

TECHNOLOGY, INFORMATION AND THE DECENTRALIZATION OF THE FIRM *

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Abstract

This paper analyzes the relationship between the diffusion of new technologies and the decentralization of firms. Centralized control relies on the information of the principal, which we equate with publicly available information. Decentralized control, on the other hand, delegates authority to a manager with superior information. However, the manager can use her informational advantage to make choices that are not in the best interest of the principal. As the available public information about the specific technology increases, the trade-off shifts in favor of centralization. We show that firms closer to the technological frontier, firms in more heterogeneous environments and younger firms are more likely to choose decentralization. Using three datasets of French and British firms in the 1990s, we report robust correlations consistent with these predictions.

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I. Introduction

Recent years have witnessed increasing interest in the determinants of firms' organizational choices. This interest is partly motivated by the belief that new technologies are inducing firms to become less hierarchical and more decentralized. Despite this interest, there is limited work on the determinants of the decentralization decisions of firms. This paper undertakes a theoretical and empirical investigation of how the allocation of authority within firms changes as the information structure in an industry evolves.

We develop a simple model where firms make choices on how to implement new technologies. Different organizational forms are distinguished by the amount of information they use in these decisions. As in Aghion and Tirole [1997], centralized control relies more on the information of the principal, which we equate with publicly available information about past implementations of similar technologies.¹ Decentralized control delegates authority to a manager, who potentially possesses more information than available in the public history. Nevertheless, because the interests of the principal and the manager are not perfectly aligned, the manager can use his informational advantage to make choices that are not in the best interest of the principal. This trade-off between the superior knowledge of the manager and the agency costs of managerial delegation determines the optimal degree of decentralization. The main focus of our analysis is on how learning from the experiences of other firms changes this trade-off. Typically, the more a principal learns from other firms regarding the implementation of new technologies, the less she needs to delegate control to the manager.

Using this basic framework we derive three sets of empirical predictions:

1. Firms closer to the technological frontier are more likely to choose decentralization, because they are dealing with new technologies about which there is only limited information in the public history.

2. Firms in more heterogeneous environments are more likely to be decentralized because greater heterogeneity makes learning from the experiences of others more difficult.

3. Young firms, that have had a limited history to learn about their own specific needs, are also more likely to be decentralized than older firms.

The bulk of the paper investigates these predictions using two large datasets of French firms and establishments and one smaller set of British establishments in the 1990s. We document a range of empirical patterns consistent with these predictions; firms closer to the technology frontier of their industry, firms operating in more heterogeneous environments and younger firms are more likely to choose decentralization.

In addition, since our theoretical approach emphasizes the importance of learning about the implementation of new technologies, we also separately look at high-tech industries (defined as those using information technology intensively). Consistent with our theoretical approach, we find that the relationship between heterogeneity or distance to frontier and decentralization is significantly stronger in high-tech than in low-tech industries.

Our main measure of decentralization is whether different units of the firm are organized into “profit centers”. We show that our main results are robust to proxying decentralization by the extent of delayering or measures of managerial autonomy over

investment decisions. The results are also robust to the inclusion of a range of controls, to using various different measures of heterogeneity and to different estimation strategies.

On the theoretical side, our paper is most closely related to the literature on the costs and benefits of delegation or decentralization in firms. A first strand of this literature, for example Baron and Besanko [1992] and Melumad, Mookherjee, and Reichelstein [1995], investigate the conditions for delegated contracting to replicate the constrained efficient centralized contracting. As emphasized by Mookherjee [2006], however, the presence of complete contracts in these models implies that delegation can at best replicate the constrained efficient allocation, which is also achievable by centralized contracting. A second strand emphasizes information processing and communication costs as determinants of centralization or decentralization in firms.² Although we also stress the importance of learning, our focus is different, namely on how public information affects how much autonomy the principal would like to grant to the agent. Closer to our paper are the recent models emphasizing the trade-off between loss of control and better information under decentralization—in particular, Aghion and Tirole [1997], Baker, Gibbons, and Murphy [1999], Rajan and Zingales [2001], Dessein [2002], and Hart and Moore [2005].³ The main differences between these papers and ours are twofold: first, because there are no incentive effects of the form of the organization, our framework is significantly simpler and allows us to focus on the basic trade-off between information and loss of control; second; we allow the principal to learn from other firms' or from their own past experience, which is the source of all the comparative static results we investigate in the empirical work.⁴

The main contribution of our paper is the empirical evidence we provide on the determinants of decentralization. Previous work in the literature focuses on the general

move towards “flatter” organizations.⁵ Rajan and Wulf [2006] provide the most systematic statistical description of recent organizational trends, showing a strong movement towards flatter corporations in the United States between 1986 and 1999. Caroli and Van Reenen [2001] and Bresnahan, Brynjolfsson, and Hitt [2002] report a positive association between various measures of decentralization and organizational change on the one hand and information technology (and human capital) on the other. Baker and Hubbard [2003, 2004] document the effect of new technologies (on-board computers) on ownership patterns in the US trucking industry. Other related papers include Colombo and Delmastro [2004], who present empirical models of decentralization in Italian manufacturing plants, Lerner and Merges [1998], who examine the allocation of control rights in biotechnology alliances, and the papers by Black and Lynch [2001], Ichinowski, Prenushi, and Shaw [1997] and Janod and Saint-Martin [2004], which examine the impact of human resource practices and firm reorganization on productivity. None of these papers investigate the relationship between decentralization (or organizational change) and distance to frontier or heterogeneity.

The remaining part of the paper is organized as follows. Section II presents some preliminary data description to motivate the basic theoretical framework, which is developed in Section III. Section IV describes the data and our main econometric specification. Section V presents the empirical results. Section VI concludes. Appendix A, which contains a more detailed exposition of the theory and the proofs from Section III, and Appendix B, which contains additional data description and robustness checks, are available upon request and on the Web.⁶

II. Basic Patterns

To motivate our focus in the paper, we first present some salient patterns from a database of several thousand French manufacturing firms, the “Changements Organisationnels et Informatisation” (COI). This dataset, as well as our two other datasets are described below. Our key indicator for decentralization from the COI is whether a firm is organized into profit centers or whether it is more centrally controlled with divisions organized as cost centers (or in some other more centralized manner). A manager of a profit center is concerned with all aspects of the business that contribute to profitability, while managers in charge of cost centers focus on only cost targets. When a firm organizes its divisions into profit centers, it typically delegates substantially more authority to its managers (see the discussion in Section IV).

Figures I-III show the proportion of the 3,570 firms in our baseline COI sample that are decentralized into profit centers broken down by various firm characteristics. Figure 1 divides firms into deciles depending on the “heterogeneity” of the firm’s environment. Heterogeneity is measured as the difference between log productivity (value-added per hour) growth at the 90th and the 10th percentiles of the relevant four-digit industry. This variable is a natural measure of technological heterogeneity among firms within a four-digit industry; it will be greater in industries where some firms are experiencing much faster productivity growth than others. The construction of this variable is discussed in greater detail in Section IV.

Figure I shows a general increase in the probability of decentralization as we move from the firms in the least heterogeneous industries to the most heterogeneous industries;

while 24 percent of the firms are decentralized in the second decile, this number is 41 percent in the tenth decile. The first decile is somewhat anomalous, but closer investigation shows that there is a disproportionately large number of less productive and older firms in these sectors, aspects which we now turn to.

Figure II plots the fraction of firms decentralized into profit centers against the “proximity to the frontier” (measured as the ratio of the firm’s value added per hour to the value added per hour of the firm at the 99th percentile of the distribution in the same four-digit industry). While 27 percent of the firms in the bottom quintile of the proximity distribution are decentralized, 38 percent of the firms in the top quintile, which are closer to the technology frontier, are decentralized.

Finally, Figure III shows that younger firms are, on average, more decentralized than older firms: about 45 percent of the firms under the age of five years are decentralized compared to a rate of 30 percent for the older firms.

In the rest of the paper, we document that the patterns shown in Figures I-III are robust to a variety of controls, different estimation techniques and different empirical measures approximating our theoretical concepts. For example, we show that the same broad patterns apply when we use the variation in productivity levels within four-digit industries (rather than productivity growth) and also a firm-specific index of heterogeneity, measuring the “distance” between the product mix of a firm and those by other firms in the population of French firms. We also show that our main results are robust to using alternative measures of decentralization, including measures of delayering and managerial autonomy over investment and/or employment decisions (the age results are somewhat weaker with some of these alternative measures of decentralization).

Overall, the patterns in Figures I-III, and our more detailed results below, suggest that firms that operate in more heterogeneous environments, that are closer to the technological frontier, and that are younger are more likely to be decentralized. These correlations, especially the relationship between decentralization and heterogeneity, indicate that information acquisition and learning may be the important factors in the decentralization decisions of firms. In particular, firms in more heterogeneous environments, those closer to the technology frontier and younger firms naturally face greater uncertainty regarding their business decisions in general and the optimal implementation of new technologies in particular compared to firms that are in more homogeneous environments, farther from the frontier and more experienced. This motivates our theoretical approach emphasizing the relationship between learning and decentralization, which is presented in the next section. Although there may be alternative explanations for some of our findings, we are not aware of other approaches that can explain the evidence as satisfactorily as our theoretical framework.

III. Theory

In this section, we describe a theoretical environment linking information and technology choices to decentralization decisions. Our purpose is to highlight a number of implications that will be investigated in the empirical work below. More details on the theoretical framework, as well as the proofs of all the results stated here, are contained in the working paper version, Acemoglu *et al.* [2006], as well as in Appendix A.

Suppose that there is a ladder of technologies, $k = 1, 2, \dots$. At each point in time, $t = 1, 2, \dots$, each firm i has previously implemented up to some technology, say $k - 1$. The

next technology in the ladder, k , becomes available to this firm with probability $p_i \in (0, 1]$. The parameter p_i thus measures the speed at which firm i climbs the technology ladder. The realizations of technological opportunities are independent across firms and over time. When a new technology becomes available to a firm, it decides how to implement it. In particular, the firm chooses between two actions, L and R , which correspond to two different choices in the implementation of the new technology. Dropping the time index, the choice of the firm is denoted by $x_{i,k} \in \{L, R\}$. One of these choices, $x_{i,k}^* \in \{L, R\}$, leads to successful implementation, while the other leads to an unsuccessful outcome. We will refer to $x_{i,k}^*$ as the *correct action*. Successful implementation of a technology increases the firm's productivity by a factor $\gamma > 1$, while unsuccessful implementation leaves the productivity of the firm unchanged.

