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Americans Do I.T. Better: US Multinationals and the Productivity Miracle

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Abstract

The US has experienced a sustained increase in productivity growth since the mid-1990s, particularly in sectors that intensively use information technologies (IT). This has not occurred in Europe. If the US "productivity miracle" is due to a natural advantage of being located in the US then we would *not* expect to see any evidence of it for US establishments located abroad. This paper shows in fact that US multinationals operating in the UK do have higher productivity than non-US multinationals in the UK, and this is primarily due to the higher productivity of their IT. Furthermore, establishments that are taken over by US multinationals increase the productivity of their IT, whereas observationally identical establishments taken over by non-US multinationals do not. One explanation for these patterns is that US firms are organized in a way that allows them to use new technologies more efficiently. A model of endogenously chosen organizational form and IT is developed to explain these new micro and macro findings.

Keywords: Productivity, Information Technology, multinationals, organization
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> "[The acceleration in US productivity] may be plausibly accounted for by a pickup in capital services per hour worked and by increases in *organizational capital*, the investments businesses make to reorganize and restructure themselves, in this instance in response to newly installed information technology"
>
> *Economic Report of the President, (2006), p.26*

One of the most startling economic facts of the last decade 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). Decompositions of US productivity growth show that the great majority of this growth occurred in those sectors that either intensively use or produce IT (information technologies)[1]. 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 retail, wholesale and financial services)[2]. Consistent with these trends, Figure 2 shows that IT intensity appears to be substantially higher in the US than Europe and this gap has widened 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.

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1 See, for example, Kevin Stiroh (2002). Dale Jorgenson (2001), Stephen Oliner and Daniel Sichel (2000). In the 2002-2004 period Oliner and Sichel (2005) find that US productivity growth remained strong, but there was a more widespread increase in productivity growth across sectors. See Robert J. Gordon (2004) for a general discussion.

2 Mary O'Mahony and Bart Van Ark (2003) decompose productivity growth for the same sectors in the US and Europe under common measurement assumptions. Compared to the 1990-1995 period, US productivity growth in sectors that intensively used IT accelerated by 3.5 percentage points between 1995 and 2001 (from 1.2% per annum to 4.7% per annum). In Europe, productivity growth in these sectors showed no acceleration (it was 2% per annum pre and post 1995). Productivity growth accelerated in the IT producing sectors by similar amounts in the US (1.9 points) and Europe (1.6 points). In the other sectors there was no acceleration in either the US or Europe.

There are at least two broad classes of explanation[3] of 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 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 organized or managed that enables better exploitation of IT.

These explanations are not mutually exclusive. In the final section of this paper we build a model that has elements of both (i.e. organizational practices in US-based firms are affected by the US regulatory environment and some of these practices are transplanted overseas through foreign affiliates of American multinationals). Nevertheless, one straightforward way to test whether the "US firm organization" hypothesis has any validity is to *examine the IT performance of US owned organizations in a non-US environment*. If US multinationals at least partially export their business models outside the US – 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 firm organization model 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").

In this paper, we examine the productivity of IT in a large panel of establishments located in the UK, examining the differences in IT-related productivity between establishments owned by US multinationals, establishments owned by non-US multinationals and domestic establishments. The UK is a useful testing ground for at least two reasons. First, it experiences extensive foreign ownership with frequent ownership change. Second, the UK Census Bureau has collected panel data on IT expenditure and productivity in both manufacturing and services since the mid-1990s.

[3] Another possibility is international differences in productivity measurement (Olivier Blanchard, 2004). This is possible, but the careful work of Mary O'Mahony and Bart Van Ark (2003) focusing on the same sectors in the US

Therefore, we have arguably constructed the richest micro-dataset on IT and productivity in the world.

We report that the key fact in understanding productivity differences is the apparent ability of US multinationals to obtain higher productivity than non-US multinationals (and domestic UK establishments) *from their IT capital*. 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 versus a non-US multinational. Prior to takeover by a US firm the establishment's IT performance is no different from that of other plants that are taken over by non-US firms. After takeover, the American establishment's productivity of IT capital increases substantially (while the productivity of non-IT capital, labor, and materials does not).

Overall, these findings suggest that the higher productivity of IT in the US has something to do with specific characteristics of US establishments, which we define as their "internal organization" (we discuss other possible explanations as well). We also show that US firms are organized differently to non-US firms and that they can change their organizational structure more quickly.

Finally, we present a simple dynamic model that is consistent with the new micro and macro stylized facts. Based on our earlier discussion, we first assume complementarity between organization and IT. Then, tailoring our model to the comparison between US and European firms, we assume that in adjusting their organizations, otherwise identical firms face country-specific costs arguably related to differences in labor market regulations. Firms optimally choose their organizational form and factor inputs (including IT) in response to the acceleration in the fall of quality-adjusted IT prices post-1995. The higher adjustment costs for firms in Europe imply that they take longer to make the organizational changes, so during the transition US labor productivity and IT rise more quickly. Because multinationals find it costly to have different organization forms in their overseas plants, US firms in Europe will "transplant" their organizational practices, generating the results we see in our data. We also present some direct evidence supporting the model by using explicit indicators of institutions that could generate organizational inflexibility

and EU, using common adjustments for hedonic prices, software capitalization and demand conditions, still find a difference.

(i.e. measures of labor market regulation). Although there may be other theories that can rationalize the data, some of which we discuss in extensions of the model, we argue that this model provides a parsimonious framework for understanding recent productivity changes.

Our paper is related to several other areas of the literature. First, there is a large literature on the impact of IT on productivity at the aggregate or industry-level.[4] Second, there is growing evidence that the returns to IT are linked to the internal organization of firms. On the econometric side, Tim Bresnahan, Erik Brynjolfsson and Lorin Hitt (2002) and Eve Caroli and John Van Reenen (2001) 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 a large range of evidence[5]. For example, Larry Hunter et al (2000) describe how IT radically changed the organization of US banks in the late 1980s. The introduction of ATMs substantially reduced the need for tellers. At the same time, PCs and credit-scoring software allowed staff to be located on the bank floor and to directly sell customers mortgages, loans and insurance, replacing bank managers as the primary sales channel for these products. Along with the IT enabled ability of regional managers to remotely monitor branches, this led to a huge reduction in branch-level management and much greater decentralized decision-making for the front-line staff. This re-organization of banks did not happen in much of Europe, however, until much later because of strong labor regulation and trade-union power. 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. Erik Brynjolfsson and Lorin Hitt (2003) argue that this is due to complementary investments in "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 (Mark Doms and Bradford Jensen, 1998) and in other countries, such as the UK (Chiara Criscuolo and Ralf Martin, 2005). We suggest that the main reason for this difference is the way in which US multinationals use new technologies more effectively than other multinationals[6]. Finally, our paper is linked to

[4] See, for example, Basu et al. (2003) or Stiroh (2004).
[5] Olivier Blanchard, Martin Bailey, Hans Gersbach, Monika Schnitzer and Jean Tirole (2002) discuss a large number of industry-specific examples.
[6] In a similar vein, John Haltiwanger Ron Jarmin and Torsten Shank (2003) suggest that differences in the productivity distribution of Germany and American plants could be due to greater experimentation in the US.

the literature on growth and regulation.[7] One of the unintended consequences of labor market regulation in our model is that it slows down the ability of firm's to re-organize. When faced by a radical technological shock (such as the big fall in IT prices), these adjustment costs can have serious consequences in terms of technological diffusion and productivity growth.

The structure of this paper is as follows. Section I describes the empirical framework, Section II the data and Section III presents the main results. In Section IV we sketch a simple model that can account for the stylized facts we see in the data and Section V concludes.

I. Empirical Modelling Strategy

A. Basic Approach

We assume that the basic production function can be written as follows

$$q_{it} = a_{it} + \alpha_{it}^{M} m_{it} + \alpha_{it}^{L} l_{it} + \alpha_{it}^{K} k_{it} + \alpha_{it}^{C} c_{it} \tag{1}$$

Q denotes gross output of establishment *i* in year *t*. *A* denotes (total factor) productivity, *M* denotes materials, *L* denotes labor, *K* denotes non-IT fixed capital and *C* denotes computer/IT capital. Lower case letters indicate that a variable is transformed into natural logarithms, so $q_{it} \equiv \ln Q_{it}$, etc.

We are particularly interested in the role of IT capital and whether the impact of computers on productivity is systematically higher for the establishments belonging to US firms. With this in mind, consider parameterizing the output elasticities in equation (1) as:

$$\alpha_{it}^{J} = \alpha_{h}^{J,0} + \alpha_{h}^{J,USA} D_{it}^{USA} + \alpha_{h}^{J,MNE} D_{it}^{MNE} \tag{2}$$

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 base case is that the establishment belongs to a non-multinational domestic UK firm), the sub-script *h* denotes sector (e.g. industries that use IT intensively vs. all other sectors) and the super-script *J* indicates a

[7] For example, Juan Botero, Simeon Djankov, Rafael Porta, Florencio Lopez-De-Silanes and Andrei Schleifer (2004).

particular factor of production (*M, L, K, C*). We further assume that establishment-specific efficiency can be parameterized as:

$$a_{it} = a_i + \delta_h^0 + \delta_h^{USA} D_{it}^{USA} + \delta_h^{MNE} D_{it}^{MNE} + \gamma_h ' z_{it} + \xi_{kt} + u_{h,it} \tag{3}$$

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 dummies[8] interacted with a full set of time dummies. So, (combining equations (1) through (3)) the general form of the production function that we will estimate is:

$$\begin{aligned} q_{it} = & \sum_{M,L,K,C \in J} \alpha_h^{J,0} x_{it}^J + \sum_{M,L,K,C \in J} \alpha_h^{J,USA} D_{it}^{USA} x_{it}^J + \sum_{M,L,K,C \in J} \alpha_h^{J,MNE} D_{it}^{MNE} x_{it}^J \\ & + a_i + \delta_h^{USA} D_{it}^{USA} + \delta_h^{MNE} D_{it}^{MNE} + \delta_h^0 D_{it}^0 + \gamma_h ' z_{it} + \xi_{kt} + u_{h,it} \end{aligned} \tag{4}$$

where $x^M = m$, etc. Note that the industry*time interactions (ξ_{kt}) control for output prices, demand and any other correlated industry specific shock.

Although we will estimate equation (4) in some specifications, most of the interactions between factor inputs and ownership status are not significantly different from zero. One interaction that does stand out is between the US ownership dummy and IT capital: the coefficient on computer capital is significantly higher for US establishments than for other multinationals and/or domestic establishments. Consequently, our preferred specifications are usually of the form:

$$\begin{aligned} q_{it} = & \alpha_h^M m_{it} + \alpha_h^L l_{it} + \alpha_h^K k_{it} + \alpha_h^{C,0} c_{it} + \alpha_h^{C,USA} D_{it}^{USA} c_{it} + \alpha_h^{C,MNE} D_{it}^{MNE} c_{it} \\ & + a_i + \delta_h^{USA} D_{it}^{USA} + \delta_h^{MNE} D_{it}^{MNE} + \delta_h^0 D_{it}^0 + \gamma_h ' z_{it} + \xi_{kt} + u_{h,it} \end{aligned} \tag{5}$$

where the key hypotheses are whether $\alpha_h^{C,USA} D_{it}^{USA} = 0$ and/or $\alpha_h^{C,USA} D_{it}^{USA} = \alpha_h^{C,MNE} D_{it}^{MNE}$.

[8] 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.

(i.e. whether the output elasticity of IT is significantly greater for US establishments).

B. Sub-sample of establishments who are taken over

One concern with our strategy is that US firms may "cherry pick" the best UK establishments. In other words, it is not US multinational's internal organization that helps improve the productivity of IT but rather the ability to recognize (and take over) UK establishments that are better at using IT capital. To tackle this issue, we focus on a sub-sample of UK establishments that have been taken over by another firm at some point in the sample period. We then estimate equation (5) before and after the takeover to investigate whether the IT coefficient changes if a US multinational versus a non-US multinational takes over a UK plant. We also investigate the dynamics of change: because organizational changes are costly, we should expect to see change taking place slowly over time (so we examine how the IT coefficients change one year after the takeover compared to two years later, and so on).

The identification assumption here is <u>not</u> 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. We are effectively making two assumptions here. First, we assume that US multinationals are not systematically taking over plants that are more (or less) 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 selection[9]. Second, we are assuming that US multinationals are not systematically better than non-US multinationals at predicting (pre-takeover) the higher future productivity of IT for statistically identical British establishments. Although we regard this assumption as plausible it is not directly testable. If US managers *did* possess such foresight (and we will show that it is only for post-takeover IT

[9] If US multinationals have higher IT productivity why do we not observe some systematic selection of US firms taking over particular UK establishments? In the model we sketch in section IV, for example, US firms would want to take over firms who were organized in a similar fashion to themselves (as indicated by their prey's higher IT productivity). It is likely this incentive, however, is small compared to the many other causes of international merger and acquisition activity we observe in the data (which we confirm empirically in section III). Allowing for endogenous takeovers is an interesting area for future work. Identification of such a model of course requires some instrument which affects takeover probabilities without directly affecting productivity.

productivity that the US takeovers appear to be different than non-US multinational's takeover), we cannot identify this separately from the more general superiority of American firms' IT usage.

C. Unobserved Heterogeneity

In all specifications, we choose a general structure of the error term that allows for arbitrary heteroscedasticity 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 rigorous, as there may be many unobservable omitted variables correlated with IT that generate an upwards bias for the coefficient on computer capital.

D. Endogeneity of the Factor Inputs

We also were concerned about the endogeneity of the factor inputs attributable to unobserved transitory shocks. We take several approaches to deal with this issue. We experiment with the "System GMM" estimator of Richard Blundell and Stephen Bond (1998) and with a version of the Steve Olley and Ariel Pakes (1996) estimator.

