasi-fixed, when IT prices unexpectedly fall the firm with the largest initial stock of *O* stands to gain the most because it will obtain a higher marginal return from increasing the IT to labor ratio.

[60] For example, in our establishment level data a regression of ln(IT capital stock per employee) on the ln(proportion of employees using computers) gives a coefficient of 0.63.

We should consider (B1) this as a revenue function with monopolistic competition and iso-elastic demand so $\alpha^O + \alpha^L + \alpha^C < 1$. Note that it is not necessarily the case that $\alpha^O > 0$. In some industries higher levels of people management may not be beneficial for output ($\alpha^O = 0$).

Since this is a non-standard production function (we think of it as an approximation to a more flexible form such as a translog), so we have to be careful in ensuring that it is concave.

We assume that

$$0 \le \alpha^L - \sigma O \le 1 \tag{B2}$$

and

$$0 \le \alpha^C + \sigma O \le 1 \tag{B3}$$

We first consider the case where is *O* is fixed (short-run). We then consider a variety of cases where we allow management practices to vary. We consider the very long-run where O is perfectly flexible, then consider two intermediate cases where *O* can be changed (i) only by entry/exit and takeover and (ii) by paying a convex adjustment cost.

II. Fixed Management (O)

Flow profits are:

$$\Pi = Q - WL - \rho^C C - \rho^0 O \tag{B4}$$

where *W* is the wage rate, ρ^O is the rental price of people management and ρ^C is the rental price of IT capital. The first order conditions (FOC) for IT and labor are:

$$\alpha^C \frac{Q}{C} + \sigma \frac{OQ}{C} = \rho^C \tag{B5}$$

$$\alpha^L \frac{Q}{L} - \sigma \frac{OQ}{L} = W \tag{B6}$$

Combining these first order conditions we obtain:

$$\ln\left(\frac{C}{L}\right) = \ln\left(\frac{W}{\rho^C}\right) + \ln\left(\frac{\alpha^C + \sigma O}{\alpha^L - \sigma O}\right) \tag{B7}$$

Consequently, IT intensity is increasing in people management:

$$\frac{\partial \ln(C/L)}{\partial O} = \left(\frac{\sigma}{\alpha^C + \sigma O}\right) + \left(\frac{\sigma}{\alpha^L - \sigma O}\right) > 0 \tag{B8}$$

This establishes that observed *C/L* will tend to be higher for firms with higher *O*. Interestingly this implies that the rate of growth of IT intensity should be the same for high and low *O* firms (if *O* is fixed). This is consistent with what we observe in the data (US and EU growth rates of IT capital were similar after 1995).

What happens when IT prices unexpectedly decline? Consider expressing the production function in terms of output per worker. We get an increase of the IT to capital ratio *(C/L)* and from the production function this will lead to high labor productivity. Importantly, this increase will be greater the larger is the initial level of *O*

$$(q - l) = \sigma[(c - l) * O)] + \alpha^C (c - l) + \alpha^O (o - l) + a + (\alpha^C + \alpha^L + \alpha^O - 1)l \tag{B9}$$

III Variable Management (O)

We consider three cases for variable *O*. First, in sub-section B1 we consider the long-run fully flexible case. Second, in sub-section B2 we consider the case where *O* changes through takeover. Third, in sub-section B3 we consider the case where firms can change through paying adjustment costs.

B1 PERFECTLY FLEXIBLE *O*

We begin with the "long-run" case of perfectly flexible *O*. To ensure that the second order condition ($\frac{\partial^2 Q}{\partial O^2} < 0$) with respect to *O* holds we assume the following condition:

$$-\left(\frac{2\alpha^O}{\sigma O} + \ln\left(\frac{\alpha^C + \sigma O}{\alpha^L - \sigma O}\right)\right) < \ln\left(\frac{W}{\rho^C}\right) < \ln\left(\frac{\alpha^L - \sigma O}{\alpha^C + \sigma O}\right) \tag{B10}$$

This ensures concavity of the production function. The first order condition for *O* is well defined as:

$$\alpha^O \frac{Q}{O} + \sigma Q \ln\left(\frac{C}{L}\right) = \rho^O \tag{B11}$$

We can substitute the first order conditions for labor and capital into the first order condition for *O* to derive a function that implicitly defines *O* as:

$$\lambda(O) = Ae^Z[\alpha^O O^{\alpha^O - 1} + \sigma O^{\alpha^0} \ \ln(W / \rho^C)] - \rho^O = 0 \tag{B12}$$

Where:

$$Z = -\sigma O \ln\left(\frac{\rho^C}{W}\left(\frac{\alpha^L + \sigma O}{\alpha^C - \sigma O}\right)\right) + \frac{(\alpha^C + \alpha^L)[a + \ln O + \sigma O \ln(W / \rho^C)] - \alpha^C \ln \rho^C - \alpha^L \ln W + \alpha^L (1 + 2\sigma)\ln(\alpha^C + \sigma O) + \alpha^C (1 - 2\sigma)\ln(\alpha^L - \sigma O)}{1 - \alpha^L - \alpha^C}$$

We can consider the comparative statics noting using the implicit function theorem

$$\frac{\partial O}{\partial x} = -\frac{\partial \lambda / \partial x}{\partial \lambda / \partial O}$$

This generates long-run optimal levels for the three endogenous variables (O*, C*, L*) as a function of the exogenous factor prices $\rho = \{\rho^C, \rho^O, W\}$, and technological parameters, $\theta = \{\alpha^C, \alpha^O, \alpha^L\}$.

$$O^*(\rho^C, \rho^O, W; \theta),\ C^*(\rho^C, \rho^O, W; \theta),\ L^*(\rho^C, \rho^O, W; \theta)$$

From this we can get our basic predictions:

1. $\left(\frac{\partial O^*}{\partial \rho^O}\right) < 0$. So if ρ^O (the price of *O*) is higher in the EU than US then $\overline{O}^{US} > \overline{O}^{EU}$.