We assume that the successful action for firm i in the implementation of technology k is given by

$$(1) \quad x_{i,k}^* = \begin{cases} x_k^* & \text{with probability } 1 - \varepsilon \\ \sim x_k^* & \text{with probability } \varepsilon \end{cases},$$

where $x_k^* \in \{L, R\}$ is the *reference action* for technology k , $\sim x_k^*$ denotes “not x_k^* ” (i.e., if $x_k^* = L$, then $\sim x_k^* = R$) and $0 < \varepsilon < 1/2$. Conditional on x_k^* , the realizations of $x_{i,k}^*$ and $x_{i',k}^*$ for any $i \neq i'$ are independent.⁷ We assume that, for each technology, the prior probability that L (or R) is the reference action is equal to $1/2$.

This specification implies that there is a generally correct (“conventional”) way of implementing each technology, given by the reference action, but differences in firms' specific needs and competencies imply that some firms need to take a different action for successful implementation. Equation (1) thus makes it clear that ε is a measure of the

heterogeneity among firms: when ε is equal to zero, the reference action is the correct action for all firms; when ε is equal to $1/2$, the correct action is unrelated across firms.

Each firm is owned by a principal who maximizes its value conditional on the public information available. Successful implementation and hence profits depend on the organization of the firm. The two alternative organizational forms available to each firm are: *centralization* and *delegation*. With centralization (denoted by $d_{i,k} = 0$), the principal manages the firm and chooses $x_{i,k}$; with delegation ($d_{i,k} = 1$), the choice of $x_{i,k}$ is delegated to a manager.

The principal in firm i has no special skills in identifying the right action. Therefore, under centralization she bases her decision on the history of publicly available information relevant for technology k at the time of its decision, denoted by h_k^i . In contrast, the manager of firm i observes the correct action $x_{i,k}^*$, so that he knows exactly which action will lead to successful implementation. However, his interests may not be aligned with those of the owner. Following Aghion and Tirole [1997], we model this in a reduced form way and assume that the preferred action of the manager for technology k is given by

$$(2) \quad z_{i,k}^* = \begin{cases} x_{i,k}^* & \text{with probability } \delta \\ \sim x_{i,k}^* & \text{with probability } 1 - \delta \end{cases} .$$

This specification implies that δ is a measure of *congruence* between the firm's and the manager's objectives. Notice that equation (2) implies that the manager is informed about the right action for this particular firm (not only about the right reference action).

We adopt a number of simplifying assumptions to focus on the main implications of this framework. First, we assume that the relationship between the firm and each manager is short-term. Second, when $x_{i,k} = z_{i,k}^*$, the manager obtains a private benefit.

We assume that managers are credit constrained and cannot compensate principals for these private benefits and that these private benefits are sufficiently large that it is not profitable for the principal to incentive contracts to induce managers to take the right action. These assumptions imply that delegation will lead to the implementation of the action that is preferred by the manager; thus, when there is delegation, $x_{i,k} = z_{i,k}^*$.⁸

Finally, we assume that $\delta \in (1/2, 1 - \varepsilon)$, which implies that the manager's interests are more likely to be aligned with those of the principal than otherwise ($\delta > 1/2$) and that the conflict of interest between the principal and the manager is sufficiently severe that a principal who knows the reference action is more likely to make the correct choice if she, rather than the manager, decides ($\delta < 1 - \varepsilon$).

The organizational form and implementation decisions by the principal of firm i for technology k depend on the history of public information h_k^i , which includes the outcomes of all previous attempts with technology k (in particular, which actions were chosen and whether they led to successful implementation). Since conditional on x_k^* the success or failure of different firms in the past are independent, all payoff-relevant information can be summarized by $h_k^i = \{n_k^i, \tilde{n}_k^i\}$. Here, n_k^i is the number of firms that have attempted to implement this technology before firm i , and $\tilde{n}_k^i \leq n_k^i$ is the number of firms for whom L turned out to be the profitable action.⁹ Note also that n_k^i is a direct measure of *distance to the technology frontier*. If n_k^i is high, it means that many other firms have implemented technology k before firm i . Therefore, comparative statics with respect to n_k^i will be informative about the impact of the distance to the technology frontier on decentralization decisions.

Let $\pi(d_{i,k}; h_k^i)$ denote the probability that firm i chooses the correct action conditional

on history h_k^i and the organizational form $d_{i,k}$. It can be shown that profit maximization in this context is equivalent to maximizing $\pi(d_{i,k}; h_k^i)$ in every period (see Acemoglu *et al.* [2006]). Hence, the principal will choose $d_{i,k} = 1$ (delegation) if $\pi(d_{i,k} = 1; h_k^i) > \pi(d_{i,k} = 0; h_k^i)$.

The above discussion establishes that when the principal chooses delegation, we have $\pi(1; h_k^i) = \delta$. On the other hand, under centralization, i.e., $d_{i,k} = 0$, the principal makes the optimal implementation decision given the publicly available information. Consequently, the probability of success when the principal chooses centralization, $\pi(0; h_k^i)$, is a stochastic variable that depends on history $h_k^i = \{n_k^i, \tilde{n}_k^i\}$. That is, it depends both on the firm's distance to the frontier, n_k^i , and on the experiences of firms that have previously implemented the technology, \tilde{n}_k^i . As the distance to frontier, n_k^i , increases, the history available to the principal expands and she learns the reference action, x_k^* , with greater precision. More specifically, when firm i is at the technology frontier, so that $n_k^i = 0$, the principal has no useful information and $\pi(0; h_k^i) = 1/2$. In contrast, as the principal observes the experiences of sufficiently many other firms, the probability that she chooses the correct action under centralization increases. In particular, it can be shown that $\text{plim}_{n_k^i \rightarrow \infty} \pi(0; h_k^i) = 1 - \varepsilon$.¹⁰ This implies that when n_k^i is small, $\pi(0; h_k^i)$ will be less than $\pi(1; h_k^i) = \delta > 1/2$, but as n_k^i increases, it will approach $1 - \varepsilon$ and thus exceed $\pi(1; h_k^i) = \delta$ (since $\delta < 1 - \varepsilon$). This argument establishes that delegation will be chosen by firms closer to the technology frontier, but not by those that are sufficiently behind. Denoting the optimal organizational choice given history h_k^i by $d_{i,k}^*(h_k^i)$, we can therefore establish the following result.

Proposition 1 (Distance to Frontier) Consider the adoption decision of technology

k by firm i , and suppose that $\delta \in (1/2, 1 - \varepsilon)$. Then:

(i) For a firm at the technology frontier, i.e., $n_k^i = 0$, the principal chooses delegation. That is, $d_{i,k}^*(h_k^i = \{0, 0\}) = 1$.

(ii) For a firm sufficiently far from the technology frontier, i.e., as $n_k^i \rightarrow \infty$, the principal (almost surely) chooses centralization. That is, $\text{plim}_{n_k^i \rightarrow \infty} d_{i,k}^*(h_k^i = \{n_k^i, \tilde{n}_k^i\}) = 0$.

In the empirical analysis, we proxy distance to the technology frontier with the gap between the productivity of a particular firm and the highest productivity (or the highest percentile productivity) in the same industry. Firms that are further behind the frontier (i.e., those with higher n_k^i 's) will be less productive because they have been unlucky in the past and have had fewer opportunities to adopt technologies, and also because these are typically the firms with lower p_i 's that are slower in climbing the technology ladder. Using this proxy, we test the prediction that centralization increases with the distance to the frontier.¹¹

Our next result links the parameter of heterogeneity, ε , to firms' decentralization decisions. Let $\Pr(d_{i,k}^*(h_k^i) = 1)$ be the unconditional probability that firm i will choose delegation when implementing technology k .

Proposition 2 (Heterogeneity) Consider the adoption decision of technology k by firm

i . Given the distance to frontier n_k^i , an increase in heterogeneity, ε , makes delegation more likely. That is, $\partial \Pr(d_{i,k}^*(h_k^i) = 1) / \partial \varepsilon \geq 0$ for all h_k^i .

Intuitively, when ε is small, there is less heterogeneity in the environment and the

performance of firms that have implemented the same technology in the past reveals more information about the reference action. Consequently, when ε is small, firms' posterior beliefs are more responsive to public information. In other words, given a history h_k^i , $\partial\pi(0; h_k^i)/\partial\varepsilon \leq 0$, so that as ε increases, delegation becomes more attractive at each history h_k^i .¹² The complication in the proof comes from the fact that a change in ε also affects the likelihood of different histories. Nevertheless, it can be proved that a greater ε changes the ex ante distribution of different histories in a direction that also increases the probability of delegation.

Proposition 2 provides the most interesting testable implication of our approach; it suggests that there should be more decentralization in industries with greater dispersion of performance across firms and also that decentralization should be more likely for firms that are more dissimilar to others. In the empirical section, we proxy heterogeneity using three different measures. First, we use the dispersion of productivity growth within a four-digit industry. This is a natural measure since a higher ε corresponds to greater variability in the successful implementation of a *given* technology and thus to greater variability in productivity growth. Second, we check these results using the dispersion in levels of productivity within an industry. Finally, we use a firm-level proxy for heterogeneity, the (IT-weighted) distance between the product mix of a particular firm and those of other firms in the same industry, the idea being that firms with a product mix that is more similar to others should be able to learn more from past experiences of other firms.

In Acemoglu *et al.* [2006], we extended this framework to derive a relationship between firm age and organizational structure. Firms learn not only from other firms, but also from their own past experiences. The implication of this extension is that younger

firms that have accumulated less “firm-specific” information are more likely to choose delegation. Motivated by this observation, in our empirical analysis we also investigate the relationship between firm age and delegation.

IV. Econometric Specification and Data

IV.A. Empirical Strategy

In our empirical analysis, we will document a number of correlations motivated by the theory presented in the previous section. Recall that the main predictions of our approach are:

1. Delegation should be more common for firms closer to the technological frontier.
2. Delegation should be more prevalent in environments with greater heterogeneity.
3. Young firms should be more likely to choose delegation.