II. Data

Our dataset is a panel of establishments covering almost all sectors of the UK private sector, called the Annual Business Inquiry (ABI). It is similar in structure and content to the US Longitudinal Research Database (LRD), which contains detailed information on revenues, investment, employment and material inputs. Unlike the US LRD though, the ABI can be matched to establishment-level IT expenditure data for several years and it also covers the non-manufacturing sector from the mid-1990s onwards. This is important, because the majority of the sectors that intensively use IT, such as retailing and wholesaling, are outside manufacturing. The dataset is unique in containing such a large sample of establishment-level longitudinal information on IT and productivity. A full description of the datasets appears in Appendix A.

We build IT capital stocks from IT expenditure flows using the perpetual inventory method and following Dale Jorgenson (2001), sticking to US assumptions about depreciation rates and hedonic prices. Our dataset runs from 1995 through 2003, but there are many more observations in each year after 1999. After cleaning, we are left with 21,746 observations with positive values for all the factor inputs. There are many small and medium-sized establishments in our sample[10] - the median establishment employs 238 workers and the mean establishment employs 811. The sampling framework of the IT surveys means that our sample, on average, contains larger establishments than the UK economy as a whole. At rental prices, 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 Susanto Basu et al (2003).

We also considered several experiments by changing our assumptions concerning the construction of the IT capital stock. 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. Finally, we use an entirely different measure of IT use based on the number of workers in the establishment who use computers (taken from a different survey). Qualitatively similar results were obtained from all methods.

We have large numbers of multinational establishments in the sample. 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 for a typical year (2001). 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.[11] But US establishments also look systematically larger and more intensive in their non-labor input usage than other multinationals.

[10] Table A2 sets out the basic summary statistics of the sample.

[11] This is consistent with evidence that the plants of multinational US firms are more productive both on US soil (Mark Doms and Bradford Jensen, 1998) and on foreign soil (Chiara Criscuolo and Ralf Martin (2004)).

US establishments have 14 percentage points more employees and use about 8 percentage points more materials/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; this alone could be the reason for their higher productivity in previous studies (as they have not been able to control for IT capital). In the econometric analysis, we will show that this is not the full story because for a given amount of IT capital US productivity appears to be higher.

III. Results

A. Main Results

One key result in our paper is that US establishments' IT use is associated with greater productivity than non-US establishments' IT use. Some indication of this can be seen in the raw data. In the first row of Table 2 we show that the mean value added per worker (normalized by the industry average) in establishments with high IT intensity (defined as above the sample median IT capital per worker) compared to those with lower IT intensity (below the sample median) is 34% higher among the US owned establishments. In the second row, we show that the equivalent "IT premium" is only 24% for establishments owned by non-US multinationals. The implied "difference in differences" effect is a significant US premium in IT productivity of 10%. There are a host of reasons why this comparison might be misleading, of course, but as we investigate them below it will become clear that the basic contrast in Table 2 turns out to be remarkably robust.

In Table 3 we examine the output elasticity of IT in the standard production function framework described in Section II. 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% difference between the US and non-US multinationals coefficients is also significant at the 5% level (p-value =0.02) as shown at the base of the column. This implies that about two-thirds (6 percentage points of the 9 percentage point gap) of the labor productivity gap between US and other multinationals shown in Table 1 can be accounted for by our observables, such as greater non-IT factor intensity in the US establishments, but a significant gap remains.

The second column of Table 3 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; this explains some of the productivity gap. But it only accounts for about 0.2 percentage points of the initial 3.2% (= 0.0712 - 0.0392) productivity gap between US and non-US 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 5.35% (= 0.0449 + 0.0086) for a US multinational but only 4.5% (= 0.0449 + 0.0001) 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. Furthermore, the linear US dummy is not significantly different from zero. Interpreted literally, this means that we can "account" for *all* of the US multinational advantage by their more effective use of IT. Hypothetically, US establishments with less than about £1,000 (about $2,000) of IT capital (i.e. ln(C) = 0) are no more productive than their UK counterparts (none of the US establishments in the sample have IT spending this low, of course).

To investigate the industries that appear to account for the majority of the productivity acceleration in the US we split the sample into "high 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 and printing/publishing[12]. The US interaction with IT capital is much stronger in the IT intensive sectors, in that it is not significantly

[12] See Appendix Table A1 for a full list. We follow the same definitions of the sectors that intensively use IT as Kevin Stiroh (2002). We group the IT producing sectors (like semi-conductors) with the "Other Sectors" because we could

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 with a higher value of the interaction than in the non-fixed effects results. In particular, column (7) demonstrates that US establishments appear to have significantly higher productivity of their IT capital stocks than domestic establishments or other multinationals. A doubling of the IT capital stock is associated with 1% higher productivity for a domestic establishment and 1.6% for a non-US multinational, but 3.9% higher productivity for an establishment owned by a US multinational[13].

The reported US*IT interaction tests for significant differences in the output-IT elasticity between US multinationals and UK domestic establishments. However, note that in our key specifications 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*IT and the MNE*IT coefficient (i.e. Ho: $\alpha_h^{C,USA} D_{it}^{USA} = \alpha_h^{C,MNE} D_{it}^{MNE}$).

B. Robustness Tests

Table 4 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 3. 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 - 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

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not find significant differences in the IT coefficient between US and non-US firms. This is consistent with the aggregate evidence that the productivity acceleration in these sectors was similar in Europe and the US.

[13] The linear US dummy is negative and significant, implying that US multinationals with very low IT stocks are less productive than domestic establishments. However, using the estimates of column (4) only 2% of the employees of US multinationals are in these plants (5% using column (7)). Moreover, we show that when US firms take over an establishment's productivity can remain low for a year or two during the restructuring process, explaining the negative direct US dummy given the short time dimension of the sample.

the factor coefficients on other inputs, particularly on materials, also would be systematically different for US establishments. 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 (for example, the joint test of the all the US interactions except the IT interaction has a p-value of 0.48). We cannot reject the specification of equation (5) in column (1) as a good representation of the data versus the more general interactive models of equation (4) in column (3).[14] 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 (Tor Klette and Zvi Griliches, 1996).

Another piece of evidence against the transfer pricing story is that our results are strongest in the IT-using sectors, which are mainly services, like retail. Manipulating the transfer prices of intermediate inputs is more difficult in services than manufacturing, as intermediate inputs generally are purchased from independent suppliers. If we estimate the model solely for the retail sector, for example, the coefficient on the US*IT interaction is 0.0509 with a standard error of 0.0118 (the interaction of other multinationals with IT has a coefficient of -0.0142 with a standard error of 0.0096).

Systematic mismeasurement of American establishments' IT capital stock - One concern is that we may be underestimating the true IT stock of US multinationals in the initial year: this could generate a positive coefficient on the interaction term, because of greater measurement error of IT capital for the US establishments. This also could be due to transfer price concerns, causing the US firms to underestimate their IT expenditure for some reason.

[14] The p-value = 0.33 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 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 from the authors on request.

To tackle this issue we turn to an alternative IT survey (the E-commerce Survey, described in the Appendix) 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[15]. In Column (4) we replace our IT capital stock measure with a measure of the number of workers using computers. 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 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 0.0278 to 0.0268) and remains significant.

Selection of US establishments into sectors with high IT productivity - 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 potential bias, we include in our regression as an additional control the percentage of US multinationals in the specific four-digit industry ("USA_IND")[16] and its interaction with IT. The interaction was positive but statistically insignificant (see column (6)), and the coefficient on the IT*US interaction remains significant and largely unchanged.

Skills - In column (7), we considered the role of skills. Our main control for labor quality in Table 3 was the inclusion of establishment-specific fixed effects which, so long as labor quality does not change too much over time, should control for the omitted human capital variable. As an alternative, we assume that wages reflect marginal products of workers, so that conditioning on the

[15] 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.

average wage in the establishment is sufficient to control for human capital[17]. 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 insignificant (a coefficient of 0.0365 and a standard error of 0.0403)[18]. Nevertheless, even in the presence of these skills controls, the coefficient on the US ownership and IT interaction remains significantly positive.

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's home base (in our data most foreign multinationals are European if they are not American) and only the most productive firms are able to overcome the 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 (8) though, the European and non-European multinationals are statistically indistinguishable from each other; again, it is the US multinationals that appear to be different.

Unmeasured software inputs for US establishments - Could the US*IT interaction effect 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 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

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[16] The variable is constructed as an average between 1995 and 2003 and is built using the whole ABI population.

[17] 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 John Van Reenen, 1996, on sharing the quasi-rents from new technologies).

[18] As an alternative we matched in education information by aggregating up individual level survey (the Labor Force Survey) into industry by regional cells. In the specifications without fixed effects, there was some evidence for a positive and significant interaction between skills and IT consistent with complementarity between technology and human capital. The US*IT capital interaction remained significant. Including fixed effects, however, renders the skills

of the "global size" of the multinational parent of our establishments. In our UK ABI data, US multinationals 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[19].

We also used a measure of software capital constructed analogously to our main IT capital variable (see Appendix A). 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[20].

So the evidence does not appear to support a large role for unmeasured software inputs driving the superior US productivity of IT. But even if this did play some role, it would still leave the puzzle of why US firms have so much higher software inputs than other multinationals. Commercial software is available globally and is costless to transport. One could argue that US firms have access to a better pool of computer programmers, for example from Silicon Valley, and these develop more advanced in-house software.[21] But even if this were true, market forces would rapidly provide this commercially if it had such a large positive effect on productivity. The model presented below in section IV offers one explanation of why the US may have "moved first" in

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variables and their interactions insignificant (even though US*IT interaction remains significant). Interactions between the US dummy and skills were insignificant in all specifications.

[19] The global size variable was only available for a sub-sample of 3,000 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 0.032 (instead of 0.028 in the baseline) and significant at the 5% level. When we include the global size term the point estimate rose to 0.036 (the point estimate on the global size interaction was -0.0017). We are very grateful to Ralf Martin and Chiara Criscuolo for matching in the data.

[20] The IT hardware capital interaction had a coefficient of 0.0263 with a standard error of 0.0118.

[21] There is, of course, a highly successful European software industry, including firms like SAP that provides global enterprise application software.

organizational change based on lower labor market regulations: it is less clear why this should have been the case for software.

Controlling for endogenous inputs – We also estimated the production functions to control for the endogeneity of factor inputs using the GMM "System" estimator of Blundell and Bond (1998) and the Olley and Pakes (1996) estimator. The full results are shown in Appendix Table A3. 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.[22]

C. US Multinational Takeovers of UK establishments

One possible explanation for our results is that US firms "cherry pick" the best UK establishments, that is, those that already have the highest productivity of IT. This would generate the positive interaction we find but it would be due entirely to selection on unobserved heterogeneity rather than to higher IT productivity caused by US ownership. 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. We considered both US and non-US acquirers. Because of the high rate of merger and acquisition activity in the UK, this is a large sample (4,888 observations)[23].

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 very similar to those for the whole sample in column (2) of Table 3. Unlike the full sample, though, the US and non-US ownership dummies are insignificant, suggesting that the establishments taken over by multinationals are not *ex ante* more productive than those acquired by domestic UK firms.

[22] The coefficient on the US*IT interaction in the GMM system estimator is 0.118 with a standard error of 0.064 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 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.

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 columns (3) and (4) we estimate production function specifications identical to columns (1) and (2) but on the *post-takeover* sample. In column (3), the non-US and US multinational ownership coefficients are positive and significant. Thus, a transfer of ownership from domestic to multinational production is associated with an increase in productivity, particularly for a move to US ownership.

Column (4) is the key result for Table 5. It contains the estimates of a specification that allows the IT capital stock coefficient to vary by ownership status for the *post*-takeover sample. For the post-takeover period we indeed see that the interaction between IT and the US dummy is positive and significant at the 5% level but is insignificant for non-US multinationals. Hence, after a takeover by a US multinational, an establishment enjoys significantly higher IT-related productivity than a statistically similar establishment taken over by a non-US multinational. Note that the inclusion of the US interaction with IT also drives the coefficient on the linear US multinational term into insignificance, suggesting that the main reason for the improved performance of establishments after a US takeover is linked to the increased IT productivity (just as we saw in Table 3 for the whole sample). The fifth column of Table 5 breaks down the post takeover period into the first year after the takeover and the subsequent years (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 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 restructure before obtaining higher productivity gains from IT. Domestic

[23] 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.

and other multinationals again reveal no pattern, with all dummies and interactions remaining insignificant.[24]

The sample in Table 5 includes some firms that are taken over by domestic UK firms, so a stronger test is to drop these 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.

As another cut on the cherry-picking concept we ran linear probability models of US takeovers where the dependent variable was equal to one for establishments taken over by a US firm and otherwise zero. There is no evidence that US firms are more likely to take over establishments that are more IT intensive, or that establishments are increasing their IT intensity (see Appendix Table A4 for full results)[25].

IV. A Simple Theoretical Model of IT and Productivity

In this section, we consider a formal model that potentially can rationalize the macro stylized facts with the results we see in the micro-econometric analysis. We have established that foreign affiliates of US firms appear more productive than affiliates of other multinationals and that this productivity advantage appears to be linked strongly to their use of IT, suggesting an unobserved complementary input that is more abundant in US firms. The literature suggests that one candidate for this complementary input may be the internal organization of US firms. In this section, we build a model in which firms optimally are choosing their organizational form. We show how the predictions from the simple dynamic model are consistent with what we have observed in the micro (and macro) data. First (in sub-section IV.A), we present some survey data to corroborate the idea that US firms have distinctive organizational features. Then (in sub-section IV.B), we

[24] Taken literally, the negative coefficient on the US linear term in column (4) implies a negative US effect for firms with IT capital below approximatively £4,500 ($9,000). Only 0.1% of employment in US establishments is below this threshold.

[25] For example, the marginal effect of (lagged) IT capital in the US takeover equation was 0.0029 with a standard error of 0.0095 (we included controls for size, non-IT intensity, productivity, age and industry dummies – none of which were significant).

sketch the basic model and finally (in sub-section IV.C) we show how some extensions of the model fit other features of the data.