2. $\left(\frac{\partial C^*}{\partial \rho^C}\right) < 0$. As IT prices fall firms will increase their level of IT inputs.

3. $\left(\frac{\partial O^*}{\partial \rho^C}\right) < 0$. As IT prices fall more O is accumulated if $\ln\left(\frac{W}{\rho^C}\right) > -\left(\frac{1-\alpha^L-\alpha^C}{\alpha^C+\sigma O}\right)$. Note that a sufficient (but not necessary) condition for this is W > ρ^C . To see this note that

$$\frac{\partial \lambda}{\partial \rho^C} = Ae^Z \alpha^O O^{\alpha_O - 1} \frac{\partial Z}{\partial \rho^C} - \sigma A e^Z O^{\alpha_O}\left[\frac{1}{\rho^C} - \ln\left(\frac{W}{\rho^C}\right)\frac{\partial Z}{\partial \rho^C}\right] \tag{B13}$$

The first term on the right hand side of $\frac{\partial \lambda}{\partial \rho^C}$ is negative since $\frac{\partial Z}{\partial \rho^C} = \frac{-(\alpha^C+\sigma O)}{\rho^C(1-\alpha^L-\alpha^C)}$ < 0. The second term will also be negative if W > ρ^C. If W < ρ^C, we also require that $\ln\left(\frac{W}{\rho^C}\right) > -\left(\frac{1-\alpha^L-\alpha^C}{\alpha^C+\sigma O}\right)$.

B2. MANAGEMENT (*O*) CAN CHANGE ONLY BY TAKEOVER (ENTRY/EXIT)

Some models assume that management is fixed for a given firm and can only change with entry/exit. We consider a related model where *O* changes by takeover (but allow *O* to be different across firms of different nationalities). Consider a model where a firm that takes over another firm can raise its management practices to the level of the predator, but has to pay a one period fixed cost, F, in order to do this (disruption costs associated with re-organizing the managerial structures). This captures the idea that re-organizing is easier to do via M&A activity than internally.

When IT prices fall, firms will want to increase *O*, call this new optimal level O*. Other firms with higher levels of *O* will seek to takeover the low *O* firms. Consider what happens when a higher *O* firm takes over a low *O* firm. The acquired firm will see (after one period) its *O* rise. Post-restructuring, the coefficient on IT in the production function will be higher because of this higher *O*. The firm's IT capital will also increase because the marginal value of IT is higher because of the higher *O*.

During the period of restructuring the predictions are more ambiguous. Assume the disruption cost depends on the size of the acquired firm, F = fQ. During the re-organization period the firm will bear the cost of lost output due to disruption so this will tend to lower productivity. However, if there are adjustment costs to IT (see below) then the firm may accumulate more IT assets in rational anticipation of higher *O* in subsequent periods: this will tend to raise labor productivity. In any case, the gains in labor productivity stemming from the increase in the productivity-IT correlation will not be apparent immediately after the takeover, but will occur with a lag.

In terms of the endogeneity of takeovers consider a domestic plant with management, O^{DOM}, being considered by two multinationals, US and EU. The differential costs of organization in the US and EU mean that on average:

$$O^{US} > O^{EU} > O^{DOM}$$

For firms with "low O" (defined as having an optimal level of *O* is greater than O^{EU}) the US firm will tend to select these firms. Both EU and US firms will place a positive value on taking over the plant so long as the disruption cost is less than the increased value of the firm arising from transferring across management practices. The US firm has an advantage over the EU firm, however, because it is able to raise *O* to a higher level (its optimal level in fact if $O^{US} \geq O^*$) whilst bearing the same disruption costs as the EU firm. Consequently, we may expect to see US firms selecting the worse performing European plants (with particularly low *O*).

B3 ADJUSTMENT COSTS IN MANAGEMENT (*O*)
More generally, management practices can change for a given firm, but this will be a costly process. In Bloom et al (2007) we consider in detail this more complex model. In short, this makes the analysis more complex so the model must be numerically simulated. But it does not change the key results and intuitions from the above model.

One way to model this is to define $g(\Delta O)$ as the adjustment cost function where Δ is the first difference operator (e.g. $\Delta O_t = O_t - O_{t-1}$). We assume that the management adjustment cost term $g(\Delta O)$ has a quadratic component and a fixed disruption component and is borne as a financial cost. This is parameterized as

$$g(\Delta O) = \omega_m(\Delta O)^2 + \eta PQ|\ \Delta O \neq 0|$$

where m = {EU,US}. Bloom, Sadun and Van Reenen (2007) consider a case where $\omega_{EU} = \omega_{US}$ and the more realistic case that $\omega_{EU} > \omega_{US}$. They show how the main intuition in the basic model goes through, but one needs to use numerical methods to show the transitional dynamics of firms in the two economies.