We investigate these predictions by studying the relationship between various explanatory factors and decentralization decisions of several thousand French and British firms. Consider the following econometric model for delegation:

$$(3) \quad d_{ilt}^* = \alpha H_{ilt-1} + \beta PF_{ilt-1} + \gamma age_{ilt-1} + \mathbf{w}'_{ilt-1} \boldsymbol{\zeta} + u_{ilt},$$

where i denotes firm, l denotes industry and t denotes time. Here, d_{ilt}^* is a latent variable indicating the propensity to delegate authority to managers, H_{ilt-1} is a measure of heterogeneity, PF_{ilt-1} is a measure of “proximity to the frontier” (inverse measure of “distance to the frontier”), age_{ilt-1} denotes the age of the firm and \mathbf{w}_{ilt-1} is a vector of other controls. All right-hand side variables refer to $t - 1$, while the dependent variable is for t , which is an attempt to prevent the most obvious form of reverse causality. Nevertheless,

we do not view estimates from equation (3) as corresponding to causal effects, since there may be other omitted factors, simultaneously affecting both the (lagged) right-hand side variables and the delegation decisions. All omitted factors are captured by the error term u_{ilt} , which we assume to be normally distributed.

In all of our specifications, we observe an indicator of decentralization, $d_{ilt} \in \{0, 1\}$, and in our baseline specifications, we assume that

$$(4) \quad d_{ilt} = \begin{cases} 1 & \text{if } d_{ilt}^* > 0 \\ 0 & \text{if } d_{ilt}^* \leq 0 \end{cases} ,$$

where d_{ilt}^* is given by (3). Equation (4), combined with the fact that u_{it} is normally distributed, leads to the standard probit model (Wooldridge [2002]). We therefore estimate (3) by maximum likelihood probit. We check the robustness of our results by using logit and linear probability specifications.

IV.B. Data and Measurement

We use two French and one UK datasets. The use of multiple datasets is an important cross-validation of the robustness of our results. Our first and main dataset, “Change-ments Organisationnels et Informatisation” (COI), covers just over 4,000 manufacturing firms.¹³ Using unique identifiers, firms in this dataset are matched to the dataset FUTE, which contains the entire population of French firms with more than 20 employees.¹⁴ Many of our right-hand side variables are constructed from the FUTE and thus refer to this entire population. Since the COI contains some firms with less than 20 employees, the match leaves us with a total of 3,570 firms for our basic analysis.

Using the COI, we build a measure of decentralization based on the organization of a firm’s business units into profit centers (see Appendix B for a more detailed descrip-

tion). In practice, once a firm grows beyond a certain size it faces the choice of retaining centralized control or allowing some decentralization. Firms are generally organized into business units, with different degrees of responsibility delegated to the managers of these units. While some firms retain complete command and control at the center, most create some form of “responsibility centers” for business unit managers.¹⁵ These responsibility centers (from the most to the least decentralized) are profit centers, cost centers and revenue centers. Our key indicator for decentralization is whether the firm is organized primarily into profit centers. When a firm organizes into profit centers, the manager keeps track of both revenues and costs with the aim of maximizing profits; he is given considerable autonomy in the purchase of assets, hiring of personnel, the management of inventories and determination of bonuses and promotions.¹⁶ In contrast, a cost (revenue) center manager is responsible only for costs (revenue). Milgrom and Roberts [1992, pp. 229-230] contrast cost and profit centers managers as follows: “Managers who are given responsibility for profits, for example, are commonly given broader decision authority than those responsible just for costs or sales.” Overall about 30 percent of French firms in our sample are organized into profit centers.

Our second dataset, the “Enquête Reponse” (ER), is a survey of just under 3,000 French establishments covering all sectors of the economy conducted in 1998. This dataset is also matched with the FUTE to construct the right-hand side variables, which leaves us with a dataset of around 2,200 establishments. In this dataset, delegation can be measured in two ways. First, there is a direct question asked to plant managers regarding the degree of autonomy they enjoy from headquarters in their investment decisions. Since this question only makes sense for firms that are part of a larger group, the analysis is

restricted to this sub-sample (of 1,258 establishments). Second, this dataset also includes a question on delayering, in particular, on whether there was any reduction in the number of hierarchical layers between 1996 and 1998. Although, a priori, delayering may be associated with more or less delegation (for example, because it may make the chief executive more informed about lower layers), existing evidence shows that delayering tends to involve delegating more power to lower layers of the managerial hierarchy (see Caroli and Van Reenen [2001] and Rajan and Wulf [2006]).

Finally, we draw on a British dataset, the 1998 Workplace Employee Relations Survey (WERS), which is similar in structure to ER. WERS does not have a question on plant managers' autonomy over investment decisions, but contains a question on their autonomy from headquarters in making employment decisions. We use this question to measure the degree of decentralization. Unlike the French data, for confidentiality reasons WERS cannot be matched with productivity at the firm-level, though we can match productivity information at the four-digit industry level. Details on all three datasets are in the Appendix B.

Our indicator of proximity to the frontier is the gap between the log labor productivity of a firm (measured as value-added per hour) and the frontier (log) labor productivity in the primary four-digit industry of the firm, $\ln y_{it} - \ln y_{Ft}$, where F denotes the frontier, measured in a number of alternative ways. In addition to average labor productivity, we report robustness checks using Total Factor Productivity (TFP). We also construct several alternative indicators of “frontier” productivity. Our main measure is the highest productivity in the firm's primary four-digit industry (defined as the 99th percentile to mitigate any measurement error from outliers that might arise had we used the maximum) again

calculated from the FUTE dataset. We repeat the same exercise using other percentiles (90th and 95th), and we consider alternative measures based on the firm's productivity *rank* in the four-digit industry.

In addition to our main specification, we also allow $\ln y_{ilt-1}$ and $\ln y_{FIt-1}$ to have different coefficients in the regression equation, by estimating

$$(5) \quad d_{ilt}^* = \alpha H_{ilt-1} + \beta_1 \ln y_{ilt-1} + \beta_2 \ln y_{FIt-1} + \gamma age_{ilt-1} + \mathbf{w}'_{ilt-1} \boldsymbol{\zeta} + u_{ilt}.$$

This specification allows us to test whether $\beta_2 < 0$ (that is, whether, as predicted by our theory, delegation is negatively correlated with lagged frontier productivity) and also whether $\beta_1 = -\beta_2$. This robustness check is particularly important, since a positive correlation between distance to frontier and decentralization may reflect a positive effect of decentralization on the firm's own productivity. If this were the case, in equation (5) we would estimate that $\beta_2 = 0$.

For heterogeneity H_{it} , we use three measures. All three measures are constructed from the FUTE dataset for the entire covered population of firms (in the United Kingdom we use the ABI Census data). Our benchmark measure of heterogeneity, H_t^G , is the dispersion of firm productivity growth within a four-digit sector. This measure captures the effect of the parameter ε in the model of Section III, since high values of ε correspond to greater heterogeneity in the performance of firms implementing the same technology, thus to greater variability in productivity growth within a sector. We measure productivity growth by the average annual growth in value added per hour over the 1994 to 1997 period, and our main measure of dispersion is the difference in productivity growth rates

between the 90th and the 10th percentiles in the four-digit industry, so that

$$(6) \quad H_l^G \equiv (\Delta \ln y_{il})^{90} - (\Delta \ln y_{il})^{10},$$

where $(\Delta \ln y_{il})^P$ denotes the P th percentile of the distribution of productivity growth across all firms in industry l . We also consider several alternatives such as the difference between the 95th and the 5th percentiles, the standard deviation of firm productivity growth rates and the standard deviation of the trimmed productivity growth distribution.

We also present results with an alternative measure of a heterogeneity, H_l^L , constructed similarly to H_l^G , but using productivity levels instead of growth rates (i.e., $H_l^L \equiv \ln y_{il}^{90} - \ln y_{il}^{10}$). This measure has two empirical disadvantages relative to our benchmark. First, it is likely to be correlated with the distance to the frontier, so the heterogeneity and proximity terms may be hard to identify separately. Second, the growth-based measure, H_l^G , is likely to be a better proxy for ε since it differences out time-invariant omitted variables affecting the level of productivity that are observable to firms but not the econometrician (such as management quality, brand differences, etc.).

Both of these measures of heterogeneity do not vary within a four-digit industry. Our third measure, H_i^F , is a firm-specific index of heterogeneity and quantifies (the inverse of) how many other firms are close “neighbors” of the firm in question in the product space. When there are more similar firms (neighbors), the firm will have greater opportunity to learn from the experiences of others and this will correspond to a lower value of ε in terms of our theoretical model.¹⁷ To calculate this measure, for each firm i we compute the distribution of production across all four-digit sectors. We define $s_i \equiv (s_{i1}, \dots, s_{iL})$ as firm i 's shares of production in each industry $l = 1, \dots, L$ (by definition $\sum_{l=1}^L s_{il} = 1$).

An element of the vector s_i will be equal to zero if a firm produces nothing in industry l and will be equal to one if a firm produces all its output in that particular industry. We then calculate the “closeness” of any two firms, i and i' in the FUTE as the uncentered correlation coefficient,

$$c_{ii'} \equiv \frac{\sum_{l=1}^L s_{il} \cdot s_{i'l}}{\left(\sum_{l=1}^L s_{il}^2\right)^{\frac{1}{2}} \cdot \left(\sum_{l=1}^L s_{i'l}^2\right)^{\frac{1}{2}}},$$

which takes greater values when the production profiles of two firms are more similar and is equal to one when the two profiles are identical. Since our theoretical approach emphasizes the importance of similarity in the context of experimenting with new technologies, our preferred measure of firm-specific heterogeneity is constructed with information technology (IT) weights:

$$(7) \quad H_i^F \equiv \log \left(\frac{\sum_{i', i' \neq i} c_{ii'} \cdot IT_{i'}}{\sum_{i', i' \neq i} IT_{i'}} \right)^{-1},$$

where $IT_{i'}$ is the level of investment in IT by firm i' . We also check the robustness of our results by looking at an alternative unweighted measure. The “inverse” in equation (7) makes sure that high levels of H_i^F correspond to high values of ε in terms of our theory.