We base this theory on the costs of making organizational changes, as this seems to be consistent with a range of information from case studies and other papers. We readily concede that this is not the only model that could rationalize some of the facts (see sub-section V.B below). However, we think that it is a compelling model fitting the general facts in our empirical study as well as the more general literature. We offer some direct evidence on the model using explicit measures of labor market regulation in sub-section IV.D.

A. The Organization of US firms

Before we present the model it is worth considering some supporting evidence on the different internal organization of US versus European firms. In Figure 3, panels 3a and 3b provide new evidence we collected on the internal organization of over 700 firms in the US and Europe. These show that, on average, firms operating in the US are significantly more decentralized than those operating in Europe.[26] This is also true when looking at US multinationals in Europe compared to non-US multinationals in Europe, with the US firms again being significantly more decentralized. In Panels 3c and 3d we use two other UK surveys, the Workplace Industrial Relations Survey and the Community Innovation Survey, to show that US multinationals also had a higher rate of change in organizational structure going back to the mid-1980s. So, in short, US firms are organized differently, both at home and abroad, and also change organizational structures more swiftly.

B. Basic Model

Consider two representative firms, one in the US and one in the EU. To keep things as simple as possible we assume that technology, prices, and all parameters (except organizational adjustment costs) are common in the two regions. Firms in the US and EU are always optimizing - i.e. European firms are not making systematic “mistakes” by choosing a different organizational form,

[26] Decentralization was measured in the same way as Timothy Bresnahan et al (2002) using questions related to task allocation and pace setting in order to indicate the degree of employee autonomy.

but rather are reacting optimally, given the common economic environment and their different adjustment costs.

The firms produce output (Q) by combining IT (C) inputs, non-IT capital inputs (K) and labor inputs (L), with all other inputs assumed to be zero for simplicity, and defined as follows:

$$Q = A\, C^{\alpha+\sigma O}\, K^{\beta-\sigma O}\, L^{1-\alpha-\beta}$$

Organizational structure is denoted O and is normalized on a scale from zero, from "centralized" production, to one, as modern "decentralized" production[27]. The α, β and σ are production function parameters where $0 < \alpha + \beta < 1$ and $0 < \sigma < \beta$.[28] This specification of the production function is a simple way of capturing the notion that IT and organizational form are complementary as $\sigma > 0$. Second, we have modelled O as having only adjustment costs. There is no "price" of a level of organizational capital, nor is there always a positive marginal product of output with respect to O. This implies that the optimal organizational form will depend on the relative prices of the factor inputs and technology. In earlier time periods the higher relative price of IT meant that firms were more intensive in non-IT capital (K), which gave no incentive to maintain positive levels of O.

The firm sells its output in a market with iso-elastic demand elasticity e (>1) so that $P = BQ^{-1/e}$ where P is the output price and B is a demand shock parameter. Combining the production with this demand function we can write revenue as:

$$PQ = Z(C^{\alpha+\sigma O}\, K^{\beta-\sigma O}\, L^{1-\alpha-\beta})^{1-1/e}$$

[27] We choose centralization/decentralization based on some of the case study evidence concerning the introduction of IT, but to some extent this is just labelling. What matters is that the optimal organizational form changes with IT and that there are costs associated with making this change. The new form of organization will be different in different industries, centralized in some, decentralized in others.

[28] For simplicity, we have not allowed O to enter into the exponent of L. Nothing fundamental would change by allowing this – what matters is the strength of the positive interaction between ln(C) and O is stronger than it is with the other two factors.

where $Z = BA^{1-1/e}$ is an arbitrary constant (since A and B are arbitrary scaling constants). Defining $\psi = \alpha(1 - 1/e)$, $\mu = \beta(1 - 1/e)$, $\gamma = (1-\alpha- \beta)(1 - 1/e)$ and $\lambda = \sigma(1 - 1/e)$, we combine the production function parameters and the demand parameters to re-write revenue as:

$$PQ = C^{\psi+\lambda O}K^{\mu-\lambda O}L^{\gamma}$$

Flow profits then can be defined as:

$$\Pi = C^{\psi+\lambda O}K^{\mu-\lambda O}L^{\gamma} - g(\Delta O) - WL - \rho^{C}C - \rho^{K}K$$

where W is the wage rate, ρ^C is the rental cost of IT capital and ρ^K is the rental cost of non-IT physical capital, $g(\Delta O)$ is the adjustment cost function and Δ is the first difference operator (e.g. $\Delta O_t = O_t - O_{t-1}$). The rental costs of IT and non-IT capital are calculated using the Hall-Jorgenson formula, $\rho_t^x = p_t^x\left(r + \delta^x - [p_{t+1}^x / p_t^x - 1]\right)$ where $x = \{C, K\}$, r is the discount rate, p_t^C and p_t^K are the prices of IT and non-IT capital respectively, and δ^C and δ^K are the depreciation rates of IT and non-IT capital respectively.

As appears to be the case in the data (e.g. Dale Jorgensen, 2001) we assume that the cost of IT investment goods, p_t^C was falling at 15% per year until 1995 and at 25% per year after 1995. Non-IT capital prices and wage rates, in comparison, have been relatively more stable and, for simplicity in the model, are assumed to be constant.

We assume that the organizational adjustment cost term $g(\Delta O)$ has a quadratic component and a fixed disruption component and is borne as a financial cost. Our critical assumption is that the quadratic component is higher in Europe. We show some econometric evidence below that this may reflect tougher labor laws making it expensive to rapidly hire and fire workers in any organizational change. The fixed component of adjustment costs reflects the business disruption from any organizational change[29].

[29] We assume this to be common in Europe and the US for modelling simplicity – allowing this to be higher in the EU would tend to reinforce the qualitative results reported below.

$g(\Delta O) = \omega_m(\Delta O)^2 + \eta PQ|\,\Delta O \neq 0|$ where m = {EU,US} and $\omega_{EU} > \omega_{US}$

Firms maximize their present discounted value of profits. Introducing explicit time sub-scripts and given the structure of the problem, we can write the deterministic value function for a firm as:

$$V_t(O_{t-1}, \rho_t^C) = \max_{C_t, K_t, L_t, O_t} \{C_t^{\psi+\lambda O_t} K_t^{\mu-\lambda O_t} L_t^{\gamma-\lambda O_t} - g(\Delta O_t) - WL_t - \rho_t^C C_t - \rho^K K_t + \frac{1}{1+r} V_{t+1}(O_t, \rho_{t+1}^C)\}$$

Applying standard results from Nancy Stokey, Robert Lucas and Edward Prescott (1988) it can be shown that this value function is continuous, strictly decreasing in ρ_t^C and has an almost everywhere unique solution in C_t, K_t, L_t and O_t. Given any initial conditions for ρ_0^C and O_0, the policy correspondence functions can be used iteratively to solve the time path of C_t, K_t, L_t and O_t .

The long-run qualitative features are reasonably obvious. As the price of IT continues to fall, the steady state optimal organizational form is complete decentralization for all firms (O equal to unity). The interesting question, however, is the transitional dynamics and whether this differs between the US and Europe. Although the model has a well-behaved analytical solution, in order to derive numerical values for any particular set of parameter values we need to use numerical methods.

To do this we define the parameter values as follows: $\alpha = 0.025$ reflecting a 2.5% revenue share for IT; $\beta = 0.3$ reflecting a 30% share for non-IT capital in value added; and $e = 3$ reflecting a 50% mark-up over marginal costs; MC, ($(P\text{-}MC)/MC = 1/(1\text{-}e)$). The parameter λ has no obvious value, so we set this at $\lambda = \psi$ so that full "decentralization" (moving from O equal zero to O equal unity) doubles the value of the marginal product of IT and reduces the value of the marginal product of capital by just under 10%. Picking larger or smaller values of λ while holding the scaling on O, constantly increases or reduces the degree of complementarity between O and λ. The discount rate is set at r = 10%, the IT depreciation rate at δ^C = 30% (Basu et al, 2003), the non-IT depreciation rate of δ^K = 10% and the wage rate is normalized to unity ($W = 1$). The fixed costs of adjustment are set at $\eta = 0.2$ percent of sales selected on the evidence for the fixed costs of capital investments (see Nick Bloom, 2006); given the lack of any direct evidence on the cost of organizational adjustment costs. The quadratic adjustment cost parameter is set so that adjustment costs are four times as high in Europe as in the US (i.e. $\omega_{EU}/\ \omega_{US} = 4$), roughly similar to the differences in the OECD's labor regulation indices in Giuseppe Nicoletti, Stefano Scarpetta and Olivier Boyland (2000). The starting values for p_0^C and O_0 are taken as $p_0^C = 0.066$ and $O_0 = 0$ in 1975, with the price process then exponentially decaying (as outlined above) until 2025 at which point prices stop falling any further, while p^K is normalized to unity. The first and last ten years of the simulation are then discarded to abstract from any initial and terminal restrictions[30].

The model has several intuitive predictions that are consistent with the stylized facts and also contains some novel predictions. First, we trace out the decentralization decisions of firms in Figure 4. We see that US firms start to decentralize first (in the late 1980s) and are on average more decentralized than European firms throughout the period under consideration (the representative EU firm begins to decentralize about nineteen years after the American firm). The US decentralizes first because of its lower adjustment costs[31].

Figure 5 examines the IT capital-labor ratio in logarithms (ln(*C/L*)). Unsurprisingly, this is rising in both regional blocs due to the global fall in IT prices. IT intensity grows at an identical rate in the two regions, until the US starts to decentralize and at this point American firms start to become more IT intensive than European firms. This is because of the complementarity underlying the production function (higher *O* implies higher optimal IT investment). Labor productivity (*Q/L*) is shown in Figure 6. The higher IT intensity translates through into higher labor productivity which accelerates from the mid 1990s.

These findings are consistent with the broad macro facts as discussed earlier. We now discuss extensions to fit the micro data results.

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[30] The code is written in MATLAB available on request from the authors and on http://www.stanford.edu/~nbloom/

[31] The fixed costs of adjustment implies that firms always change *O* in discrete "chunks" and the cost of making any given jump will always be greater for European firms because of their higher quadratic adjustment costs.

C. Extensions to the basic model

Multinationals - We now consider multinational companies who operate several establishments, at least one of which is on foreign soil. We extend the modelling framework to consider an additional cost in maintaining different organizational forms in different establishments. Multinationals appear to operate globally similar management and organizational structures (e.g. Christopher Bartlett and Sumantra Ghoshal, 1999) as this makes it much easier to integrate senior managers, human resource systems, software, etc. At different ends of the skills spectrum both McKinsey and McDonalds are recognizably similar in Cambridge, Massachusetts and Cambridge, England. To formalize this we allow an additional quadratic adjustment cost which has to be born if there is a difference between the organization of the establishment i (O_i) and its parent (O^{PARENT}), $\phi(O_i - O^{PARENT})^2(PQ)_i$.

Consider the case of a US firm purchasing a European establishment (in the period after US firms have started to decentralize). The purchased establishment will start to become more decentralized than identical establishments owned by domestic firms (or European multinationals operating solely in Europe). It will also start increasing IT intensity and labor productivity at a faster rate than European owned establishments. The degree to which the establishment resembles its American parent will depend on the size of ϕ relative to the adjustment cost differential ω_{EU}/ω_{US}. The larger is ϕ the more quickly the establishment will start to resemble its US parent[32]. Note that the presence of adjustment costs, however, suggests that this change will not be immediate so after an American firm takes over a European establishment the IT intensity and productivity will be, for some periods, below that of longer-established US affiliates.

The middle line in Figure 7 shows the simulation results for a hypothetical British establishment taken over by a US multinational in 2003. The calibration assumes ϕ=1. Under this scenario, the taken over firm initially converges to within 0.1 point of the organizational structure of the US parent company five years after the take over year.

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[32] This raises questions about the reasons for takeovers. Why should a US firm ever take over a European plant if it has to bear greater adjustment costs than a European multinational? One reason is that the US parent may have higher TFP from some firm-specific advantage that it can diffuse to the affiliate (such as better technology or management). This is not modelled here for parsimony, but could easily be included.

The model now matches the qualitative features of the data. When US firms take over European establishments we observe an increase in labor productivity and a higher coefficient on IT in the production function that accounts for all of the US establishments' productivity differential. Furthermore, this process does not happen immediately as there are adjustment costs – this is what we observed in the dynamic specifications when looking at takeovers (the last two columns of Table 5)[33].

Industry Heterogeneity - The fall in the price of IT has opened up the possibility of IT-enabled innovations to a greater extent in some industries than others. George Baker and Thomas Hubbard (2004) for example describe how on-board computers have altered business methods in the trucking industry. In our model we can capture this by allowing a different degree of complementarity between IT and organization in some industries than others (i.e. a higher σ). Those sectors that we have labelled (following Kevin Stiroh, 2002) "IT intensive" would have a higher σ and therefore follow the patterns analyzed above. Other sectors with low σ would not follow these patterns and for these industries US and EU productivity experience should be similar as both regions enjoy the benefits of faster productivity growth. This is what we find in the micro data – the differences between US and EU firms are much stronger in the sectors than intensively use IT.

Permanent Differences in Organizational/Management Quality - An alternative model to the one we have presented could be one were US firms have *always* been better managed/organized than European firms *and* that this better management is complementary with IT. This could be due to tougher competition, culture, less family run firms, etc. Under this model "*O*" would enter as an additional factor input in the production function with an exogenously lower price in the US than in Europe. For example,

$$Q = A\, O^{\chi} C^{\alpha+\sigma O}\, K^{\beta - \sigma O}\, L^{1-\alpha-\beta-\chi}$$

[33] An alternative model close to that of Andrew Atkeson and Patrick Kehoe (2006) would be to consider organizational capital based on learning about IT. If the US started learning first (again, possibly because of lower adjustment costs) and organizational capital can be transferred across countries within the multinational this would also generate the results we see in the data.

This set-up would rationalize most of the findings presented in the paper except one – that the linear US multinational dummy was insignificantly different from zero once we have accounted for the higher coefficient on IT capital for US firms (see Table 3 column (3) and Table 5 column (4)). Thus, we conclude that the results on grounds of parsimony and consistency imply $\sigma > 0$ and $\chi = 0$.