IV. Implications for Total Factor Productivity

We have focused our model on understanding the dynamics of labor productivity as this has had the clearest difference between the US and EU at the macro level. But there also appears to be some difference in TFP. Our baseline model even with quadratic managerial adjustment costs does not predict an acceleration in measured TFP, because the observed factor share of ICT capital in revenues will still give the correct weight in TFP calculations (i.e. it will be equal to $\alpha^C + \sigma$). If we allowed for adjustment costs in IT capital, however, this would lead to a measured increase in TFP in the US compared to Europe, at least after an initial acceleration in the fall of IT prices (see Bloom et al, 2007, Appendix B).

Basu et al (2003) are able to generate an increase in the observed TFP following an increase in IT capital in a simpler model. Their set-up is similar to ours with complementarity between IT and *O* (modelled as a CES nested in a Cobb-Douglas between the aggregate *G(C,O)* factor, labor, non-IT capital and materials). Investment in *O* is in the form of lost output, so in the initial stages of a sharp fall in IT prices measured TFP falls as firms rapidly accumulate IT and *O* and measured output is "too low". In subsequent periods after the *O* stock has been built, however, output is correctly measured, but the *O* capital input is underestimated so TFP is overestimated. Since the US invested in IT more quickly this could explain the faster measured US TFP growth post 1995.

This is elegant and also fits the facts, but it does not explain why the US started to adjust before the EU. Our model suggests that this is because the US already had a higher level of *O* prior to the acceleration in the decline of IT prices in the mid 1990s: this is why labor productivity growth picked up faster in the US for a similar rate of increase of IT capital growth in both regions. It may be, in addition, that adjustment costs of adjustment are lower in the US and this could explain why the US "moved first" both in Basu et al's model and in our extended model.

APPENDIX C: ADDITIONAL RESULTS

Table A4 contains alternative econometric estimates of the production function allowing for endogenous factor inputs. The structural model of firm behaviour underlying the Olley-Pakes (1996) approach is not consistent with simply including interactions, so instead we estimate the production function separately for the three ownership types separately: US multinationals in column (1), non-US multinationals in column (2) and UK domestic firms in column (3). For the same reason we do not normalize the outputs and inputs by labor in this table. Note that the extension of Olley and Pakes to two observable state variables that are influenced by the firm (the IT and non-IT capital stock) is straightforward (see Ackerberg et al, 2008). We have two investment equations (for IT and non-IT) that we could invert to control for the unobserved productivity shocks, ω_{it}. We found similar results for either and the results below use non-IT capital. To be precise, assuming strict monotonicity, we invert the non-IT investment equation, $i_{it}^K = i_t^K(c_{it}, k_{it}, \omega_{it})$ to solve for $\omega_{it} = \omega_t(c_{it}, k_{it}, i_{it}^K)$[61]. This enters the unknown function $\phi_{it} = \phi(\alpha^K k_{it} + \alpha^C c_{it} + \omega_t(c_{it}, k_{it}, i_{it}^K))$ which is included in the first step when we estimate the coefficients on the variable factor inputs.

The key empirical finding is that IT coefficient is twice as large for US multinationals as it is for non-US multinationals (0.0758 vs. 0.0343), which is consistent with our earlier findings[62].

Column (4) presents results for the System GMM estimator of Blundell and Bond (1998). Note that if the Markov Process determining the evolution of unobserved productivity shock in Olley and Pakes can be represented by an AR(1) process, the Olley-Pakes set-up becomes a special case of Blundell and Bond (2000). It is a special case because, the Blundell Bond set-up allows for fixed effects and endogeneity of the capital inputs (capital is weakly exogenous in Olley-Pakes). A practical disadvantage of Blundell and Bond is that it requires at least four continuous time series observations to exploit all the moment conditions which results in a smaller sample size for estimation purposes.

[61] The only difference from standard Olley-Pakes is that non-IT investment is a function of IT capital stock as well as non-IT capital stock and the unobserved productivity term.

[62] As with the main results we experimented with including four digit industry output following Klette and Griliches (1996) to allow for monopolistic competition. Again, there was some evidence of imperfect competition with larger mark-ups for US multinationals, but this did not affect the finding that the IT coefficient for US multinationals was again double the magnitude of that on non-US multinationals (0.077 vs. 0.035).

The results of column (4) of Table A4 are consistent with those observed in the rest of the paper. The interaction of IT with the US is positive and significant at the 5% level. This is significantly different from the IT coefficient on non-US multinationals at the 10% level (in the short-run and the long-run). The LM and Sargan-Hansen tests are consistent with the validity of the instrument set.

Note that the specification is not identical to Blundell and Bond (2000) but actually follows Nickell (1996). We also experimented with including the full set of lagged right hand variables as in Blundell and Bond (2000) but found that the common factor restrictions were rejected. This was because almost all the other lags were insignificant. The only lagged factor input that appeared to be significant was materials. When lagged materials is also included in the regression the US IT coefficient remained significantly higher than the non-US IT coefficient at the 10% level (see column (5) of Table A4).