A potential concern with this firm-level heterogeneity measure, H_i^F , is that it may be related to the level of product market competition. If there are many other firms “close” to a company in the product market space, then this company may be facing tougher competition.¹⁸ To alleviate this concern, we control for various measures of product market competition, in particular the Lerner index (a proxy for price-cost margins), calculated as gross profits—value added minus labor costs—divided by sales, from the FUTE dataset. Moreover, we document below that there is a robust positive relationship between product market competition and delegation¹⁹, so the possible negative correlation between

product market competition and H_i^F will, if anything, bias the results towards finding a negative effect of heterogeneity on delegation, which is the *opposite* of the prediction in Section III.

In addition, since our theory emphasizes the importance of learning in the context of the implementation of new technologies, we estimate (3) and (5) separately in high-tech and low-tech subsamples (as measured by industry IT intensity). We expect the patterns suggested by our model to be more pronounced for high-tech firms.

We measure age, age_{ilt-1} , using four dummies; age less than 5 years, between 5 and 9 years, between 10 and 19 years, and the reference category, greater than or equal to 20 years.

Means, medians and standard deviations for all the main variables are presented in Table I (these are mainly based on our core French dataset, the COI). Appendix B gives greater detail on the data used. The average firm in our data has 323 employees, was born 22 years ago and has 3 plants.

V. Results

V.A. Decentralization

Table II presents our basic findings using the decentralization measure from COI. Throughout, all regressions are estimated by maximum likelihood (ML) probit and we report marginal effects evaluated at the sample mean. All standard errors are computed using the Huber formula, where we allow for heteroskedasticity and clustering at the four-digit industry level. All regressions also include a full set of three-digit industry dummies.²⁰

The first column of Table II includes only our key variables: heterogeneity (measured by the 90-10 of firm productivity growth), frontier productivity (measured as the 99th percentile of the productivity distribution in the firm’s primary four-digit industry), own productivity, age dummies and the three-digit industry dummies. The results are consistent with the predictions in Section III—all key variables take their expected signs and are statistically significant at the 5 percent level. The marginal effects of heterogeneity and own productivity are positive, whereas the marginal effects of frontier productivity and age are negative.²¹ Firms in more heterogeneous environments are significantly more likely to be decentralized (the marginal effect is 0.211, while the standard error is 0.107). The youngest firms (under five years old) are 15 percent more likely to be decentralized than the oldest firms (those over 20 years old) and this difference is significant at the 5 percent level.²² In column (2), we combine the frontier productivity and the own productivity terms in a single “proximity to frontier” term as in equation (3). The marginal effect of proximity to frontier is 0.167 (standard error = 0.024), while the marginal effect of heterogeneity is 0.252 (standard error = 0.102).²³

The remaining columns in Table II include a range of additional firm-level and industry-level controls to check whether the correlations we report are driven by omitted variables. The additional firm-level covariates are: the Lerner index, the log number of plants of the firm, log firm size (employment), the fraction of employees working with computers, the fraction of high skilled workers, the (log of) capital stock divided by value added, a foreign ownership dummy, the average age of workers, the firm’s market share and a specialization/inverse diversification index. The additional industry-level covariates are the Herfindahl index, (the log of) capital stock divided by employment and IT expen-

ditures divided by employment. The fixed capital stock and computer use variables are included both as potential controls and also to bring the measure of labor productivity closer to TFP by controlling for the contribution of various components of the capital stock. Firm-level worker characteristics are included since these may affect organizational choices; for example, firms with more skilled workers and/or younger workers might be more likely to decentralize control. The additional controls improve the fit of the model, but the heterogeneity, age and productivity terms all remain individually significant at the 5 percent level or less. Also notable is that in the specification of column (3), which includes all the additional covariates, we do not reject the hypothesis that $\beta_1 = -\beta_2$, that is, the hypothesis that frontier and own labor productivity terms have equal and opposite-signed coefficients (p-value>0.10).

It is also worth noting that the estimated effects of these covariates are consistent with the existing literature. Firms that are more skill-intensive (Caroli and Van Reenen [2001]), that employ younger workers (Aubert, Caroli, and Muriel [2006]), that have more workers using computers and/or that are more in more IT-intensive industries (Bresnahan, Brynjolfsson, and Hitt [2002]) appear significantly more likely to be decentralized. Furthermore, firms that are large, multi-plant, foreign owned and/or less specialized (more diversified) are also more likely to be decentralized, possibly because their production processes are more complex. Firm-level capital stock or industry-level capital stock do not appear to have a major effect on decentralization. There is also a robust negative relationship between the Lerner index, our (inverse) proxy for product market competition, and the probability of decentralization, which implies that more competitive environments are associated with greater decentralization (similarly high market share firms are signif-

icantly less likely to decentralize). We discuss the association between competition and decentralization further in the concluding section.

Since our theory in Section III relates decentralization decisions to the adoption of new technologies, we expect a stronger relationship between decentralization and heterogeneity in the high-tech sectors than in the low-tech sectors. We define a “high-tech” sample consisting of industries with an average ratio of IT investment per worker greater than the sample median. The “low-tech” sample contains the remaining industries. We re-estimate our main regression equation on these two samples separately. Consistent with our expectations, the marginal effects and significance of all the key variables are greater for high-tech sectors than for low-tech sectors. For example, the heterogeneity index, H_t^G , is positive and significant in the high-tech sample (column (5)), but negative and insignificant in the low-tech sample (column (6)). The marginal effects of proximity to frontier and of the youngest age dummy are twice as large in the high-tech sample as in the low-tech sample. Wald tests show that these differences are significant at the 1 percent level for heterogeneity and at the 5 percent level for proximity to frontier (but insignificantly different for age).

Overall, the results in Table II suggest that, consistent with our theory and the relationships shown in Figures 1-3, firms that operate in more heterogeneous environments, that are closer to the technology frontier, and that are younger are significantly more likely to be decentralized.

V.B. Magnitudes

To gauge the quantitative magnitudes of the estimates in Table II, we look at the

impact of doubling each variable starting from its sample mean.

Using the estimate of the marginal effect of heterogeneity in column (4) of Table II, 0.251, we find that doubling the mean value of heterogeneity (the 90-10 of firm productivity growth in the industry) from 0.275 to 0.550 increases the predicted probability of a firm being decentralized into profit centers by approximately 7 percentage points ($0.251 \times 0.275 \approx 0.069$) starting from a base of 30 percent, which is a sizeable effect. Thus, in “elasticity” terms, a doubling of heterogeneity is associated with a 23 percent increase in the probability of decentralization (a 6.9 percentage point increase on a base of 30 percent).²⁴

Again using the estimate from column (4) of Table II, doubling the proximity measure leads to a substantial increase in the probability of decentralization of about 11 percentage points which represents a 37 percent increase on the base of about 30 percent ($0.164 \times \ln 2 / 0.3 \approx 0.37$). Also using the estimates from column (4) of Table II, doubling the age of a firm from four years to eight years reduces the probability of decentralization by a third (12 percentage points on a 30 percent base). These calculations suggest that the statistical associations documented in Table II appear to be economically as well as statistically significant.

V.C. Alternative Measures of Technology

Table III contrasts our basic measure of heterogeneity (H_l^G , the inter-decile range of firm productivity growth rates in the industry) with several alternative indicators of heterogeneity. The first column of Table III replicates the specification from the fourth column of Table II for comparison. The next three columns (2)-(4) use alternative mea-

asures of heterogeneity still based on the dispersion of productivity growth rates across firms within the four-digit industry. Column (2) shows a qualitatively similar result to column (1) using the difference between the productivity growth rates at the 95th and 5th percentiles (instead of the 90th and 10th percentiles). The marginal effect is 0.142 with a standard error of 0.069. In column (3) we use the standard deviation of the growth rate, which also has a positive marginal effect, but is only significant at the 10 percent level. This lack of precision may be due to a number of outliers in the firm-level productivity growth distribution. In column (4), we use the standard deviation calculated after trimming the top and bottom five percent of the firm-level productivity growth distribution and obtain a much larger and much more significant marginal effect.

Column (5) includes the heterogeneity term based on firm productivity levels, H_i^L . The marginal effect of this variable is positive, but is not statistically significant. The estimated magnitude is comparable to that in column (1), however; a doubling of H_i^L is associated with a 27 percent increase in decentralization (a 8.1 percentage point increase on a base of 30 percent) compared to 23 percent for our benchmark measure, H_i^G . Furthermore, as with our benchmark results in Table II, the level-based measure of heterogeneity, H_i^L , has a large and statistically significant marginal effect of 0.271 in the high-tech sample (column (6)). In contrast, its marginal effect is insignificant (and negative) in the low-tech sample (column (7)) and is also significantly different from the estimate in the high-tech sample (p-value=0.009).

Columns (8)-(11) report results using the firm-level measure of heterogeneity, H_i^F .²⁵ Recall that this index measure is the (inverse) IT-weighted distance of a firm to all other firms. This is an entirely different source of variation in heterogeneity and thus constitutes

a useful cross-validation of the main results. In column (8) of Table III, H_i^F has a marginal effect of 0.063 and a standard error of 0.031. The next two columns show that, as with the other measures, the effect of heterogeneity is stronger in the high-tech sample than in the low-tech sample (0.098 with a standard error of 0.048 versus 0.019 with a standard error of 0.037). Finally, in column (11) we look at the simpler unweighted measure of the firm-level heterogeneity measure. This is useful as another check to see whether the measure H_i^F is capturing some competition-related factors. If that were the case, we would expect the unweighted measure to be stronger. The unweighted measure also has a positive effect, but with a smaller coefficient that is only statistically significant at the 10 percent level. This suggests that, consistent with our theoretical approach, the IT weights increase the explanatory power of the firm-level heterogeneity index.²⁶

Overall, the results in this table show that there is a robust positive association between heterogeneity and decentralization, particularly in high-tech industries.²⁷

V.D. Further Robustness Checks

In addition, we conducted a large number of robustness checks (see Acemoglu et al [2006] and Appendix B for details). These checks show that our main results do not depend on the precise functional form, control variables or the exact sample. Here we give a brief summary of these robustness checks.

First, estimating the marginal effects by OLS or logit gave very similar marginal effects to the probit estimates of column (3) in Table II.