Adjustment Costs for IT capital and TFP measurement - For simplicity we abstracted away from adjustment costs in IT capital and other factors of production. Consider a simple extension of the model where we also have quadratic adjustment costs in IT capital, but assume that these are the same across countries. The implications of such a model are discussed formally in Appendix B. Obviously this will slow down the change in IT and organization, O, but the qualitative findings from the theory discussed above will still go through[34]. One difference, however, is that under this model *measured* TFP will appear to grow as IT is accumulated, even though actual TFP growth is stable. Under the baseline model the share of IT capital in revenue is still equal to $\psi + \lambda O$ in every period so the "weight" on IT capital in the conventionally measured TFP formula will be correct. Once we allow for adjustment costs in IT, by contrast, the empirical share of IT in revenues will be below its steady state level. This will mean that measured TFP will exceed actual TFP (A). The prediction from this extension to the basic model is that a regression of measured TFP growth on IT capital growth will generate a positive coefficient on IT. We calculated measured TFP growth as a residual using factor shares as weights and regressed this on the growth of IT capital stock, ownership dummies, a multi-plant dummy, age and year dummies. The IT capital stock coefficient was 0.0056 with a standard error of 0.0023. As with Erik Brynjolfsson and Lorin Hitt (2003), the coefficient on IT rose as we considered longer differenced specifications (e.g. it was 0.0105 for the 400 establishments where we could construct four year differences, approximately equal to the share of IT in total revenues). So this is consistent with the extension to the model.

The model with IT adjustment costs also predicts that during the initial period when the US is adjusting its organizations and rapidly accumulating IT, the correlation of measured TFP growth and IT capital growth will be stronger for US firms than EU firms. In our TFP regressions including an additional US interaction with IT growth was positive, but never significant at the 5% level. This lack of significance may be because IT adjustment costs are also higher in the EU than the US. If this is the case the "wedge" between production function parameters and IT factor share could be larger in Europe, with the coefficient on the US interaction becoming ambiguous (see Appendix B for more theoretical details).

D. A little "direct evidence" on the model

The attraction of our model is that it assumes fully rational behavior by firms, it is parsimonious and it is able to match a range of the micro and macro stylized facts discussed in the paper.[35] There are other models that may also be able to do the same, however. So in this sub-section we consider some more direct evidence that measures of institutional inflexibility that generate differential adjustment costs (like labor market regulations) might be a key difference.

Christopher Gust and Jaime Marquez (2004) show that an employment protection index is negatively correlated with country-wide IT expenditure as a share of GDP for thirteen OECD countries. Our model suggests that these regulations are partially "exported" to the multinational's establishments in the UK (through the desire to keep a globally similar organization within the multinational). To examine this idea we match in the World Bank's measure of the flexibility of labor regulation to the establishments in our dataset by country of ownership, which is shown in Figure 8. So, for example, the Germany data point plots the labor regulation index in Germany against the IT intensity for establishments owned by German multinationals. We find that the IT intensity of multinational affiliates is higher in the UK when labor market flexibility is greater in their home country (the correlation coefficient between IT intensity and labor market flexibility is 0.0579 and is significant at the 1% level)[36].

[34] For an analysis of mixed fixed and quadratic adjustment costs with two factors see Nick Bloom, Steven Bond and John Van Reenen (2006) or Nick Bloom (2006).

[35] Gustavo Crespi, Chiara Criscuolo and Jonathan Haskel (2006) and Laura Abramovsky and Rachel Griffith (2007) present some other evidence related to our organization-based model

[36] When we drop all the observations from US multinationals the correlation coefficient is 0.0351 (significant at the 10% level).

More ambitiously, Table 6 presents regressions based on the multinational-only sample where we include interactions with labor market regulation of the multinational's home country and the establishment's IT capital. The first column includes only the standard production function controls (i.e. it drops the ownership variables) and includes the index of the flexibility of labor regulation. The coefficient on the flexibility index is positive and significant suggesting higher TFP for multinationals whose home country has more flexible labor markets. The next column repeats the baseline specification of column (1) in Table 4 and shows that the standard results hold on this sample. In particular, the interaction between the US dummy and IT capital is significantly positive. In column (3) we include instead the interaction between labor regulation (in the multinational's home country) and IT. The coefficient on this interaction is also significantly positive, consistent with the theory: lighter regulations in the establishment's home country appear to be associated with greater productivity of IT in the UK. We repeat the specifications of columns (2) and (3) including fixed effects in columns (4) and (5) and show the robustness of the results. Ideally, we would like to show that the US interaction is driven to insignificance by on the interaction of IT with the labor regulation index. This is not the case; in column (6) when we include both interactions these are positive but individually insignificant[37].

Overall we take these results as supportive of our basic model. It appears to be the *flexibility* of the US economy in adapting to the challenges of major changes (such as the IT revolution) that gives it productivity advantage, not its permanent superiority in all states of the world.

V. Conclusions

Using a large and original establishment level panel dataset we find robust evidence that IT has a positive and significant correlation with productivity even after controlling for many factors, including establishment fixed effects. Our most novel result, however, is that we can account for the US multinational advantage in productivity by the higher productivity of their IT capital. Furthermore, the stronger association of IT with productivity for US firms is confined to the same "IT using intensive" industries that largely accounted for the US "productivity miracle" since the mid 1990s. These results were robust to examining establishments that were taken over by other

[37] The interactions are jointly significant at the 10% level.

firms: US firms who took over establishments have significantly greater IT productivity relative to non-US multinationals who took over statistically similar establishments.

US firms appear to obtain significantly higher productivity from their IT capital than other multinational establishments (and domestic establishments), even in the context of a UK environment. This suggests that part of the IT-related productivity gains underlying the recent US "productivity miracle" may be related to US firm characteristics rather than simply the natural advantage (geographical, institutional or otherwise) of being located in the US environment. We rationalized the macro and micro stylized facts with a simple model that combines the importance of internal organization and environmental factors. Firms in the US and Europe optimally choose their organization and factor inputs like IT with identical production functions and face the same rapid falls in IT prices. The lower adjustment costs for US firms (possibly due to more flexible labor regulations) allows them to re-organize more swiftly to take advantage of the new IT enabled innovations. Coupled with the idea that multinationals face costs of maintaining different organizational forms in different countries this model delivers predictions consistent with our results.

There are many outstanding issues and research questions. First, according to our model the US is not always superior. Rather, it is the *flexibility* of the US economy in adapting to major changes (such as the IT revolution) that gives it a temporary productivity advantage. This model predicts that Europe will start to realize enhanced IT-enabled productivity growth over the next few years and resume the catching up process with the US that was observed until the mid 1990s. There may be some evidence of this occurring as Europe's productivity growth in 2006 picked up as America's slowed slightly[38]. Of course, if the world economy has moved into a stage of development where technology-related turbulence is inherently greater, then the more flexible US will retain an edge over Europe for the foreseeable future.

Second, we would like to confront our model more directly with measures of organization and IT. This paper has looked at the consequences of organizational change on "standard" observables

[38] *The Economist*, April 14th 2007, Economic Focus "Making Less With More"

(although IT is also rarely observed at the micro level). A follow-up study to Nick Bloom and John Van Reenen (2006) has collected data from several thousand firms on internal organization structure, management and IT across eleven countries. We can use this data to directly examine some of the model's implications.

Thirdly, we would like to understand the determinants of decentralization and other organizational design features of firms in much more detail. What are the other factors determining how and when firms change their structure? Daron Acemoglu et al (2006) make a start in this direction.

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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APPENDIX A: DATA AND ADDITIONAL RESULTS

A1 ESTABLISHMENT DATASET: 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 (including manufacturing) 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 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 intermediate inputs – energy, materials, etc.). Value added is constructed as the sum of turnover, variation of total stocks, work of capital nature by own staff, insurance claims received minus purchases. The construction of the IT and non-IT capital stocks are described in the next section. 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 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 are compiled at the reporting unit level, and 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.[39] 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.

A2.1 Data Sources

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 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)."

[39] 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.

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. Of these 32,000 companies, all establishments with over 300 employees are selected each 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[40]. 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[41] 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 is:

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

where I_t^h represents real investment of asset type h (e.g. computer hardware, I_t^C) and δ_t^h is the asset specific depreciation rate. To construct real investment we deflate nominal investments using the economy-wide (asset specific) hedonic price indices for software and 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).

<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>

[40] 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.

[41] 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.

In order to apply the PIM methodology, we need to approximate a starting value to start the recursion. We apply a similar methodology as the one devised by Martin (2005) to construct establishment level capital stocks in the ARD. For each firm, we first build 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 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: $C_{i0} = (I^C_{it} / I^C_{jt})\mathrm{C}_{jt} \ \forall \ i \in j$ 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.

<u>Depreciation</u>
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.

<u>Across-Survey Stocks</u>
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 the 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 provenience 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 currently 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 <u>not</u> 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.

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 extreme values 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[42].

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)[43]. 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[44]. 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.

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). Labor accounts for 31% of revenues and materials 58% on average. IT capital is estimated at 1% of revenues (non-IT capital is 10%).

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. Unsurprisingly, across all establishments the IT capital-output ratio is much

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[42] 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.

[43] 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.

[44] 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. See Griffith et al (2004) for more details on the methodology.

higher in the IT intensive industries compared to other sectors (3% compared to 2%). More interestingly, US multinationals have a higher IT capital-output ratio than non-US multinationals only in the IT intensive sectors (4% compared to 3%). In the other sectors US and non-US multinationals have a similar IT-output ratio (3% in each). The levels of IT capital show much higher values for US establishments than non-US multinationals (especially in the IT intensive sectors).

A8 ADDITIONAL RESULTS

Table A3 contains alternative econometric estimates of the production function allowing for endogenous factor inputs. First, in column (1) we present results using the Blundell- Bond (1998) system GMM estimator. We have to restrict the sample to firms where we have at least four continuous years of information on all variables which, given our short time series and sampling frame, severely reduces the sample size (this is also the reason why we use all sectors, not just the IT intensive sectors). Even on this sub-sample we are still able to identify a significant interaction effect between IT capital and the US dummy variable. The coefficient on IT for US firms is significantly different from the IT coefficient on non-US firms at the 10% level. 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 (2), non-US multinationals in column (3) and UK domestic firms in column (4). The IT coefficient is twice as large for US multinationals as it is for non-US multinationals, which is consistent with our earlier findings. The standard errors are also large, however, due to the smaller sample size, so we are not able to reject the null that the coefficients are the same.

Table A4 estimates takeover regressions as a function of lagged covariates. The sample is of those establishments who were at some point taken over by another firm. In columns (1) and (2) the dependent variable is equal to one if the establishment was taken over by a US multinational and zero otherwise (i.e. if it was taken over by a non-US multinational or a domestic UK firm). In columns (3) and (4) we drop the takeovers by UK domestic firms so that the dependent variable is equal to one if the establishment was taken over by a US multinational and zero otherwise (i.e. if it was taken over by a non-US multinational). Columns (1) and (3) examine whether more IT intensive establishments were more likely to be taken over by a US multinational. Columns (2) and (4) examine whether establishments which were growing more IT intensive were more likely to be taken over by a US multinational. There seems to be no significant correlation between lagged IT levels or growth and the probability of being taken over by a US firm.

APPENDIX B: TFP DYNAMICS AND ADJUSTMENT COSTS FOR IT CAPITAL

In this Appendix we consider the extension to the model where we allow adjustment costs in IT capital and discuss the implied dynamics of measured TFP. Note that all the main implications from the basic model go through in terms of the implications for labor productivity so we do not repeat these again. In particular, the production function is the same so we expect a larger coefficient on IT for US firms in the production function. The difference in the theory predictions when allowing for IT adjustment costs lies in the analysis of measured TFP growth.

B1. MODEL BASICS

Figure B1 shows there are five distinct regimes defined by how organizations are changing. The exact years will differ from the baseline model because IT adjustment costs slow down adjustment, but the qualitative features remain the same. In Regimes 1 and 5 neither the EU nor the US is adjusting O, so that $O = 0$ in the earliest regime (1) and $O = 1$ in the last regime (5). The interesting changes are the three "transition" regimes (2 through 4). In Regime 2 US firms are adjusting their organizations EU firms are not. In Regime 3 both EU and US are adjusting and in Regime 4 only the EU is adjusting.

If we consider the growth of the IT stock (Δc, noting that $c = \log(C)$) this will depend on the target level of c and on the adjustment costs in c, which we now assume to be twice-differentiable, minimized at zero and convex (for example quadratic). EU growth of c will be slower as growth of O is slower. As a result in Regime 2 US Δc will be faster. In Regimes 3 and 4 US Δc will initially be faster, but at some point there will be a "crossing point" when Δc is equal between the US and the EU. In Regime 5 EU Δc will be faster as it catches up with the US.