Table A5 contains some additional results from the European firm-level panel. The first column includes our baseline results of Table 6 column (3) for comparison purposes. Column (2) is an equivalent specification except we use the z-score of the three shopfloor operations management questions instead of the people management scores. The interaction with IT is positive but insignificantly different from zero. The third column uses the 5 questions on monitoring which again produces a positive, but insignificant interaction. Column (4) does the same for the 5 target management questions with similar results. Finally in column (5) we use the z-score of all 18 management questions. In this case we do observe a weakly significant positive interaction (at the 10% level). The coefficient and significance levels are far lower than column (1), however, suggesting that it really is the people management practices that seem to matter.

TABLE A1 – BREAKDOWN OF THE INDUSTRIAL SECTORS BY IT USAGE

IT Intensive Sectors

Manufacturing	***Services***
18 Wearing apparel, dressing and dyeing of fur	51 Wholesale trades
22 Printing and publishing	52 Retail trade
29 Machinery and equipment	71 Renting of machinery and equipment
31 Manufacture of Electrical Machinery and Apparatus n.e.c. excludes 313 (insulated wire)	73 Research and development
33 Precision and optical instruments, excluding 331 (scientific instruments)	
351 Building and repairing of ships and boats	
353 Aircraft and spacecraft	
352+359 Railroad equipment and transport equipment	
36-37 miscellaneous manufacturing and recycling	

Other Sectors

Manufacturing	***IT producing sector?***	***Services***	***IT producing sector?***
15-16 Food drink and tobacco	No	50 Sale, maintenance and repair of motor vehicles	No
17 Textiles	No	55 Hotels and catering	No
19 Leather and footwear	No	60 Inland transport	No
20 Wood	No	61 Water transport	No
21 Pulp and paper	No	62 Air transport	No
23 Mineral oil refining, coke and nuclear	No	63 Supporting transport services, travel agencies	No
24 Chemicals	No	64 Communications	Yes
25 Rubber and plastics	No	70 Real estate	No
26 Non-metallic mineral products	No	72 Computer services and related activity	Yes
27 Basic metals	No	741-743 Professional business services	No
28 Fabricated metal products	No	749 Other business activities n.e.c.	No
30 Office machinery	Yes		
313 Insulated wire	Yes	***Other sectors***	
321 Electronic valves and tubes	Yes	10-14 Mining and quarrying	No
322 Telecom equipment	Yes	50-41 Utilities	No
323 Radio and TV receivers	Yes	45 Construction	No
331 Scientific instruments	Yes		
34 Motor vehicles			

Notes: See text for definitions. IT intensive sectors are those that have above median IT capital flows as a proportion of total capital flows (in the US) and are <u>not</u> IT producing sectors. These are taken directly from Stiroh's (2002) definitions.

TABLE A2 - DESCRIPTIVE STATISTICS

Panel A: All Establishments in UK Establishment Panel

Variable	Mnemonic	Mean	Median	Standard Deviation
Employment	L	811.098	238.000	4,052.766
Gross Output	Q	87,966.380	20,916.480	456,896.000
Value Added	VA	29,787.610	7,052.000	167,798.700
IT Capital	C	1,030.595	77.438	10,820.690
Value Added per worker	VA/L	40.429	29.530	55.192
Gross Output per worker	Q/L	124.745	86.034	136.555
Materials per worker	M/L	82.377	47.226	103.518
Non-IT Capital per worker	K/L	85.275	48.563	112.535
IT Capital per worker	C/L	0.964	0.339	2.079
Share of Materials in revenue	M/PQ	0.572	0.602	0.229
Share of Labour Expenditures in revenue	WL/PQ	0.300	0.262	0.196
Share of Non-IT Capital services in revenue	$\rho^K K/PQ$	0.124	0.096	0.130
Share of IT Capital services in revenue	$\rho^C C/PQ$	0.010	0.004	0.018
Multi-plant dummy (i.e. is establishment part of larger group?)		0.532	1.000	0.499

Panel B: Breakdown by Ownership Status and Sector in UK Establishment Panel

		IT Capital over value added (C/VA)			Ln(IT Capital)		
		All Sectors	IT Using Intensive Sectors	Other Sectors	All sectors	IT Using Intensive Sectors	Other Sectors
All firms	**Mean**	0.03	0.03	0.02	4.46	4.78	4.27
	St. Deviation	0.04	0.04	0.04	2.03	2.06	1.99
	Observations	7,121	2,703	4,418	7,121	2,703	4,418
US Multinationals	**Mean**	0.04	0.04	0.03	5.57	5.69	5.46
	St. Deviation	0.05	0.05	0.04	2.00	1.94	2.05
	Observations	569	260	309	569	260	309
Other Multinationals	**Mean**	0.03	0.03	0.03	5.18	5.34	5.07
	St. Deviation	0.04	0.04	0.04	1.96	1.99	1.93
	Observations	2,119	853	1,266	2,119	853	1,266
UK domestic	**Mean**	0.02	0.03	0.02	3.98	4.33	3.79
	St. Deviation	0.04	0.04	0.03	1.91	1.99	1.83
	Observations	4,433	1,590	2,843	4,433	1,590	2,843

Notes: The UK establishment panel consists of 7,121 establishments in 2001. All monetary amounts are in sterling in year 2001 prices. Total stocks are constructed as described in the Appendix. All variables in units of 1,000s except variables given in ratios and employment.

TABLE A2 - DESCRIPTIVE STATISTICS – CONT.