Second, alternative measures of productivity and distance the frontier also gave similar results. For example, results using total factor productivity were very close to those

using labor productivity. We also experimented with alternative definitions of the distance to frontier using an ordinal measure (the rank of the firm's labor productivity in the four-digit industry) or lower percentiles of the productivity distribution to the 99th percentile in order to measure the frontier (e.g., the 95th and the 90th). Again, the results were qualitatively similar, but the marginal effects of the frontier became progressively weaker as we used the 95th and the 90th percentiles. This pattern is not surprising, since we expect 95th and 90th percentiles to be poorer proxies for the technology frontier than the 99th percentile.

Third, although a single firm can be organized into divisions with each division being decentralized as a profit center, the measure of profit centers may be more natural for firms that are part of larger groups. To investigate this issue and also to exclude potentially owner-managed firms, which may be different for a variety of reasons, we re-estimated our basic specification on the sub-sample of 1,793 firms that are part of a larger corporate group. Reassuringly, the effects of heterogeneity and proximity to frontier are considerably larger and more significant in this subsample (0.461 with a standard error of 0.140 for heterogeneity and -0.303 with a standard error of 0.056 for the frontier).

Another concern is that we have allocated a single "frontier" productivity to each firm, whereas firms that operate across multiple industries will have multiple "frontiers". To address this concern, we limited the sample to firms that have at least 80 percent of their sales in their primary four-digit industry, since the multiple industry issue should not be a serious concern for these firms. In this limited sample of 2,555 firms, both heterogeneity and the frontier terms remain highly significant, but the marginal effect of the frontier term is somewhat smaller; -0.179 instead of -0.225 in the baseline specification.

We also estimated instrumental-variable models to address the issue of endogeneity of our main right-hand side variables. Our strategy was to use the UK counterparts of our key variables as instruments. Although this approach does not solve all possible endogeneity problems, it is a useful check against reverse causality concerns. We constructed heterogeneity variables identical to H_i^G based on the dispersion of productivity growth among British firms for the same time period to instrument French industry-level heterogeneity. We also constructed the 99th percentile of the productivity distribution in each four-digit British industry as a potential instrument for the French proximity to frontier. The details are provided in Acemoglu *et al.* [2006]. Briefly, these instruments are highly significant in the first stages. Using instrumental-variables probit (see Lee [1981]), we estimated positive and significant effects of both heterogeneity and proximity to frontier in the second stage. The marginal effects in this case were 1.572 for heterogeneity and 0.456 for the proximity to frontier (compared to 0.230 and 0.167 when treating these variables as exogenous). These instrumental-variable results therefore suggest that, if anything, treating heterogeneity and proximity as exogenous may be causing some attenuation due to measurement error and making us underestimate the impact of heterogeneity and proximity to the frontier on decentralization.

V.E. Alternative Measures of Decentralization

Two alternative measures of decentralization are control over investment decisions and delayering. Whether an establishment's senior managers can make investment decisions without consulting headquarters is directly related to delegation of authority. In addition, case studies and econometric evidence suggest that reducing the layers of the

managerial hierarchy tends to be associated with decentralized decision-making.²⁸ There are questions on delayering and the autonomy of investment decision-making in our second French dataset, the Enquête Reponse (ER).²⁹ Delayering is defined as the removal of one or more layers of the managerial hierarchy between 1996 and 1998. Our indicator of investment autonomy/decentralization is equal to one if the plant manager has “full” or “important” authority in making investment decisions independently of central headquarters and to zero if he has “limited” or “no” autonomy in making such decisions. In this case, we also limit the sample to firms that are part of a larger group, because the question on delegation of investment decisions from headquarters is only relevant for these firms.

Table IV shows the results of estimating equation (5) for these alternative measures both for the full sample and also separately for the high-tech and the low-tech samples (constructed using industry IT intensity as in Table II). In columns (1)-(3) the dependent variable is an indicator of whether the firm allows autonomy over investment decisions to its plant managers. In columns (4)-(9), the dependent variable is an indicator for whether there was a reduction in the number of layers in the managerial hierarchy between 1996 and 1998.

In column (1) of Table IV frontier productivity is negatively and significantly related to the probability of allowing managers to make investment decisions without consulting headquarters (decentralization). Heterogeneity is positively related to decentralization, but (like the firm’s own productivity) is insignificant. When we distinguish between high-tech (column (2)) and low-tech samples (column (3)), the results are stronger. The marginal effect of heterogeneity for high-tech sectors is positive and significant at the 5

percent level, whereas in the low-tech sample, heterogeneity is insignificant. Similarly, the marginal effect of proximity to the frontier is negatively and significantly related to decentralization in the high-tech sample, but is positive and insignificant in the low-tech sample. Own productivity and age are insignificant in both samples.

The next six columns use the measure of delayering as the dependent variable. In column (4) the productivity terms are both correctly-signed and significant, suggesting that the closer is a firm to the technology frontier the more likely it is to choose delayering. Younger firms are also significantly more likely to delayer than older firms.³⁰ The heterogeneity term is positive and significant at the 10 percent level. When we split the sample into high-tech (column (5)) and low-tech (column (6)) sectors, the marginal effects of heterogeneity and proximity are again much larger for high-tech sectors than for low-tech sectors, but the standard errors are also much larger in both samples. In contrast, the age effects are larger in the low-tech sample, which is the opposite of the prediction of our theory.

Since the delayering variable measures “organizational change” (rather than the “level” of decentralization as in our previous dependent variable), we also considered regressions where the productivity terms are in differences rather than in levels. Since we do not have reliable time-series information on the heterogeneity term and some of the other covariates, they are still included in levels. The results, presented in columns (7)-(9), are similar to the benchmark estimates, but somewhat weaker. The frontier growth term is correctly-signed, but no longer significant and the own productivity term is also insignificant.³¹ The heterogeneity measure remains positive and significant in the full sample. With the sample split, however, heterogeneity is no longer significant in either

sample (presumably because of the smaller number of observations), though, as expected, the marginal effect is substantially larger in the high-tech sample.

In summary, the results from using delayering and autonomy over investment decisions as alternative indicators of decentralization broadly support our earlier conclusions. Decentralization appears to be more likely when the environment is more heterogeneous and when firms are closer to the technology frontier, particularly in the high-tech sample, though the age results appear to be somewhat less robust.

V.F. Decentralization in Britain

We complement our evidence from the French micro datasets with an analysis of the British Workplace Employee Relations Survey (WERS98). The French Enquête Reponse was modeled on WERS and we use the 1998 wave to match the year used in ER. The WERS cross-section does not have a question on autonomy over investment decisions, but there is a similar question on the establishment manager's autonomy over employment decisions. Senior managers were asked whether they were able to take decisions on staff recruiting without consulting company headquarters. Our WERS sample is further restricted because we are only able to match manufacturing establishments to industry-level information (since census information on non-manufacturing is not available over this time period). Finally, we are unable to condition on the rich set of firm-level covariates as in the French data, because confidentiality restrictions limit the data that can be matched at the firm-level (such as firm-level output, capital or age).

The results are presented in Table V. Column (1) includes the first measure of heterogeneity (the difference between the 95th percentile and the 5th percentile of the produc-

tivity growth rates in the four-digit industry) with only a full set of three-digit industry dummies as extra controls. Heterogeneity is positively and significantly associated with decentralization at the 5 percent level. The next column performs the same exercise for the 90-10, the relationship is still positive and significant at the 10 percent level. Column (3) includes the frontier growth term which is negatively signed as we would expect from the theory, but insignificant. The fourth column includes the age dummies. These are insignificant and show no clear pattern (possibly because in this dataset we only have establishment age rather than firm age).

The fifth and sixth columns include all the covariates. There appears to be some evidence that firms facing less competition are significantly less likely to decentralize. More importantly, the heterogeneity terms measured either as the 90-10 (column (5)) or the 95-5 (column (6)) percentile differences remain positive and significant. The frontier term is negative and significant at the 5 percent level in both columns. These findings are consistent with our theory and with the results from the French datasets, even though they use a different dataset from a different country.

VI. Conclusions

Despite considerable academic and popular interest in the changes in the internal organization of the firm, we are far from a theoretical or an empirical consensus on the determinants of the organizational decisions of firms and on the reasons why there has recently been a significant move towards greater decentralization. In this paper we presented a simple model of the relationship between technology, information and decentralization and empirically investigated the main predictions of this model using three micro-level

datasets. In our model, firms delegate authority to managers, i.e., “decentralize”, in order to use the manager’s superior information about the implementation of new technologies. Because the interests of the manager and the principal are not perfectly aligned, such delegation entails a costly loss of control for the principal. The model predicts that as the amount of publicly available information about the optimal implementation of new technologies increases, firms should become less likely to decentralize, whereas firms dealing with new (frontier) technologies should be more likely to decentralize. We also showed that firms in more heterogeneous environments and young firms are more likely to choose decentralization. These are intuitive, but quite novel, predictions, and have, to the best of our knowledge, never been investigated empirically.

We documented that in all three datasets the correlations are broadly consistent with the predictions of our model. Firms in more heterogeneous environments and those that are closer to the frontier of their industry are more likely to choose decentralization. Moreover, consistent with the predictions of the theory, these results are stronger for firms in high-tech sectors. The results are robust to using a variety of alternative measures of decentralization and heterogeneity. We also found that younger firms tended to be more likely to decentralize, though this result was less robust when we looked at alternative measures of decentralization. These results suggest that the recent move towards more decentralized organizations may be driven, in part, by the rapid diffusion of new technologies and the entry of young firms.

The theory and empirical results taken together suggest that learning and information accumulation may have important effects on the internal organization of firms and may be especially important for decentralization decisions. Our analysis also highlights a

number of avenues for future research. First, it would be useful to study decentralization and vertical integration decisions jointly, since the same forces pushing towards decentralization may also encourage spin-offs and reduce the incentives for vertical integration.

Second, our empirical results showed a robust positive association of competition and decentralization. An interesting question is to investigate the channels through which competition may affect decentralization. One possibility is that competition may increase the value of information because falling behind competitors may be costly to firms, thus encouraging delegation to the manager who has superior information. Yet another effect of a more competitive environment may be through disciplining the manager; faced with greater competition, managers may be forced to take profit-maximizing decisions more often, thus reducing the conflict of interest between the principal and the manager. This would naturally increase delegation, since delegation becomes more attractive to the principal.