B2. TFP MEASUREMENT

We can defined the change in measured TFP ($\Delta\text{TFP}^{\text{M}}$) as

$$\begin{aligned} \Delta\text{TFP}^{\text{M}} &= \Delta\text{y} - \text{s}_\text{c}\Delta\text{c} - \text{s}_\text{k}\Delta\text{k} - \text{s}_l\Delta l \\ &= \Delta a + (\alpha_\text{c}\Delta\text{c} + \alpha_\text{k}\Delta\text{k} + \alpha_l\Delta l) - (s_\text{c}\Delta\text{c} + s_\text{k}\Delta\text{k} + s_l\Delta l) \\ &= \Delta a + (\alpha_\text{c} - s_\text{c})\Delta\text{c} - (\alpha_\text{k} - s_\text{k})\Delta\text{k} - (\alpha_l - s_l)\Delta l \end{aligned} \quad \text{(B1)}$$

where α_x is the elasticity of revenue with respect to factor x, s_x is the share of factor x in revenues, Y is revenue (PQ) and Δa is actual TFP growth. So using the results of Section IV $\alpha_c = \psi + \lambda O$, $\alpha_k = \mu - \lambda O$ and $\alpha_l = \gamma$ (we are ignoring time subscripts). Measured TFP will differ from actual TFP if the shares are different from the revenue function "coefficients". In all our models we assume that actual TFP growth is zero ($\Delta a = 0$). In the basic model with only organizational adjustment costs $\Delta\text{TFP}^{\text{M}} = 0$ as all revenue function coefficients equal their factor shares (e.g. $\alpha_c = s_c$). If we introduce IT adjustment costs into the model this equality still holds for non-IT capital and labor as they have no adjustment costs. But for IT the factor share will not longer equal the revenue function coefficient. Furthermore, since in the model IT is always rising as an input share, actual levels of IT will always be below the target levels of IT, so that $\alpha_c > s_c$. Thus, with the addition of IT adjustment costs we obtain the "wedge" between actual and measured TFP:

$$\Delta\text{TFP}^{\text{M}} = (\alpha_\text{c} - s_\text{c})\Delta\text{c} \quad \text{(B2)}$$

We can characterize the magnitude of the bias if we place more structure on the problem.[45] Assume IT adjustment costs take the form $G(C_t, C_{t-1}) = \theta_C C_{t-1}(C_t/C_{t-1} - 1)^2$, i.e. standard homogeneous quadratic adjustment costs ignoring depreciation. Then C is also a state variable, so that the Bellman equation is

$$\text{V}(\text{C}_{t-1}, \text{O}_{t-1}, \rho_t^\text{C}) = \max_{\text{C}_t, \text{O}_t, \text{L}_t, \text{K}_t} \left\{ \begin{aligned} &\text{Y}(\text{C}_t, \text{O}_t, \text{L}_t, \text{K}_t) - \rho_t^\text{C}\text{C}_t - \text{WL}_t - \rho^\text{K}\text{K}_t \\ &- \theta_C \text{C}_{t-1}(\text{C}_t/\text{C}_{t-1} - 1)^2 - \omega_m(\Delta\text{O}_t)^2 + \frac{1}{1+r}\text{V}(\text{C}_t, \text{O}_t, \rho_{t+1}^\text{C}) \end{aligned} \right\} \quad \text{(B3)}$$

[45] For simplicity we abstract away from the fixed adjustment costs for O.

The first order condition for C is:

$$\alpha_c \frac{Y_t}{C_t} - \rho_t^C - 2\theta_C (C_t / C_{t-1} - 1) + \frac{1}{1+r} \frac{\partial V_t}{\partial C_t} = 0 \quad \text{(B4)}$$

Now if C is always increasing then $\alpha_c Y_t/C_t - \rho^C_t > 0$, i.e. the instantaneous returns to C are positive as the firm has too little C from a current state perspective. Rearranging equation (B4) thus implies:

$$\alpha_c - \frac{\rho_t^C C_t}{Y_t} = \frac{C_t}{Y_t} \left(2\theta_C \Delta c_t - \frac{1}{1+r} \frac{\partial V_t}{\partial C_t} \right) > 0 \quad \text{(B5)}$$

The right hand side of equation (B5) is positive and gives the magnitude of the "wedge" between the production function parameters and the observed factor shares. The size of the wedge will determine the observed TFP growth.

B3. EMPIRICAL IMPLICATIONS

We can now derive a set of empirical implications for TFP dynamics. We consider a time-series regression[46] of measured TFP growth on the change in all factor inputs, but in particular on IT capital growth.

(1) In all periods the coefficient on the change in labor and capital will be zero. In all periods we will obtain a positive coefficient on the growth of the IT stock, Δc, from equation (B2).

(2) The size of the coefficient on Δc will vary by ownership type over time. First, consider the early period (Regime 1) before either the US or EU started adjusting O, during which time the gap between actual and desired IT will be equal for the EU and the US. Consequently the interaction with IT growth and ownership in the TFP regression will be zero. Next, consider the initial period of adjustment in O by the US firms (Regime 2) when US firms begin adjusting O upwards and European firms are not changing O. Over this period the "wedge" between α_c and the observed factors share, s_c, will be higher for US firms (Δc is higher), so that their IT coefficient in the measured TFP equation will be higher than the European coefficient. Thirdly, consider the final period of adjustment (Regime 5) when the US has completely changed organizational form ($O = 1$) while Europe is still changing. Over this period European firms will be increasing their IT stocks faster than US firms, so that now the EU wedge, and therefore EU coefficient on Δc in equation (B2), will be higher. In the middle periods (Regimes 3 and 4) the prediction is ambiguous as the size of the wedge depends on the growth of the IT stock and level of $\partial V/\partial C$, which could be higher or lower in the EU.

(3) Finally, relax the assumption that the adjustment costs in IT capital are the same in the US and EU. Imagine that these adjustment costs are higher in the EU[47] (our baseline model assumed that organizational adjustment costs were higher in the EU but everything else was the same). In this case the relationship between US "wedge" ($\alpha_C^{US} - s_C^{US}$) and the EU "wedge" ($\alpha_C^{EU} - s_C^{EU}$) will be ambiguous. The US will be adjusting its level of IT faster than the EU (at least until the start of Regime 3) implying a larger US wedge between actual and desired IT input shares. But the EU will have higher adjustment costs for any given change of IT implying a higher EU wedge. Which effect dominates will depend on the relative magnitudes of the IT and organizational adjustment costs and the period of adjustment. Hence, allowing for asymmetric IT and organizational adjustment costs makes the coefficient on the interaction of IT and ownership in the TFP regression ambiguous even in Regime 2. This may be the reason why the interaction of Δc and US ownership in the TFP growth equation is insignificant (although positive) in our data.

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[46] By "time series regression" we mean data generated from observations of "representative" EU and US firms (or the economy-wide aggregates). In the actual data we use there will also be some idiosyncratic shocks causing heterogeneity around these averages that we are not considering for now.

[47] We can think of the non-organizational adjustment costs for IT as things like the absolute change in firm size (holding organizational structure constant), the physical adjustment of buildings and equipment, and the resale of loss of old-IT etc.

TABLE 1 - DESCRIPTIVE STATISTICS BROKEN DOWN BY MULTINATIONAL STATUS

(Normalized to 100 for the three digit industry-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 – DIFFERENCE IN DIFFERENCES

Labor Productivity in establishments owned by US multinationals and by non-US multinationals

	High IT intensity Establishments	Low IT intensity Establishments	Diff
US Multinationals	3.893	3.557	**0.336*****
	(0.742)	(0.698)	**(0.043)**
	1,076	729	
Other Multinationals	3.711	3.473	**0.238*****
	(0.756)	(0.664)	**(0.022)**
	4,014	2,827	
Diff	**0.182*****	**0.084****	
	(0.036)	**(0.037)**	
Diff in Diffs			**0.098****
			(0.048)

Notes: Productivity is measured as ln(Value Added per Employee). "High IT intensity establishments" are observations where the ratio of IT capital to employment (demeaned by the three-digit industry and year average) is greater than the median. 8,646 Observations; only multinationals considered. Standard errors are clustered by establishment.

TABLE 3 – ESTIMATES OF THE PRODUCTION FUNCTION ALLOWING THE I.T. COEFFICIENT TO DIFFER BY OWNERSHIP STATUS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable: ln(Output)	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**
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) **USA ownership*IT capital**	-	-	0.0086* (0.0048)	0.0196** (0.0078)	0.0033 (0.0061)	0.0049 (0.0064)	0.0278*** (0.0105)	-0.0085 (0.0071)
MNE*ln(C) **Non-US multinational *IT capital**	-	-	0.0001 (0.0030)	-0.0030 (0.0041)	0.0037 (0.0042)	0.0042 (0.0034)	0.0055 (0.0052)	0.0034 (0.0044)
Ln(C) **IT capital**	-	0.0457*** (0.0024)	0.0449*** (0.0026)	0.0399*** (0.0036)	0.0472*** (0.0035)	0.0146*** (0.0028)	0.0114** (0.0047)	0.0150*** (0.0034)
Ln(M) **Materials**	0.5575*** (0.0084)	0.5474*** (0.0083)	0.5475*** (0.0083)	0.6212*** (0.0142)	0.5065*** (0.0104)	0.4032*** (0.0178)	0.5020*** (0.0280)	0.3605*** (0.0209)
Ln(K) **Non-IT Capital**	0.1388*** (0.0071)	0.1268*** (0.0068)	0.1268*** (0.0068)	0.1108*** (0.0094)	0.1458*** (0.0092)	0.0902*** (0.0159)	0.1064*** (0.0229)	0.0664*** (0.0209)
Ln(L) **Labor**	0.2985*** (0.0062)	0.2690*** (0.0062)	0.2688*** (0.0062)	0.2179*** (0.0102)	0.2869*** (0.0076)	0.2917*** (0.0173)	0.2475*** (0.0326)	0.3108*** (0.0195)
USA **USA Ownership**	0.0712*** (0.0140)	0.0642*** (0.0135)	0.0151 (0.0277)	-0.0824* (0.0438)	0.0641* (0.0354)	-0.0110 (0.0424)	-0.1355* (0.0768)	0.0472 (0.0405)
MNE **Non-US multinational**	0.0392*** (0.0079)	0.0339*** (0.0078)	0.0338** (0.0161)	0.0325 (0.0241)	0.0194 (0.0214)	-0.0162 (0.0198)	-0.0160 (0.0327)	-0.0204 (0.0254)
Observations	21,746	21,746	21,746	7,784	13,962	21,746	7,784	13,962
Test USA*ln(C)=MNE*ln(C), p-value		-	0.0944	0.0048	0.9614	0.9208	0.0403	0.1340
Test USA=MNE, p-value	0.0206	0.0203	0.5198	0.0108	0.2296	0.9072	0.1227	0.9665

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. 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)=MNE*ln(C)" is test of whether the coefficient on USA*ln(C) is significantly different from the coefficient on MNE*ln(C), etc.

TABLE 4 – ROBUSTNESS TESTS OF THE PRODUCTION FUNCTION

Experiment	(1) Baseline Specification	(2) Value Added	(3) All Inputs Interacted with US and MNE	(4) Alternative IT measure	(5) Full "Translog" interactions	(6) % USA in 4 digit industry	(7) Wages as a proxy for skills	(8) EU and Non EU MNEs
Dependent var: ln(Output)	**ln(Q)**	**ln(VA)**	**ln(Q)**	**ln(Q)**	**Ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**
USA*ln(C)	0.0278***	0.0604**	0.0328**	0.0711**	0.0268***	0.0270**	0.0208**	0.0283***
USA ownership*IT capital	(0.0105)	(0.0245)	(0.0141)	(0.0294)	(0.0102)	(0.0105)	(0.0096)	(0.0105)
MNE*ln(C)	0.0055	-0.0070	0.0002	0.0056	0.0028	0.0050	0.0021	-
Non-US multinational*IT capital	(0.0052)	(0.0142)	(0.0065)	(0.0131)	(0.0050)	(0.0054)	(0.0047)	
Ln(C)	0.0114**	0.0263**	0.0126**	0.0285***	0.0327	0.0090*	-0.0227	0.0114**
IT capital	(0.0047)	(0.0106)	(0.0050)	(0.0083)	(0.0463)	(0.0048)	(0.0163)	(0.0047)
Ln(M)	0.5020***	-	0.4925***	0.6390***	0.2779	0.5017***	0.4455***	0.5023***
Materials	(0.0280)		(0.0312)	(0.0195)	(0.2225)	(0.0279)	(0.0296)	(0.0278)
Ln(K)	0.1064***	0.2157***	0.1075***	0.1390***	0.2686**	0.1070***	0.0767***	0.1063***
Non-IT Capital	(0.0229)	(0.0546)	(0.0228)	(0.0170)	(0.1255)	(0.0230)	(0.0216)	(0.0229)
Ln(L)	0.2475***	0.4835***	0.2530***	0.2171***	0.3002	0.2472***	0.3958***	0.2472***
Labor	(0.0326)	(0.0571)	(0.0343)	(0.0140)	(0.2095)	(0.0329)	(0.0361)	(0.0325)
USA	-0.1355*	-0.3552**	-0.2734	-0.0125	-0.1419**	-0.1323*	-0.0967	-0.1374*
USA Ownership	(0.0768)	(0.1492)	(0.2578)	(0.1113)	(0.0683)	(0.0763)	(0.0739)	(0.0769)
MNE	-0.0160	0.0733	-0.0489	-0.0087	-0.0112	-0.0148	-0.0010	-
Non-US multinational	(0.0327)	(0.0855)	(0.1687)	(0.0758)	(0.0322)	(0.0334)	(0.0309)	
USA*ln(M)	-	-	0.0335	-	-	-	-	-
USA ownership*materials			(0.0376)					
MNE*ln(M)	-	-	0.0080	-	-	-	-	-
Non-US multinational *materials			(0.0235)					
USA*ln(K)	-	-	0.0242	-	-	-	-	-
USA ownership*Non IT capital			(0.0368)					
MNE*ln(K)	-	-	-0.0142	-	-	-	-	-
Non-US multinational *Non IT capital			(0.0134)					
USA*ln(L)	-	-	-0.0767	-	-	-	-	-
USA ownership*Employment			(0.0497)					
MNE*ln(L)	-	-	0.0193	-	-	-	-	-
Non-US multinational *Employment			(0.0239)					
USA_IND	-	-	-	-	-	0.9194	-	-
[% of US Multinationals in industry]						(2.3378)		
USA_IND*ln(C)	-	-	-	-	-	0.3607	-	-
[% of US Multinationals in industry]*IT capital						(0.4119)		

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(Wage) **Average wage**	-	-	-	-	-	-	0.2137*** (0.0407)	-
ln(Wage)*ln(C) **Average Wage*IT capital**	-	-	-	-	-	-	0.0109* (0.0056)	-
EU MNE **EU ownership**	-	-	-	-	-	-	-	-0.0328 (0.0354)
NON-EU MNE **Non EU-NON USA Ownership**	-	-	-	-	-	-	-	-0.0066 (0.0910)
EU MNE*ln(C) **EU ownership*IT Capital**	-	-	-	-	-	-	-	0.0065 (0.0051)
NON EU MNE*ln(C) **Non EU-NON USA Ownership*IT capital**	-	-	-	-	-	-	-	-0.0079 (0.0158)
Observations	7,784	7,784	7,784	2,196	7,784	7,784	7,780	7,784
Test USA*ln(C)=MNE*ln(C), p-value	0.0403	0.0122	0.0224	0.0122	0.0244	0.0288	0.0575	-
Test USA=MNE, p-value	0.1227	0.007	0.3618	0.007	0.0602	0.1288	0.1982	-
Test on joint significance of all the interaction terms, excluding IT interactions (p-value)	-	-	0.3288	-	-	-	-	-
Test on joint significance of all the US interaction terms, excluding IT (p-value}	-	-	0.4837	-	-	-	-	-
Test on all the other MNE's interaction terms, excluding IT (p-value)	-	-	0.3838	-	-	-	-	-
Test on additional "translog" terms, p-value	-	-	-	-	0.0000	-	-	-
Test USA=EU, p-value	-	-	-	-	-	-	-	0.2072
Test USA=NON EU, p-value	-	-	-	-	-	-	-	0.2500
Test USA*ln(C)=EU*ln(C), p-value	-	-	-	-	-	-	-	0.0457
Test USA*ln(C)=NON EU*ln(C), p-value	-	-	-	-	-	-	-	0.0511

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns is the log of gross output. All columns are for the sectors that use IT intensively only. The time period is 1995-2003. The estimation method in all columns is OLS. All columns except (4) 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 (except column (4)). The IT measure in column (4) is the log(number of people using computers). We also include interactions of the US dummy (and the MNE dummy) with ln(labor) in this column. 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. Column (6) includes the percentage of non-US multinationals in the establishment's four digit industry. "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), etc.