Panel C: European Firm Level Panel

		(1) Employment	(2) Sales per employee	(3) PCs per employee	(4) % employees with a degree	(5) People management (z-scores)
		Normalized to 100 for the country, 3-digit SIC and year average				Absolute value
US Multinationals	**Mean**	105.9	110.5	104.1	105.7	0.395
	St. Deviation	83.3	54.9	29.2	63.7	0.639
	Observations	125	125	51	144	175
Other Multinationals	**Mean**	104.5	107.2	99.5	102.7	0.092
	St. Deviation	77.7	42.2	38.1	60.9	0.674
	Observations	254	254	121	359	419
European domestic	**Mean**	97.1	95.2	99.5	97.3	-0.134
	St. Deviation	69.4	41.4	43.9	70.6	0.677
	Observations	650	650	292	869	1,040

Notes: The European firm level panel consists of 1,029 firms in 2001 (the smaller sample size in Table 6 is due to some missing values). All monetary amounts are in sterling in year 2001 prices. Total stocks are constructed as described in the Appendix. All variables in units of 1,000s except variables given in ratios and employment.

TABLE A3: THE PEOPLE MANAGEMENT SURVEY QUESTIONS

Any score from 1 to 5 can be given, but the scoring guide and examples are only provided for scores of 1, 3 and 5. Multiple questions are used for each dimension to improve scoring accuracy.

1. PROMOTING HIGH PERFORMERS

a) Can you rise up the company rapidly if you are really good? Are there any examples you can think of?
b) What about poor performers – do they get promoted more slowly? Are there any examples you can think of?
c) How would you identify and develop (i.e. train) your star performers?
d) If two people both joined the company 5 years ago and one was much better than the other would he/she be promoted faster?

Scoring grid:	Score 1	Score 3	Score 5
	People are promoted primarily upon the basis of tenure	People are promoted upon the basis of performance	We actively identify, develop and promote our top performers

2. REWARDING HIGH-PERFORMANCE

a) How does you appraisal system work? Tell me about the most recent round?
b) How does the bonus system work?
c) Are there any non-financial rewards for top-performers?

Scoring grid:	Score 1	Score 3	Score 5
	People within our firm are rewarded equally irrespective of performance level	Our company has an evaluation system for the awarding of performance related rewards	We strive to outperform the competitors by providing ambitious stretch targets with clear performance related accountability and rewards

3. REMOVING POOR PERFORMERS

a) If you had a worker who could not do his job what would you do? Could you give me a recent example?
b) How long would underperformance be tolerated?
c) Do you find any workers who lead a sort of charmed life? Do some individuals always just manage to avoid being fixed/fired?

Scoring grid:	Score 1	Score 3	Score 5
	Poor performers are rarely removed from their positions	Suspected poor performers stay in a position for a few years before action is taken	We move poor performers out of the company or to less critical roles as soon as a weakness is identified

4. MANAGING HUMAN CAPITAL

a) Do senior managers discuss attracting and developing talented people?
b) Do senior managers get any rewards for bringing in and keeping talented people in the company?
c) Can you tell me about the talented people you have developed within your team? Did you get any rewards for this?

Scoring grid:	Score 1	Score 3	Score 5
	Senior management **do not** communicate that attracting, retaining and developing talent throughout the organization is a top priority	Senior management believe and communicate that having top talent throughout the organization is a key way to win	Senior managers are evaluated and held accountable on the strength of the talent pool they actively build

TABLE A4 – GMM-SYS AND OLLEY-PAKES ESTIMATES OF THE PRODUCTION FUNCTION

	(1)	(2)	(3)	(4)	(5)
Sample	**US multinationals**	**Other multinationals**	**Domestic UK**	**All establishments**	**All establishments**
Estimation Method	**Olley-Pakes**	**Olley-Pakes**	**Olley-Pakes**	**GMM**	**GMM**
Sectors	**IT Using Intensive**	**IT Using Intensive**	**IT Using Intensive**	**All**	**All**
Dependent Variable	**Ln(Q)**	**Ln(Q)**	**Ln(Q)**	**Ln(Q)**	**Ln(Q)**
USA*ln(C_t) **USA Ownership*IT capital**	-	-	-	0.0524*** (0.0192)	0.0368** (0.0165)
MNE*ln(C_t) **Non-US Multinational *IT capital**	-	-	-	0.0158 (0.018)	0.007 (0.0159)
ln(C_t) **IT Capital**	0.0758** (0.0383)	0.0343** (0.0171)	0.0468*** (0.0116)	0.0268* (0.0153)	0.0237* (0.0142)
ln(M_t) **Materials**	0.5874*** (0.0312)	0.6514*** (0.0187)	0.6293*** (0.0267)	0.2993*** (0.0539)	0.4423*** (0.0579)
ln(K_t) **Non-IT Capital**	0.0713 (0.0674)	0.1017*** (0.0285)	0.1110*** (0.0270)	0.0774** (0.032)	0.0686*** (0.0276)
ln(L_t) **Labor**	0.1843*** (0.0337)	0.2046*** (0.0139)	0.2145*** (0.0173)	0.179*** (0.0371)	0.1394*** (0.036)
USA **USA Ownership**	-	-	-	-0.354*** (0.1142)	-0.263*** (0.0984)
MNE **Non-US Multinational**	-	-	-	-0.0858 (0.1218)	-0.0339 (0.1075)
ln(Q_{t-1}) **Lagged Output**	-	-	-	0.4164*** (0.083)	0.5321*** (0.0861)
ln(M_{t-1}) **Lagged Materials**	-	-	-	-	-0.201*** (0.0636)
Observations	615	2,022	3,692	978	978
First order serial correlation, p value				0.000	0.000
Second order serial correlation, p value				0.707	0.572
Sargan-Hansen, p-value	-	-	-	0.943	0.972
Test USA*ln(C) = MNE*ln(C), p-value (short-run)	-	-	-	0.0926	0.1044
Test USA*ln(C)= MNE*ln(C), p-value (long-run)				0.0871	0.1077