Another interesting area for future research would be to investigate whether the statistical associations between proximity to frontier or heterogeneity and decentralization correspond to the causal effects of these variables on the internal organization of the firm, for example, by estimating a more structural model.

Finally, our approach suggests that cross-country differences in the internal organization of firms constitute a promising area for future research, since there may be less decentralization in developing countries where most firms use well-established (rather than frontier) technologies.

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1. Throughout the paper the principal could be thought of as either the owner or the chief operating officer of the firm.

2. See, among others, Sah, and Stiglitz [1986], Geanakoplos and Milgrom [1991], Radner and Van Zandt [1992], Radner [1993], Bolton and Dewatripont [1994], and Garicano [2000].

3. The possibility that the implementation of new technologies could encourage delegation was first raised by Jensen and Meckling [1992]. Aghion and Tirole [1997] emphasize the trade-off between loss of control and the agent's ex ante incentives to acquire information under decentralization. Hart and Moore [2005] show how the trade-off between loss of control and information can explain why in many hierarchies generalists command specialists. Dessein [2002] develops a model in which decentralization to a specialized agent entails a loss of control for the principal, but at the same time reduces the agent's incentive to miscommunicate her information to the principal.

4. Acemoglu and Zilibotti [1999] present a different model where endogenous accumulation of information affects the internal organization of firms. In their model, a larger number of firms in the economy enables better relative performance of evaluation and creates a shift from direct to indirect monitoring. The number of firms in the economy is, in turn, determined endogenously as a function of the stage of development and the level of the capital stock. The relationship between distance to the frontier and various aspects of the internal organization of the firm is also investigated in Acemoglu, Aghion and Zilibotti [2003, 2006].

5. This phenomenon is described by different terms in different contexts, including

decentralization, delayering and delegation. In the theory, consistent with the principal-agent literature, we use the term “delegation”, while in the empirical analysis, we adopt the terms used in the datasets (e.g. “decentralization” in the COI).

6. http://econ-www.mit.edu/faculty/index.htm?prof_id=acemoglu&type=paper.

7. This implies that when $x_k^* = L$, $\{x_{i,k}^*\}_i$ is a Bernoulli sequence with parameter of $1 - \varepsilon$, and when $x_k^* = R$, it is a Bernoulli sequence with parameter ε .

8. Put differently, in this model the choice between centralization and delegation simply corresponds to whether or not the “advice” of the manager is followed by the principal. In particular, all the results would be identical if we considered a somewhat different model in which the manager reports his recommendation and then the principal decides which action to take. In this alternative model, “delegation” would correspond to the principal following the recommendation of the manager. See Acemoglu *et al.* [2006] and Appendix A for the results in the case where the principal can use incentive contracts.

9. Note that \tilde{n}_k^i is equal to the number of firms that have adopted technology k before i , chose $x_{i',k} = L$ and were successful, plus the number of firms that chose $x_{i',k} = R$ and were unsuccessful. The public information set also includes the organizational form chosen by firms that have previously adopted technology k , but equation (2) implies that \tilde{n}_k^i is a sufficient statistic for this public information.

10. The statements here and in Proposition 1 show that as $n_k^i \rightarrow \infty$, $\pi(0; h_k^i)$ will increase towards $1 - \varepsilon$. One might also conjecture that $\pi(0; h_k^i)$ and hence the probability of centralization should be monotonically increasing in n_k^i . In Acemoglu *et al.* [2006], we showed that when n_k^i is low, integer issues may cause $\pi(0; h_k^i)$ to be non-monotonic, but

it is increasing in n_k^i “on average,” i.e., when we average over neighboring values of n_k^i to smooth out integer issues.

11. Although in this section we state the results in terms of “distance to the technology frontier,” in the empirical work it will be more convenient to use the inverse of this, “proximity to the frontier”.

12. Interestingly, this applies to both “correct” and “incorrect” beliefs. For instance, suppose that $x_k^* = L$, but R has been successful more than half of the time; when ε is small, the firm will assign higher probability to R being the correct action.

13. For previous uses of this dataset, see Greenan and Mairesse [1999], Janod [2002], Aubert, Caroli, and Roger [2004], Crépon, Heckel, and Riedinger [2004], and Janod and Saint-Martin [2004].

14. FUTE also contains the population of non-manufacturing firms with more than 10 employees which we use in some of the later tables. These data are not published in the French National Accounts, so we worked directly with the underlying micro data located in the French statistical agencies. Similarly the information on the demographic structure of each firm (e.g., skills, age, gender of employees and hours of work) had to be built up from the employee level datasources aggregated to the firm-level. See Appendix B for details.

15. For the meaning of the terms responsibility centers and profit centers in the business literature and in management, see, for example:

<http://smccd.net/accounts/nurre/online/chtr12a.htm>. In addition,

<http://www.aloa.co.uk/members/downloads/PDF%20Output/costcentres.pdf>, provides a

standard discussion of autonomy of profit centers. Janod [2002] and Janod and Saint-Martin [2004] have previously used these data on profit centers as a measure of decentralization.

16. Merchant's [1989, p. 10] book on profit centers explains: "The profit center managers frequently know their business better than top management does because they can devote much more of their time to following up developments in their specialized areas. Hence, top level managers usually do not have detailed knowledge of the actions they want particular profit center managers to take, and even direct monitoring of the actions taken, if it were feasible would not ensure profit center managers were acting appropriately."

17. This measure of closeness is inspired by Jaffe's [1986] approach in the context of patent spillovers, but uses the proportion of production in a four-digit industry. Jaffe originally used patent technology class, which has the potential disadvantage that many firms do not patent, especially in services.

18. See Bloom, Schankerman, and Van Reenen [2004] for a discussion.

19. For evidence of the positive influence of competition on organizational change see Nickell, Nicolitsas, and Patterson [2001] and McKinsey Global Institute [2002].

20. Since the frontier productivity term and the heterogeneity measure H_l^G are defined at the four-digit level, we could not identify their effects if we included four-digit industry dummies. Nevertheless, with a full set of four-digit dummies, we can still identify the marginal effects of age and firm-specific productivity. In regressions including a full set of four-digit dummies, the coefficients on these variables remain correctly-signed and

statistically significant.

21. When included individually each variable is also significant. For example, when we drop all other variables except the three-digit industry dummies, the marginal effect of heterogeneity is 0.212 and continues to be significant at the 5 percent level (see Acemoglu *et al.* [2006] for details).

22. Note, however, that since our decentralization data are cross-sectional we cannot separate age effects from cohort effects. Consequently the positive coefficient on the young firm dummy may reflect that companies founded in more recent years are more likely to adopt “best practice” organizational forms than companies founded in earlier years (see, e.g., Ichinowski, Prenushi and Shaw [1997]). One might also conjecture that firms in younger industries should be more decentralized than those in older industries. We cannot investigate this question, however, since we do not have a measure of “industry age” (average firm age is not a good measure of “industry age” because of the differential entry and exit patterns across industries).

23. The Wald test rejects the restriction that $\beta_1 = -\beta_2$ at the 5 percent level, though when additional covariates are included in columns (3) and (4), this restriction is no longer rejected.

24. A one standard deviation increase in heterogeneity (0.087) results in a smaller increase in decentralization probabilities: a 2.2 percentage point, or 7.3 percent increase.

25. All of the results in Table II are similar if we use this measure. For example, the most parsimonious specification in column (1) of Table II gives a marginal effect of H_i^F of 0.111 with a standard error of 0.034.

26. If we include both the weighted and the unweighted measures together with all the covariates, the weighted measure is positive and significant at the 5 percent level (marginal effect=0.184, standard error=0.096), while the unweighted measure is negative and insignificant (marginal effect=-0.142, standard error=0.109).

27. One concern with any measure of heterogeneity is that, since it is correlated with uncertainty in firm's environment, it may affect the extent of the moral hazard problem between the firm and the manager (an issue we have abstracted from in the model). Nevertheless, everything else equal, this effect would bias the results against finding a positive association between heterogeneity and decentralization, since greater uncertainty should increase "agency costs," making decentralization less attractive.

28. See, for example, Caroli, and Van Reenen [2001] and Rajan and Wulf [2006].

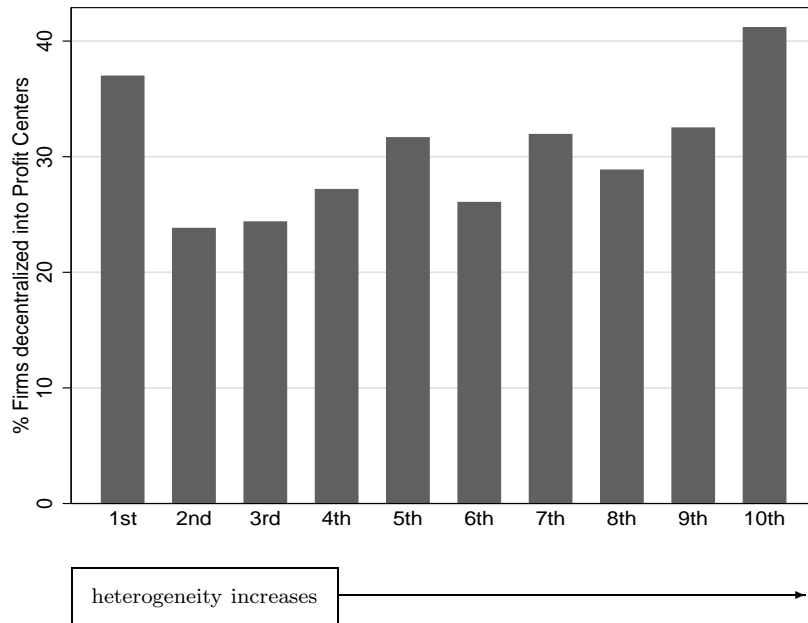
29. In the COI dataset there is an indicator of the number of hierarchical levels, but as discussed in Appendix B, a better datasource to measure delayering is the ER. This is because the ER question on delayering refers explicitly to changes in management as in our theory, while the COI question refers to the number of "hierarchical levels" and is thus likely to be more informative on hierarchies involving non-managerial workers.

30. Although the ER data are at the establishment level, the regressions in Table IV use firm age to make the results comparable to those in Tables II and III. The young firm dummy remains positive and significant if we also condition on establishment age.