TABLE 5 - 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)	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**
USA*ln(C)	-	-0.0322	-	0.0224**	-	-
USA Takeover*IT capital		(0.0277)		(0.0102)		
MNE*ln(C)	-	-0.0159	-	0.0031	-	-
		(0.0118)		(0.0079)		
Non-US multinational Takeover*IT capital						
USA	-0.0031	0.1634	0.0827***	-0.0345	-	-
USA Takeover	(0.0335)	(0.1357)	(0.0227)	(0.0550)		
MNE	-0.0221	0.0572	0.0539***	0.0412	-	-
Non-US multinational Takeover	(0.0226)	(0.0598)	(0.0188)	(0.0380)		
USA*ln(C) one year	-	-	-	-	0.0095	-0.0103
after takeover					(0.0149)	(0.0176)
USA*ln(C) two and	-	-	-	-	0.0274**	0.0315*
three years after takeover					(0.0115)	(0.0170)
MNE*ln(C) one year	-	-	-	-	0.0003	-
After takeover					(0.0109)	
MNE*ln(C) two and	-	-	-	-	0.0041	-
three years after takeover					(0.0085)	
Ln(C)	0.0582***	0.0593***	0.0495***	0.0460***	0.0459***	0.0806***
IT capital	(0.0092)	(0.0097)	(0.0061)	(0.0067)	(0.0067)	(0.0169)
Ln(M)	0.4949***	0.4950***	0.5276***	0.5286***	0.5287***	0.5913***
Materials	(0.0308)	(0.0306)	(0.0212)	(0.0211)	(0.0210)	(0.0448)
Ln(K)	0.1592***	0.1591***	0.1145***	0.1145***	0.1142***	0.0311
Non-IT Capital	(0.0256)	(0.0254)	(0.0162)	(0.0162)	(0.0161)	(0.0333)
Ln(L)	0.2723***	0.2727***	0.2927***	0.2918***	0.2924***	0.2480***
Labor	(0.0184)	(0.0185)	(0.0146)	(0.0146)	(0.0145)	(0.0367)
USA one year	-	-	-	-	0.0591	0.0466
after takeover					(0.0720)	(0.1007)
USA two and three	-	-	-	-	-0.0713	-0.1507
years after takeover					(0.0641)	(0.0951)
MNE one year	-	-	-	-	0.0230	-
after takeover					(0.0534)	
MNE two and three	-	-	-	-	0.0489	-
Years after takeover					(0.0418)	
Observations	1,422	1,422	3,466	3,466	3,466	692
Test USA*ln(C) = MNE*ln(C), p-value	-	0.5564	-	0.0880	-	-
Test USA = MNE, p-value	0.5900	0.4430	0.2216	0.2104	-	-
Test USA one year = MNE one year, p-value	-	-	-	-	0.6743	-
Test USA two plus years = MNE two plus years, p-value	-	-	-	-	0.0894	-
Test (USA one year)*ln(C) = (MNE one year)*ln(C), p-value	-	-	-	-	0.6044	-
Test (USA two plus years)*ln(C) = (MNE two plus years)*ln(C), p-value	-	-	-	-	0.0691	-

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The sample is of all establishments who were taken over at some point (the omitted base is "domestic takeovers" - UK firms taking over other UK firms). The dependent variable in all columns is the log of gross output. 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 three digit industry dummies interacted with time trends and as additional controls: age, region dummies, a multi-establishment group dummy and an IT survey dummy. "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) , etc.

TABLE 6 - IT AND LABOR MARKET REGULATION

	(1)	(2)	(3)	(4)	(5)	(6)
Fixed Effects	**NO**	**NO**	**NO**	**YES**	**YES**	**YES**
Sample	**All MNE's**	**All MNE's**	**All MNE's**	**All MNE's**	**All MNE's**	**All MNE's**
Dependent Variable	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**
USA*ln(C)	-	0.0230***	-	0.0287*	-	0.0161
USA ownership*IT capital		(0.0081)		(0.0161)		(0.0154)
USA		-0.1186***	-	-0.1483	-	-0.1600
USA Ownership		(0.0453)		(0.0988)		(0.1058)
Labor Regulation*ln(C)	-	-	0.0439**	-	0.0702**	0.0295
World Bank Labor Regulation Index*IT capital			(0.0193)		(0.0358)	(0.0332)
Labor Regulation	0.0968**	-	-0.1410	-	-0.3651	-0.0666
World Bank Labor Regulation Index	(0.0434)		(0.0998)		(0.2700)	(0.2451)
Ln(C)	0.0488***	0.0439***	0.0134	0.0152**	-0.0339	-0.0041
IT capital	(0.0056)	(0.0055)	(0.0158)	(0.0073)	(0.0270)	(0.0254)
Ln(M)	0.6347***	0.6354***	0.6352***	0.5353***	0.5375***	0.5063***
Materials	(0.0147)	(0.0147)	(0.0147)	(0.0340)	(0.0351)	(0.0296)
Ln(K)	0.0995***	0.0972***	0.0987***	0.0733*	0.0738*	0.0923**
Non-IT Capital	(0.0134)	(0.0134)	(0.0135)	(0.0402)	(0.0409)	(0.0395)
Ln(L)	0.2046***	0.2062***	0.2042***	0.2529***	0.2514***	0.2457***
Labor	(0.0140)	(0.0140)	(0.0140)	(0.0486)	(0.0485)	(0.0396)
Observations	3,144	3,144	3,144	3,144	3,144	3,144

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. The estimation method in all columns is OLS. The sample includes only multinationals. Columns (4), (5) and (6) include establishment level fixed effects. The labor regulation index is based on the "Rigidity of Employment" index, drawn from the World Bank "Doing Business" report. The index is transformed so that higher values imply more flexible systems. The transformation applied is y = (1-x) (so 0=inflexible, 1=most flexible). 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. Standard errors in brackets under coefficients in all columns are clustered by establishment (i.e. robust to heteroskedasticity and autocorrelation of unknown form). The sample is IT using intensive sectors only. See Appendix A1 for definition of IT using intensive sectors.

TABLE A1 – BREAKDOWN OF THE INDUSTRIAL SECTORS BY IT USAGE

IT Intensive Sectors

Manufacturing	*Services*
18 Wearing apparel, dressing and dying 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 and are not IT producing sectors.

TABLE A2 - DESCRIPTIVE STATISTICS

Panel A: All Establishments

Variable	Frequency	Mean	Median	Standard Deviation
Employment	7,121	811.10	238.00	4,052.77
Gross Output	7,121	87,966.38	20,916.48	456,896.10
Value Added	7,121	29,787.61	7,052.00	167,798.70
IT Capital	7,121	1,030.60	77.44	10,820.69
ln(IT Capital)	7,121	4.46	4.35	2.03
Value Added per worker	7,121	40.43	29.53	55.19
Gross Output per worker	7,121	124.74	86.03	136.55
Materials per worker	7,121	82.38	47.23	103.52
Non-IT Capital per worker	7,121	85.28	48.56	112.54
IT Capital per worker	7,121	0.96	0.34	2.08
IT expenditure per worker	7,121	0.41	0.14	0.89
Material costs as a share of revenues	7,121	0.57	0.60	0.23
Employment costs as a share of revenues	7,121	0.83	0.64	0.86
Non-IT Capital as a share of revenues	7,121	0.30	0.26	0.20
IT Capital as a share of revenues	7,121	0.010	0.004	0.018
Age	7,121	8.38	5.00	6.74
Multigroup dummy (i.e. is establishment part of larger group?)	7,121	0.53	1.00	0.50

Panel B: Breakdown by Ownership Status and Sector

		IT Capital over gross output (C/Q)			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: 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 ratios and employment.

TABLE A3 – GMM AND OLLEY PAKES RESULTS

	(1)	(2)	(3)	(4)
Sample	**All establishments**	**US multinationals**	**Other multinationals**	**Domestic UK establishments**
Estimation Method	**GMM**	**Olley Pakes**	**Olley Pakes**	**Olley Pakes**
Sectors	**All sectors**	**IT Using Intensive Sectors**	**IT Using Intensive Sectors**	**IT Using Intensive Sectors**
Dependent Variable	**Ln(Q)**	**ln(Q)**	**ln(Q)**	**ln(Q)**
USA*ln(C) **USA ownership*IT capital**	0.1176* (0.0642)	-	-	-
MNE*ln(C) **Non-US multinational *IT capital**	0.0092 (0.0418)	-	-	-
Ln(C) **IT capital**	0.0793*** (0.0382)	0.0758** (0.0383)	0.0343** (0.0171)	0.0468*** (0.0116)
Ln(M) **Materials**	0.4641*** (0.0560)	0.5874*** (0.0312)	0.6514*** (0.0187)	0.6293*** (0.0267)
Ln(K) **Non-IT Capital**	0.2052*** (0.0532)	0.0713 (0.0674)	0.1017*** (0.0285)	0.1110*** (0.0270)
Ln(L) **Labor**	0.2264*** (0.0728)	0.1843*** (0.0337)	0.2046*** (0.0139)	0.2145*** (0.0173)
Observations	1,074	615	2,022	3,692
First order serial correlation, p value	0.0100	-	-	-
Second order serial correlation, p value	0.3480			
Sargan-Hansen, p-value	0.4570	-	-	-

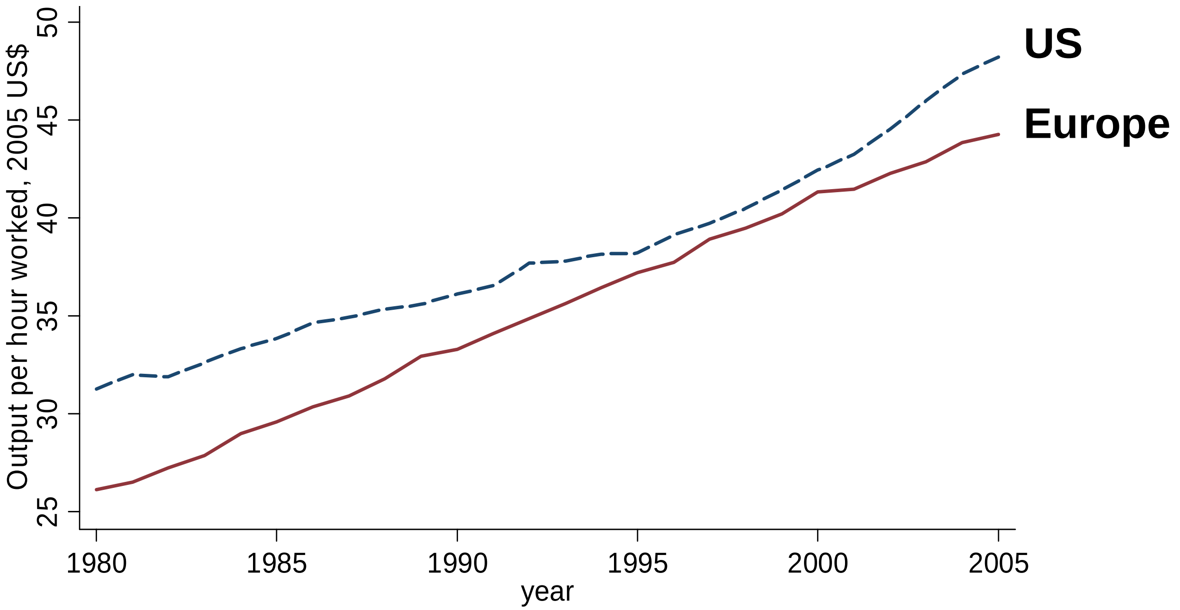
Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns is the log of gross output. The time period is 1995-2003. All variables are expressed in deviations from the year-specific three digit industry mean. Column (1) is estimated using System-GMM (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), etc. Columns (2)-(4) are estimated using Olley Pakes (1996). We use a fourth order series expansion to approximate the phi function. Standard errors in Olley-Pakes are bootstrapped (clustered at the establishment level) with 200 replications. 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 A4 - NON RANDOM SELECTION OF US TAKEOVERS COMPARED TO OTHER TAKEOVERS?