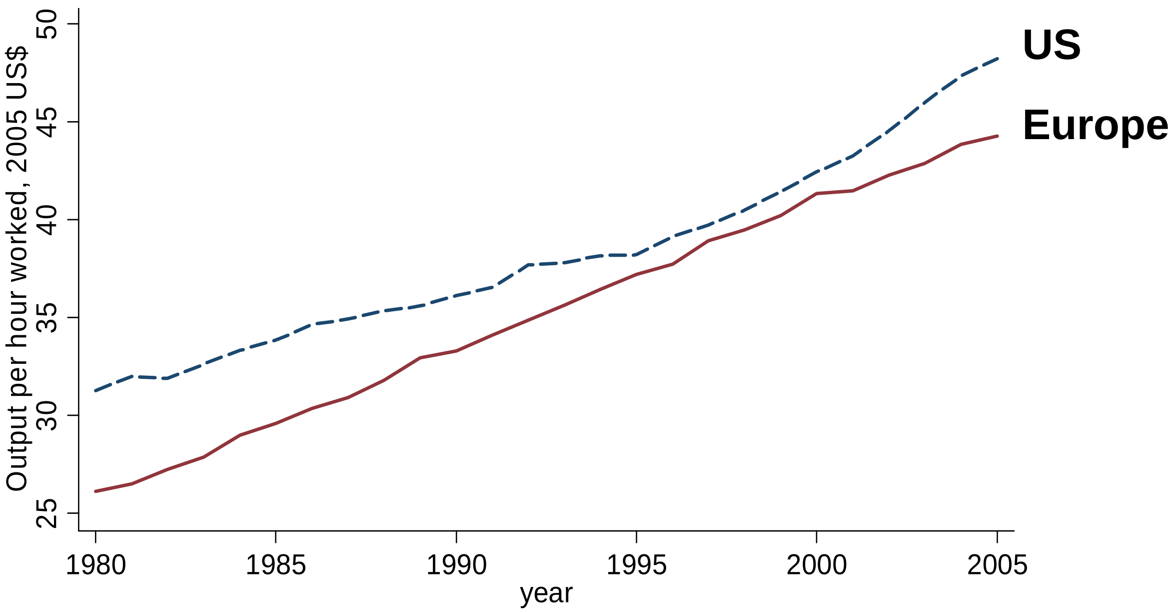
Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns is the log of gross output. The time period is 1995-2003. All variables are expressed in deviations from the year-specific three digit industry mean. Columns (1)-(3) are estimated using Olley-Pakes (1996). We use a fourth order series expansion to approximate the φ(.) function (the first stage control function). Standard errors in Olley-Pakes are bootstrapped (clustered at the establishment level) with 200 replications. Columns (4) and (5) are estimated using System-GMM (Blundell and Bond, 1998). One step GMM results reported. In column (1) instruments are all establishment level factor inputs lagged t-2 and before (when available) in the differenced equation (i.e. m_{t-2}, l_{t-2} ,k_{t-2},c_{t-2}, q_{t-2}, USA_{t-2}, MNE_{t-2}, $(USA*c)_{t-2}$, $(MNE*c)_{t-2}$,q_{t-2}) and lagged differences in the levels equation (Δm_{t-1}, Δl_{t-1} , Δk_{t-1}, Δc_{t-1}, ΔUSA_{t-1}, ΔMNE_{t-1}, $\Delta(USA*c)_{t-1}$, $\Delta(MNE*c)_{t-1}$). Serial correlation tests are LM tests of the first differenced residuals (see Arellano and Bond, 1991). Sargan-Hansen Test of instrument validity is a test of the over-identification. "Test USA*ln(C) =MNE*ln(C)" is test of whether the coefficient on USA*ln(C) is significantly different from the coefficient on MNE*ln(C). Because we include a lagged dependent variable we include both a short-run and a long-run test where the latter takes the coefficient on the lagged dependent variable into account. All columns include age, region dummies and a dummy taking value one if the establishment belongs to a multi-firm enterprise group as additional controls.