31. The weakness of the frontier growth term in this case is related to the higher correlation between productivity growth and heterogeneity variables (recall that heterogeneity is defined here as the decile ratio of productivity growth rates in the firm's four-digit

industry). In column (7) if we drop the heterogeneity and firm productivity terms, the marginal effect of frontier productivity growth increases to -0.061 and becomes significant at the 5 percent level. If we use the full specification of column (7), but just include two-digit (instead of the usual three-digit) industry dummies, the marginal effect of frontier growth becomes -0.074 with a standard error of 0.038.

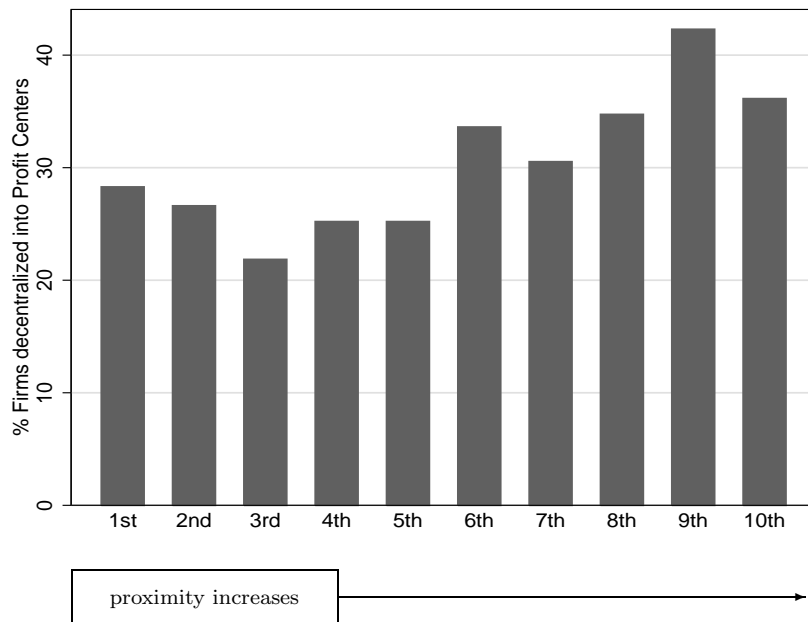
FIGURE I



HETEROGENEITY AND DECENTRALIZATION

NOTES: The X-axis divides all firms into deciles of heterogeneity from the first decile (low heterogeneity) to the tenth decile (high heterogeneity). Heterogeneity is measured by an index of dispersion (the difference of the 90th minus the 10th percentile) of productivity growth between firms in a four digit industry (see text). The Y-axis indicates the proportion of firms that are decentralized into profit centers in the relevant decile group. The sample is the COI sample (3,570 French firms in 1997).

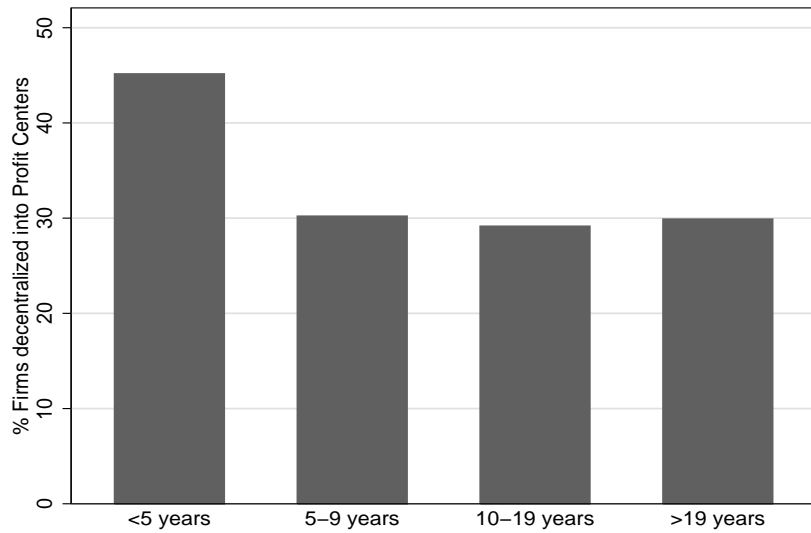
FIGURE II



PROXIMITY TO FRONTIER AND DECENTRALIZATION

NOTES: The X-axis divides all firms into deciles of proximity to frontier (in terms of value added per hour) from the first decile (low proximity to frontier) to the tenth decile (high proximity to frontier). The Y-axis indicates the proportion of firms that are decentralized into profit centers in the relevant decile group. The sample is the COI sample (3,570 French firms in 1997).

FIGURE III



FIRM AGE AND DECENTRALIZATION

NOTES: Firms are grouped into age bands (dated from the birth of the firm). The Y-axis indicates the proportion of firms that are decentralized into profit centers in the relevant age group. The sample is the COI sample (3,570 French firms in 1997).

TABLE I
DESCRIPTIVE STATISTICS
(ENQUÊTE COI, 1994-1997)

Variable	Source	Mean	Median	St dev
Decentralization measures				
Organized into profit centers	COI	0.304	0	0.460
Decentralization of investment decisions	ER	0.484	0	0.500
Delaying	ER	0.436	0	0.496
Heterogeneity measures: Industry level heterogeneity of labour productivity growth (H_i^G)				
90 th – 10 th percentiles	DADS/FUTE	0.275	0.263	0.087
95 th – 5 th percentiles	DADS/FUTE	0.443	0.406	0.160
Standard deviation	DADS/FUTE	0.177	0.165	0.066
Standard deviation after trimming	DADS/FUTE	0.088	0.082	0.033
Heterogeneity measures: Industry level heterogeneity of labour productivity level (H_i^L)				
90 th – 10 th percentiles	DADS/FUTE	0.897	0.861	0.229
Heterogeneity measure: Firm level inverse share of close firms in the product space (H_i^F)				
Share of close (IT weighted) firms, %	FUTE	0.343	0.138	0.049
ln (Firm specific heterogeneity)		7.111	6.587	2.381
Share of close (unweighted) firms, %	FUTE	0.216	0.096	0.308
Distance to technological frontier				
Firm labour productivity	DADS/FUTE	0.163	0.143	0.089
Sectoral 99 th perc. labour productivity	DADS/FUTE	0.508	0.397	0.315
Proximity to frontier	DADS/FUTE	0.358	0.334	0.159
ln (Proximity to frontier)		-1.125	-1.096	0.457
Other firm level variables				
Foreign ownership	LIFI	0.173	0	0.379
Firms belonging to a larger group	LIFI	0.547	1	0.498
Number of plants	DADS	3.092	1	8.510
Firm age	SIRENE	21.658	18	12.740
Capital stock/value added	FUTE	1.143	0.907	1.036
Number of workers	FUTE	323.463	88.375	677.080
Percentage of workers using computers	COI	59.669	71.846	26.300
Percentage of skilled workers	DADS	72.996	77.371	20.202
Age of workers	DADS	38.870	39.010	3.403
Lerner index	FUTE	0.075	0.068	0.077
Market share (%)	FUTE	1.732	0.404	4.171
Herfindahl index	FUTE	0.049	0.031	0.057
Specialization	FUTE	0.831	0.931	0.203
Other industry level variables				
Capital stock per worker)	BRN	404.987	289.242	369.064
IT investment (per worker)	EAE/FUTE	0.849	0.600	0.725

NOTES: These descriptive statistics are based on the COI sample (3,570 observations), except for “Decentralization of investment decisions” and “Delaying” (ER sample: 1,258 observations). The COI dataset is a firm level survey providing information on organization and other firm characteristics in 1997; it covers manufacturing sectors only. The ER dataset is an establishment survey containing information about organizational change between 1996 and 1998; it covers both manufacturing and non-manufacturing sectors. The FUTE files contain the firms balance sheet and further accounting information; it refers to the entire population of French firms having more than 20 employees in manufacturing industries and more than 10 employees in other industries. The DADS files consist of yearly mandatory employer reports of each worker’s hours (and gross earnings subject to payroll taxes); they cover the entire population of French firms. The LIFI files describe the structure of ownership of large French firms; it also includes information about their main interests in other companies. SIRENE is the register of all French firms. Units of currency are thousands of French Francs at the 1995 prices. See text for variable definitions.

TABLE II
DETERMINANTS OF DECENTRALIZATION
(ENQUÊTE COI)

Dependent variable Industries	Firm decentralized into Profit Centers					
	Full sample				High-tech	Low-tech
	(1)	(2)	(3)	(4)	(5)	(6)
Heterogeneity (H_l^G)	0.211 (0.107)	0.252 (0.102)	0.296 (0.127)	0.251 (0.115)	0.679 (0.189)	-0.062 (0.135)
Frontier, 99 th percentile ($\ln y_{Fl}$)	-0.101 (0.039)	-	-0.225 (0.045)	-	-	-
Labour productivity, firm level ($\ln y_{il}$)	0.182 (0.026)	-	0.141 (0.033)	-	-	-
Proximity to frontier (constrained term $\ln y_{il} - \ln y_{Fl}$)	-	0.167 (0.024)	-	0.164 (0.028)	0.224 (0.040)	0.103 (0.044)
Firm age < 5 years	0.151 (0.040)	0.151 (0.040)	0.172 (0.041)	0.174 (0.041)	0.215 (0.059)	0.122 (0.055)
5 ≤ Firm age < 10 years	0.012 (0.021)	0.012 (0.021)	0.066 (0.022)	0.066 (0.022)	0.069 (0.032)	0.049 (0.029)
10 ≤ Firm age < 20 years	-0.007 (0.019)	-0.007 (0.019)	0.039 (0.019)	0.040 (0.019)	-0.008 (0.027)	0.083 (0.028)
Other firm and industry controls (cont.)	no	no	yes	yes	yes	yes
Industry dummies	yes (73)	yes (73)	yes (73)	yes (73)	yes (52)	yes (42)
Mean of dependent variable	0.304	0.304	0.304	0.304	0.378	0.232
Observations	3,570	3,570	3,570	3,570	1,767	1,803

NOTES: All coefficients are marginal effects from probit maximum likelihood estimation. Robust standard errors corrected for arbitrary variance-covariance matrix at the four-digit industry level in parentheses. Industry variables are defined at the four-digit level (except industry dummies at the three-digit level). All right hand side variables are lagged and averaged over three years (1994-1997). Labor productivity is the log of value added per hour, frontier is defined as the 99th percentile of the productivity distribution in the firm's four-digit industry. Heterogeneity is defined as the dispersion of productivity growth rate within a four digit industry (the 90th percentile less the 10th percentile). The omitted category for firm age is "firm age greater than twenty years". High-tech subsample includes all firms in industries with greater than median IT investment per worker. Low-tech subsample includes all firms in industries with less than median IT investment per worker. See text for variable definitions.