	(1)	(2)	(3)	(4)
Dependent Variable = 1 if establishment taken over by US firm, = 0 for all other takeovers	**US Takeover=1**	**US Takeover=1**	**US Takeover=1**	**US Takeover=1**
Sample	**All takeovers**	**All takeovers**	**All except domestic takeovers**	**All except domestic takeovers**
$\ln(C/L)_{t-1}$	0.0029 (0.0095)	-	-0.0003 (0.0365)	-
$\Delta\ln(C)_{t-1}$	-	-0.0236 (0.0246)	-	-0.0876 (0.0714)
$\ln(L)_{t-1}$	0.0140 (0.0106)	0.0108 (0.0111)	-0.0183 (0.0377)	-0.0222 (0.0379)
$\ln(K/L)_{t-1}$	0.0108 (0.0209)	0.0109 (0.0204)	-0.0174 (0.0645)	-0.0346 (0.0650)
$\ln(Q/L)_{t-1}$	0.0236 (0.0269)	0.0270 (0.0263)	0.0333 (0.0860)	0.0580 (0.0843)
Age	-0.0014 (0.0038)	-0.0017 (0.0039)	-0.0003 (0.0085)	-0.0014 (0.0087)
Observations	563	563	190	190

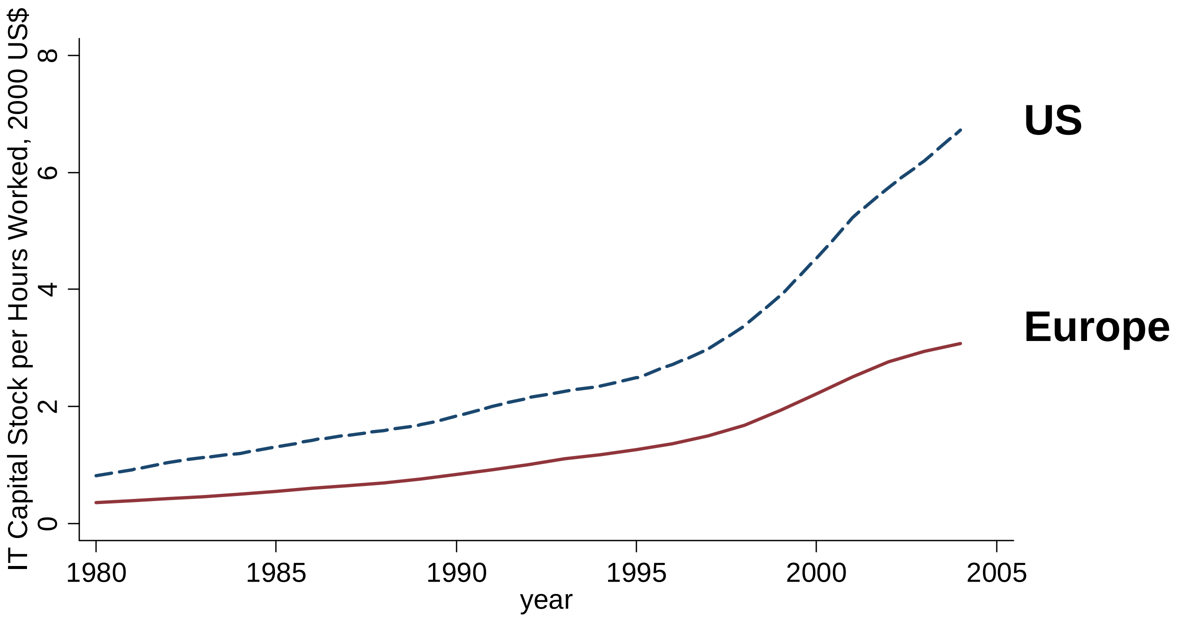
Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable in all columns is a dummy taking value 1 if the establishment is taken over by a US Multinational and zero otherwise. Takeovers by UK firms ("domestics") are excluded in columns (3)-(4). The time period is 1995-2003. All columns include two digit industry dummies, region and year dummies. The estimation method in all columns is by a linear probability model. Standard errors in brackets under coefficients are robust to heteroskedasticity.

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: Organizational devolvement, firms by country of location

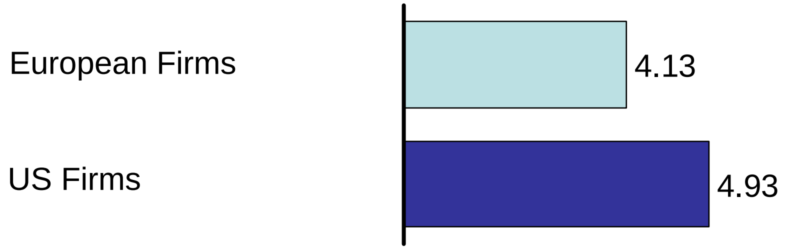


Figure 3c: Organizational change in the UK during 1981-1990

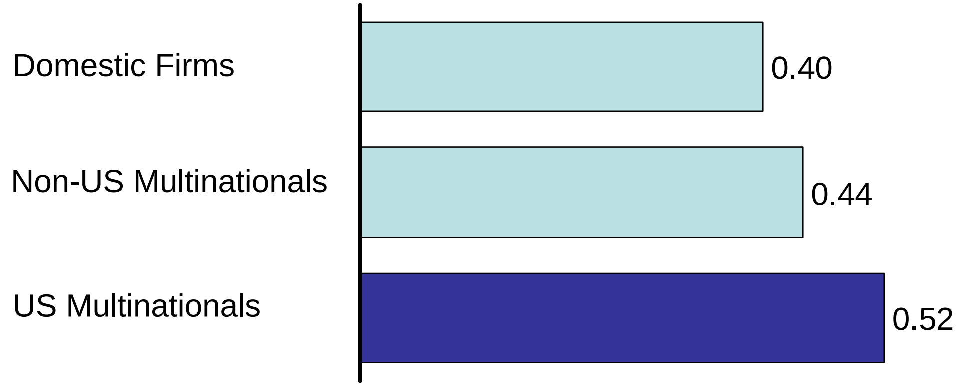


Figure 3b: Organizational devolvement, firms by country of ownership

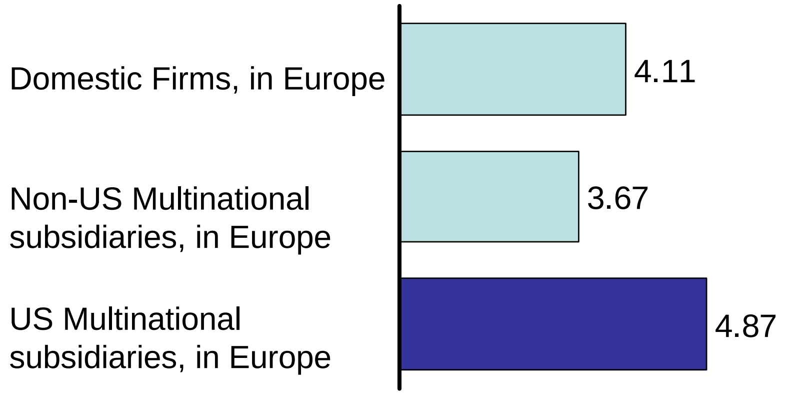
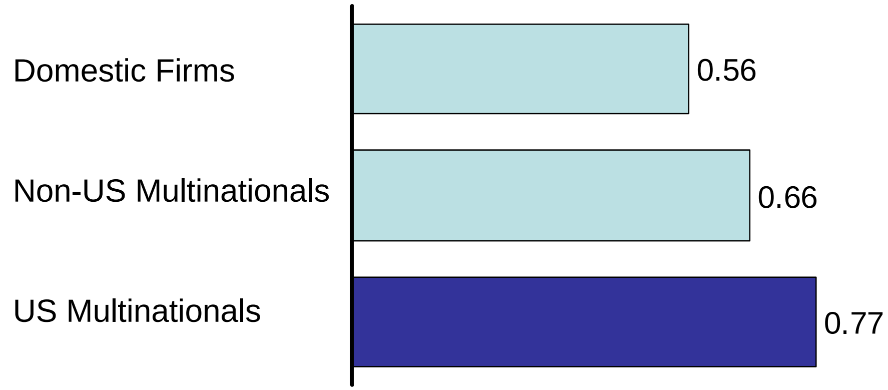


Figure 3d: Organizational change in the UK during 1998-2000



Notes: In Figures 3a and 3b the "Organizational devolvement" score is the average score for the 2 organizational questions for 548 firms in the US (219), UK (98) and France and Germany (231). The questions are taken exactly from Bresnahan et al. (2002) covering "Task allocation" and "Pace setting" where a higher scores indicate greater worker autonomy. Full survey details in Bloom and Van Reenen (2007). In Figure 3c the source is the WIRS data (1984 and 1990) which plots the proportion of establishments experiencing organizational change in previous 3 years (all establishments in the UK). US MNEs (N=190), Non-US MNEs (N=147), Domestic (N=2848). Senior manager is asked "whether there has been any change in work organization not involving new plant/equipment in the past three years". In Figure 3d the source is the CIS data: we plot the proportion of establishments experiencing organizational or managerial change in previous 3 years. The firm is asked "*Did your enterprise make major changes in the following areas of business structure and practices during the three year period 1998-2001?*" with answers to either "*Advanced Management techniques"* or "*Major changes in organizational structure"* recorded as an organizational change.

Figure 4: Decentralization (*O*) by US and European firms, model results

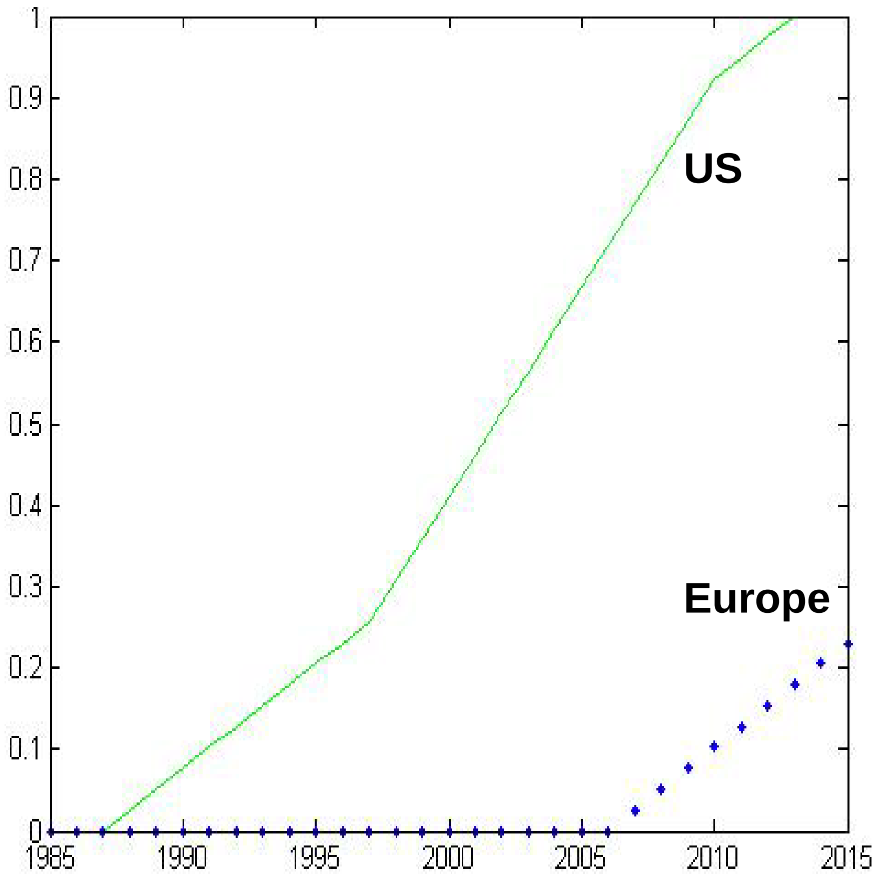
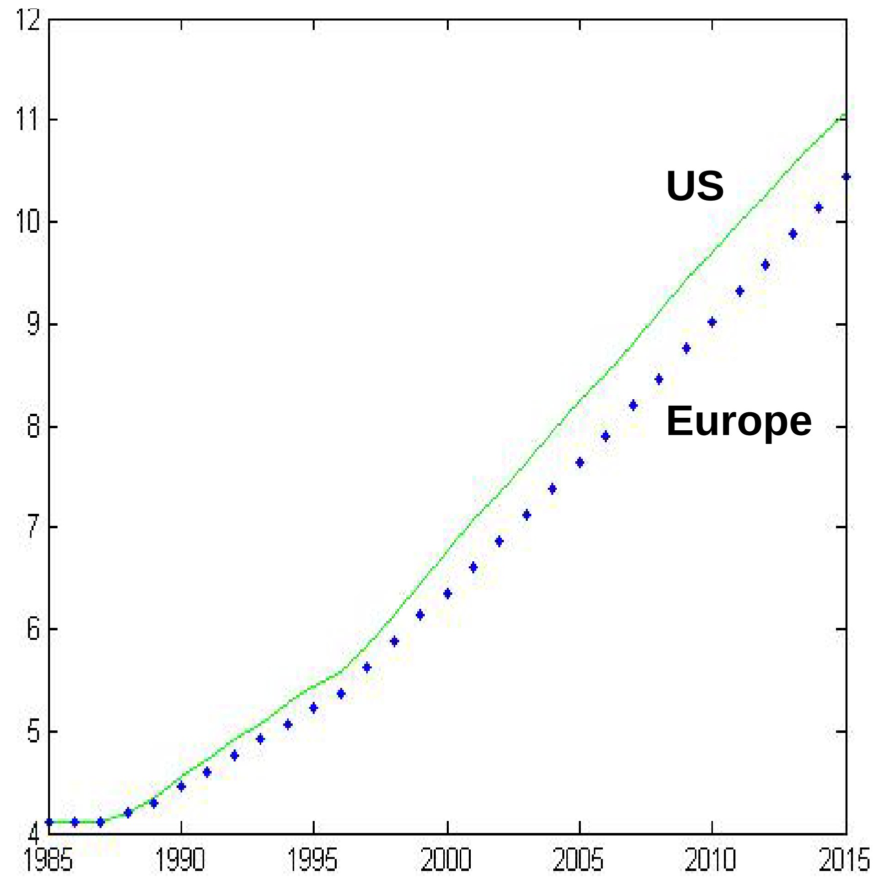


Figure 5: IT per unit of labor, *log(C/L)*, in US and European firms, model results



Notes: Results from the numerical simulation of the theoretical model 1980-2015 (the full simulation was run 1970-2025). See text for details. Decentralization is the value of *O* (between 0 for full centralization and 1 for full decentralization).