TABLE A5 – EUROPEAN FIRM-LEVEL PANEL

Dependent Variable:	(1) Ln(Q/L)	(2) Ln(Q/L)	(3) Ln(Q/L)	(4) Ln(Q/L)	(5) Ln(Q/L)
People Management	0.0188				
People management z-score	(0.0153)				
People Management*ln(C/L)	0.1451***				
People management*Computers per employee	(0.0331)				
Operations Management		0.0189			
Operations management z-score		(0.0171)			
Operations Management*ln(C/L)		0.0119			
Operations management*Computers per employee		(0.0269)			
Monitoring Management			0.0255		
Monitoring management z-score			(0.0159)		
Monitoring Management*ln(C/L)			0.0119		
Monitoring management*Computers per employee			(0.024)		
Targets Management				0.0218	
Targets management z-score				(0.0154)	
Target Management*ln(C/L)				0.0252	
Targets management*Computers per employee				(0.0353)	
Overall Management					0.0449*
Overall management z-score					(0.0268)
Overall Management*ln(C/L)					0.0703*
Overall management*Computers per employee					(0.0406)
ln (K/L)	0.1782***	0.1825***	0.1797***	0.1794***	0.1782***
Non-IT Capital per employee	(0.0276)	(0.0281)	(0.0284)	(0.0287)	(0.0280)
ln(L)	0.0421	0.0405	0.0399	0.0422	0.0437
Labor	(0.0344)	(0.0367)	(0.0366)	(0.0363)	(0.0347)
ln(C/L)	0.1430***	0.1172***	0.1168***	0.1186***	0.1372***
Computers per employee	(0.0284)	(0.0288)	(0.0280)	(0.0289)	(0.0297)
ln(Degree)	0.0375**	0.0451**	0.0433**	0.0443**	0.0397**
Percentage employees with a college degree	(0.0184)	(0.0183)	(0.0184)	(0.0184)	(0.0184)
USA	0.1111**	0.1364***	0.1308***	0.1334***	0.1146**
USA Ownership	(0.0446)	(0.0471)	(0.0473)	(0.0474)	(0.0459)
MNE	0.1604***	0.1554***	0.1545***	0.1550***	0.1606***
Non-US multinational	(0.0355)	(0.0367)	(0.0360)	(0.0358)	(0.0358)
Observations	2,555	2,555	2,555	2,555	2,555
Firms	719	719	719	719	719

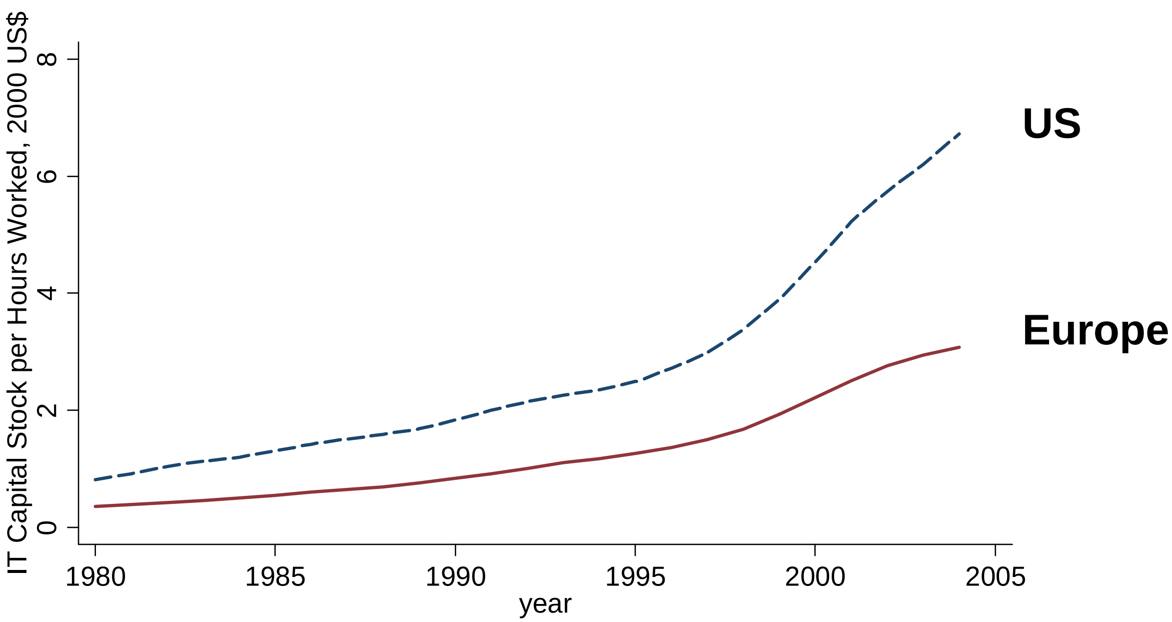
Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns is the log of sales per employee. The time period is 1999-2006, containing data from France, Germany, Italy, Poland, Portugal, Sweden and the UK. The estimation method in all columns is OLS. Standard errors in brackets under coefficients in all columns are clustered by firm (i.e. robust to heteroskedasticity and autocorrelation of unknown form). All columns include a full set of three digit industry dummies, country dummies interacted with a full set of time dummies and a public listing indicator. Columns weighted by the survey coverage rate in the Harte-Hanks data, plus include a fifth order series expansion for the coverage ratio to control for any potential survey bias.

Figure 1: Output per hour in Europe and the US, 1980-2005



Notes: Productivity measured by GDP per hour in 2005 US $ PPPs. The countries included in the “EU 15” group are: Austria, Belgium, Denmark, Finland, France, Germany, UK, Greece, Italy, Ireland, Luxembourg, Portugal, Spain, Sweden, and Netherlands. Labor productivity per hour worked in 2005 US$. Source: The Conference Board and Groningen Growth and Development Centre, Total Economy Database.

Figure 2: IT capital per hour in Europe and the US, 1980-2005



Notes: IT capital stock (in unit dollars) per hour worked. IT capital stock measured using perpetual inventory method and common assumptions on hedonics and depreciation. 2005 US $ PPPs The countries included in the “EU 15” group are: Austria, Belgium, Denmark, Finland, France, Germany, UK, Greece, Italy, Ireland, Luxembourg, Portugal, Spain, Sweden and the Netherlands. Labour productivity per hour worked in 2005 US$ using PPPs. Source: Marcel P. Timmer, Gerard Ypma and Bart van Ark, “IT in the European Union: Driving Productivity Convergence?”, Research Memorandum GD-67, Groningen Growth and Development Centre, October 2003, Appendix Tables, updated June 2005.

Figure 3a: People management z-scores, all firms by country of location

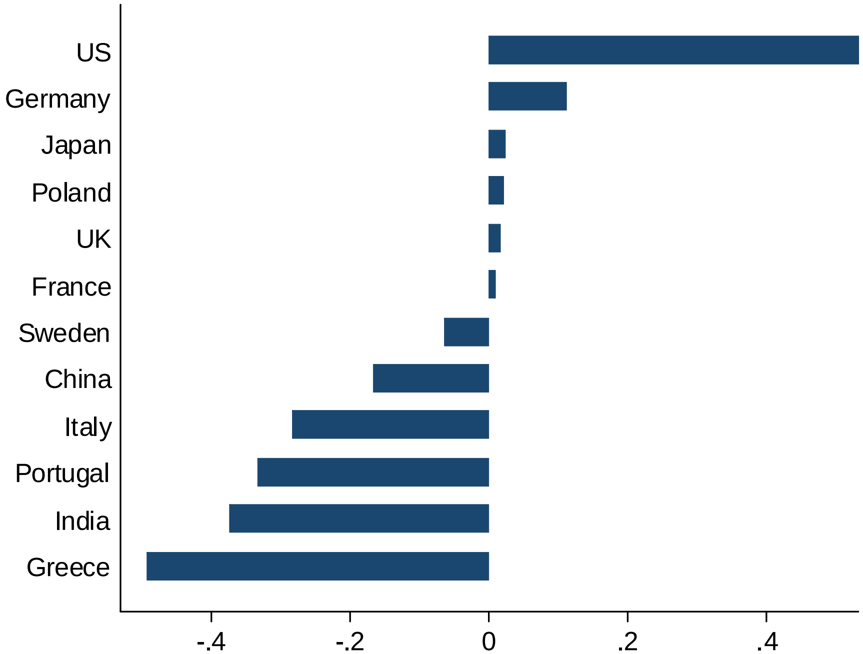
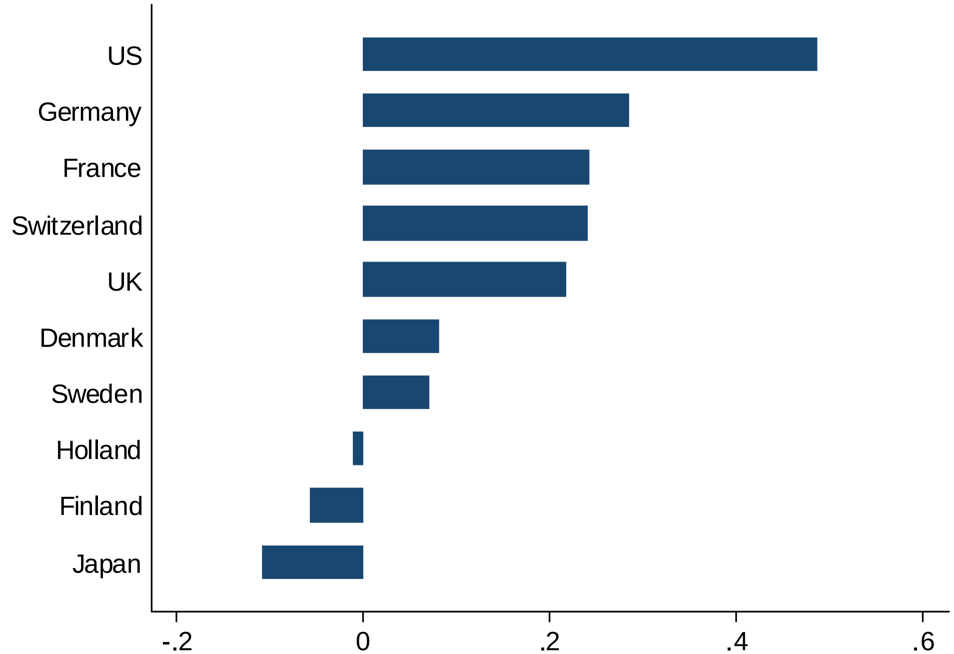


Figure 3b: People management z-scores, multinationals by country of origin



Notes: In Figures 3a and 3b the “People management z-score” is the average z-score score for the 4 management practices on people management, covering “Managing human capital”, “Rewarding high performance”, “Removing poor performers” and “Promoting high performers”. This is normalized to have a firm level standard deviation of 1. The sample in Figure 3a is all 4,003 firms sorted according to country of location. The sample in Figure 3b is the subset of 631 multinational subsidaries located in France, Germany, Italy, Poland, Portugal, Sweden and the UK, sorted accorded to country of origin and only plotted for origin countries with at least 25 firms in the sample.