Figure 6: Labor productivity, *log(Q/L),* in US and European firms, model results

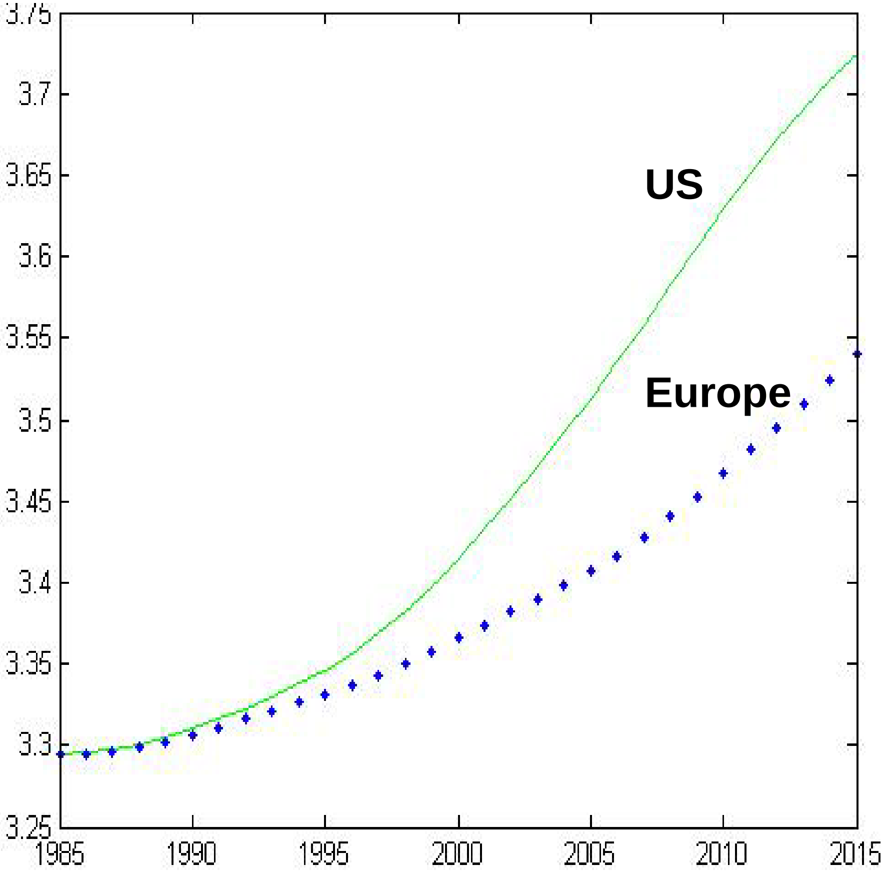
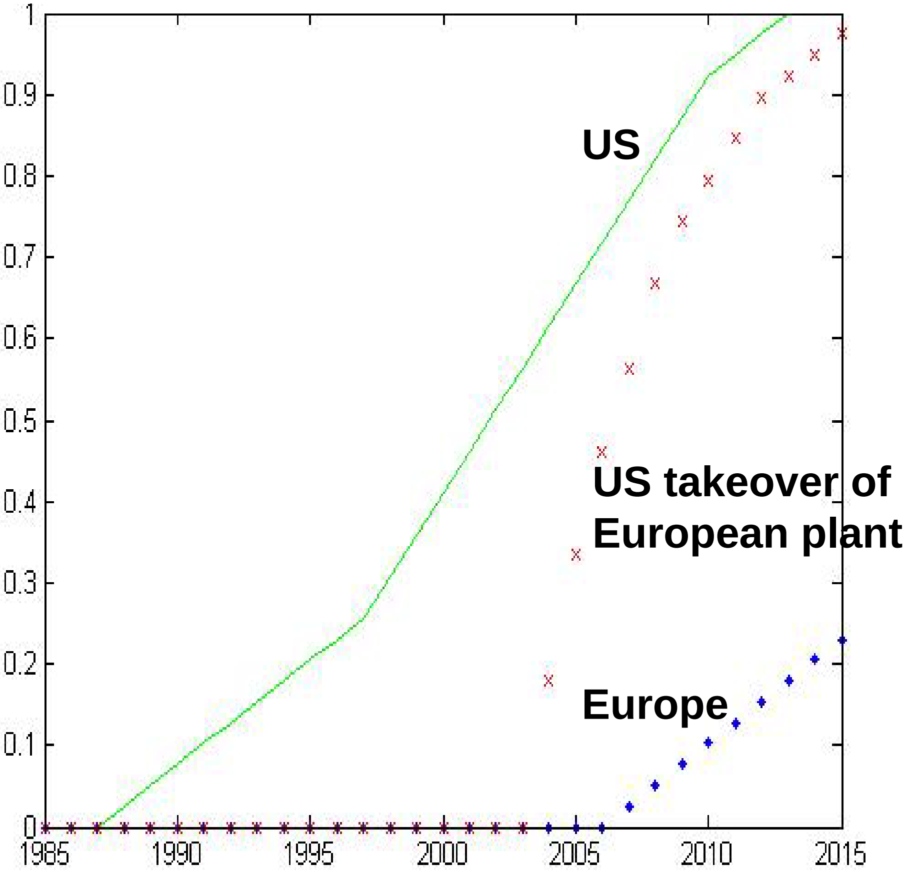
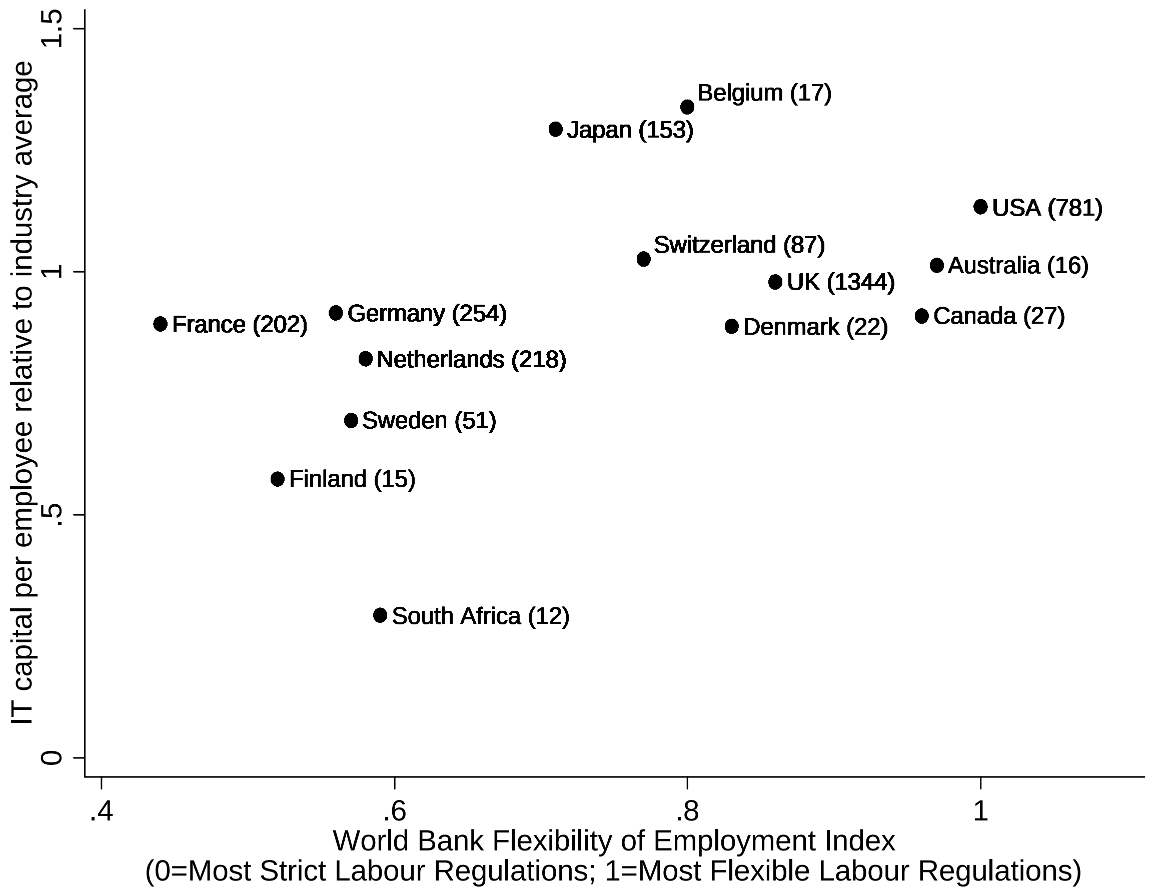


Figure 7: Decentralization (*O*) by plants taken over by US multinationals: model results



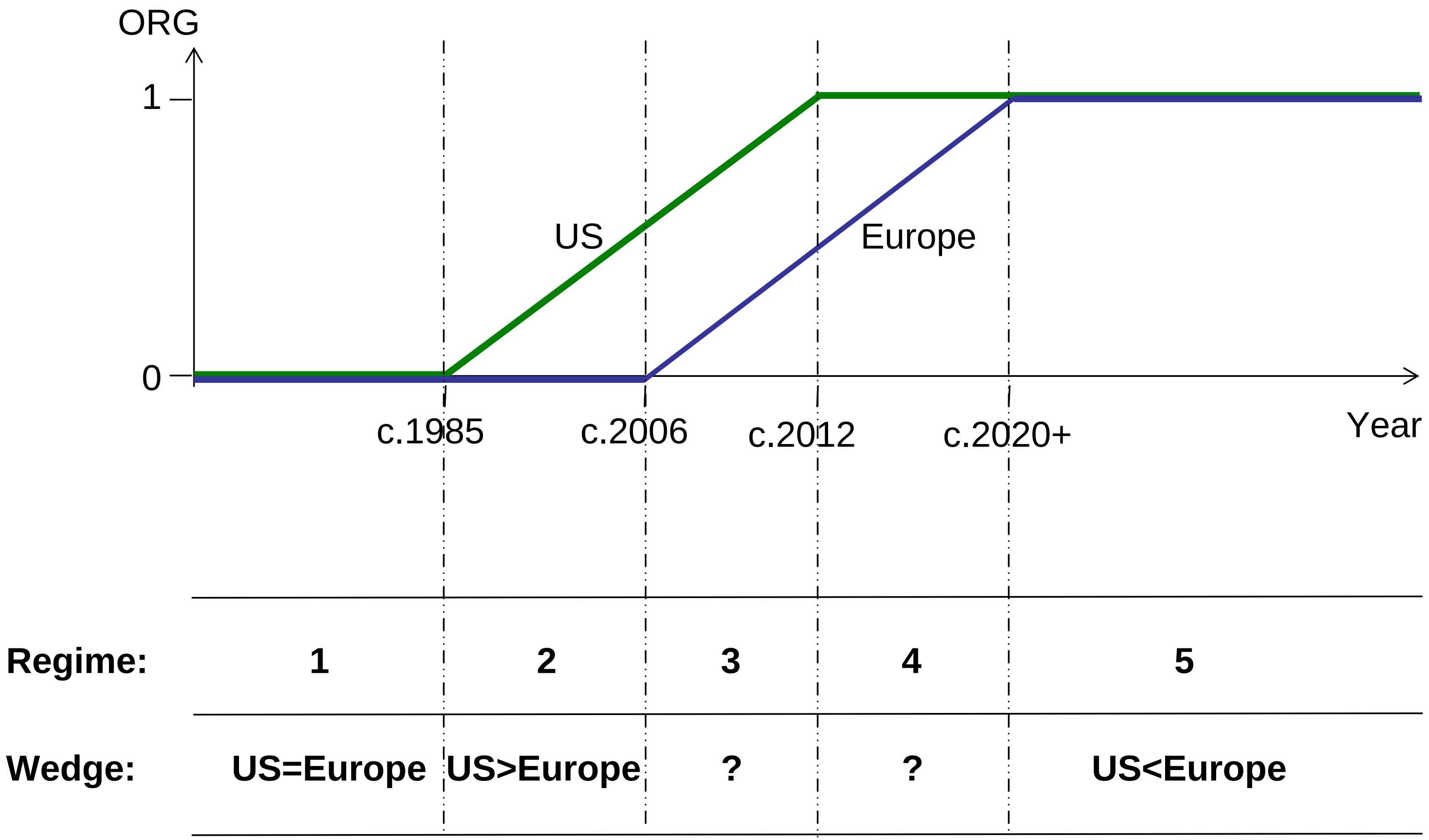
Notes: Results from the numerical simulation of the theoretical model 1980-2015 (the full simulation was run 1970-2025). See text for details. Productivity is output per worker. Decentralization is the value of *O* (between 0 for full centralization and 1 for full decentralization).

Figure 8: IT Intensity vs. Flexibility of Employment Index



Notes: The sample includes only establishments of multinationals in IT using sectors. Each point represents average IT intensity (IT capital divided by employment normalized by the three digit industry average) by country. Each country average is based on at least ten observations and three digit industries with fewer than 10 observations are excluded. The labour regulation index is the "Rigidity of Employment" index, drawn from the World Bank "Doing Business" report.

Figure B1: Organizational change over time in the US and EU



Notes: This figure illustrates the theoretical predictions of the model when we allow for adjustment costs in IT (see Appendix B for details). Note that these are analytic results rather than numerically simulated so the years are approximate. The "wedge" is the difference between actual and measured TFP (see equation (B2)). Regime 1 is where neither the EU nor US have begun adjusting organization (so O = 0). Regime 5 is where both the EU and US have fully adjusted their organization (so O = 1). In Regime 2 the US has started adjusting, but the EU has not, in Regime 3 both regions are adjusting and in Region 4 the US has fully adjusted and the EU is still adjusting.

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