TABLE II (-CONT.)
DETERMINANTS OF DECENTRALIZATION
(ENQUÊTE COI)

Dependent variable Industries	Firm decentralized into Profit Centers					
	Full sample				High-tech	Low-tech
	(1)	(2)	(3)	(4)	(5)	(6)
Lerner index	-	-	-0.660 (0.144)	-0.733 (0.136)	-0.947 (0.168)	-0.547 (0.218)
ln (Number of plants)	-	-	0.041 (0.015)	0.041 (0.015)	0.027 (0.021)	0.052 (0.017)
ln (Firm size)	-	-	0.110 (0.009)	0.110 (0.009)	0.134 (0.015)	0.098 (0.014)
Percentage of workers using computers	-	-	0.220 (0.034)	0.217 (0.034)	0.238 (0.071)	0.189 (0.034)
Percentage of skilled workers	-	-	0.169 (0.049)	0.153 (0.048)	0.206 (0.078)	0.090 (0.059)
ln (Firm capital/value added)	-	-	0.008 (0.012)	0.009 (0.012)	-0.003 (0.017)	0.022 (0.016)
Foreign ownership	-	-	0.047 (0.025)	0.045 (0.025)	0.064 (0.038)	0.015 (0.032)
Average age of workers in the firm (/10)	-	-	-0.057 (0.025)	-0.060 (0.025)	-0.155 (0.046)	0.008 (0.027)
Firm market share	-	-	-0.577 (0.260)	-0.574 (0.257)	-0.821 (0.382)	-0.520 (0.419)
ln (Firm specialization)	-	-	-0.071 (0.030)	-0.070 (0.030)	-0.119 (0.047)	-0.027 (0.039)
ln (Herfindahl index)	-	-	-0.015 (0.017)	-0.011 (0.017)	0.031 (0.027)	-0.024 (0.022)
ln (Sector capital stock per worker)	-	-	-0.064 (0.040)	-0.074 (0.040)	-0.115 (0.035)	-0.033 (0.043)
ln (Sector IT investment per worker)	-	-	0.116 (0.019)	0.102 (0.019)	0.059 (0.044)	0.111 (0.029)
Industry dummies	yes (73)	yes (73)	yes (73)	yes (73)	yes (52)	yes (42)
Mean of dependent variable	0.304	0.304	0.304	0.304	0.378	0.232
Observations	3,570	3,570	3,570	3,570	1,767	1,803

TABLE III
DETERMINANTS OF DECENTRALIZATION: ALTERNATIVE MEASURES OF HETEROGENEITY
(ENQUÊTE COI)

Dependent variable (mean=0.304)		Firm decentralized into Profit Centers									
Measure of heterogeneity	Heterogeneity: dispersion of productivity <i>growth</i> in four-digit industry (H_i^G)				Heterogeneity: dispersion of productivity <i>levels</i> in four-digit industry (H_i^L)			Heterogeneity: ln of the inverse share of “close” firms in the product space ($/10, H_i^F$)			
	90 th –10 th percentiles	95 th –5 th percentiles	Standard deviation	Std dev after trimming	90 th – 10 th percentiles			IT weighted			Un- weighted
Industry	Full sample				Full sample	High- tech	Low- tech	Full sample	High- tech	Low- tech	Full sample
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Heterogeneity	0.251 (0.115)	0.142 (0.069)	0.231 (0.132)	0.870 (0.316)	0.090 (0.062)	0.271 (0.092)	-0.064 (0.090)	0.063 (0.031)	0.098 (0.048)	0.019 (0.037)	0.055 (0.035)
Proximity to frontier	0.164 (0.028)	0.168 (0.029)	0.152 (0.028)	0.165 (0.028)	0.153 (0.028)	0.222 (0.041)	0.100 (0.044)	0.159 (0.028)	0.208 (0.039)	0.104 (0.043)	0.146 (0.027)
Firm age<5 years	0.174 (0.041)	0.173 (0.041)	0.171 (0.041)	0.173 (0.041)	0.171 (0.041)	0.211 (0.059)	0.121 (0.056)	0.177 (0.041)	0.214 (0.060)	0.123 (0.056)	0.173 (0.041)
5 ≤ Firm age<10 years	0.066 (0.022)	0.067 (0.022)	0.067 (0.022)	0.066 (0.022)	0.068 (0.022)	0.067 (0.032)	0.049 (0.029)	0.067 (0.022)	0.068 (0.032)	0.049 (0.029)	0.067 (0.022)
10 ≤ Firm age<20 years	0.040 (0.019)	0.041 (0.019)	0.040 (0.019)	0.040 (0.019)	0.039 (0.019)	-0.009 (0.027)	0.083 (0.028)	0.041 (0.019)	-0.005 (0.027)	0.082 (0.028)	0.040 (0.019)
Lerner index	-0.733 (0.136)	-0.750 (0.137)	-0.708 (0.134)	-0.743 (0.136)	-0.725 (0.132)	-0.952 (0.172)	-0.534 (0.217)	-0.721 (0.136)	-0.895 (0.168)	-0.544 (0.218)	-0.697 (0.133)
Industry dummies	yes (73)	yes (73)	yes (73)	yes (73)	yes (73)	yes (52)	yes (42)	yes (73)	yes (52)	yes (42)	yes (73)
Observations	3,570	3,570	3,570	3,570	3,570	1,767	1,803	3,570	1,767	1,803	3,570

NOTES: All coefficients are marginal effects from probit maximum likelihood estimation. Robust standard errors corrected for arbitrary variance-covariance matrix at the four-digit industry level in parentheses. In column (1) the measure of heterogeneity is the difference between the productivity *growth rate* for the firm at the 90th percentile less the 10th percentile; in column (2) it is the 95th percentile less the 5th percentile; in column (3) it is the standard deviation of productivity growth rates and in column (4) it is the same as column (2) except we trim the bottom and top 5% of productivity growth distribution in each four-digit industry. In columns (5) to (7) the measure of heterogeneity is the difference between the productivity *level* for the firm at the 90th percentile less the 10th percentile. In columns (8) to (10), the heterogeneity measure is the log of the inverse of the share of IT weighted “close” firms in the product space; whereas in column (11) these firms are not IT weighted. Full set of firm and industry level controls included as in Table II column (4); see text for variable definitions.

TABLE IV
DETERMINANTS OF DECENTRALIZATION: ALTERNATIVE MEASURES OF DECENTRALIZATION
(ENQUÊTE REPONSE)

Dependent variable Specification of proximity to frontier Industries	Decentralization of investment decisions, 1998			Some delayering between 1996 and 1998					
	Level			Level			Growth rate		
	Full sample (1)	High - tech (2)	Low- tech (3)	Full sample (4)	High - tech (5)	Low- tech (6)	Full sample (7)	High - tech (8)	Low- tech (9)
Heterogeneity (H_t^G)	0.108 (0.165)	0.455 (0.235)	-0.127 (0.415)	0.355 (0.185)	0.398 (0.283)	0.075 (0.301)	0.434 (0.200)	0.396 (0.304)	0.102 (0.294)
Frontier (99 th percentile)	-0.110 (0.054)	-0.249 (0.079)	0.021 (0.103)	-0.115 (0.051)	-0.152 (0.080)	0.011 (0.086)	-0.058 (0.048)	-0.078 (0.064)	-0.043 (0.067)
Labour productivity (firm)	0.072 (0.052)	0.064 (0.077)	0.104 (0.075)	0.126 (0.056)	0.118 (0.072)	0.066 (0.081)	-0.056 (0.101)	0.164 (0.157)	-0.137 (0.109)
Firm age<5 years	-0.036 (0.056)	-0.016 (0.080)	-0.027 (0.092)	0.183 (0.088)	0.099 (0.113)	0.275 (0.129)	0.054 (0.107)	0.102 (0.171)	0.017 (0.114)
5≤Firm age<10 years	-0.007 (0.048)	-0.044 (0.074)	0.022 (0.061)	0.047 (0.056)	-0.007 (0.064)	0.076 (0.084)	0.034 (0.059)	-0.031 (0.068)	0.095 (0.090)
10≤Firm age<20 years	0.004 (0.040)	-0.015 (0.059)	0.026 (0.054)	0.069 (0.039)	0.059 (0.054)	0.068 (0.055)	0.072 (0.040)	0.056 (0.053)	0.099 (0.054)
Lerner index	-0.034 (0.009)	-0.046 (0.024)	-0.029 (0.114)	-0.934 (0.288)	-0.166 (0.416)	-0.981 (0.402)	-0.666 (0.257)	0.048 (0.358)	-0.977 (0.359)
Industry dummies	yes (81)	yes (49)	yes (31)	yes (70)	yes (47)	yes (43)	yes (69)	yes (47)	yes (42)
Mean of dependent variable	0.484	0.475	0.493	0.440	0.553	0.325	0.436	0.553	0.320
Observations	1,258	648	610	1,049	526	523	1,011	505	501

NOTES: All coefficients are marginal effects from probit maximum likelihood estimation. Robust standard errors corrected for arbitrary variance-covariance matrix at the four-digit industry level in parentheses. All establishments are part of a large (French or foreign) group but are not Head Quarters. Heterogeneity is defined as the dispersion of productivity growth rates within a four digit industry (the 90th percentile less the 10th percentile). Full set of firm and industry level controls included as in Table II column (4); see text for variable definitions.

TABLE V
DETERMINANTS OF DECENTRALIZATION IN BRITAIN
(BRITISH WERS98)

Dependent variable (mean=0.805)	Decentralization of employment decisions					
	(1)	(2)	(3)	(4)	(5)	(6)
Heterogeneity (H_l^G) (95 th – 5 th percentiles)	0.273 (0.130)	-	-	-	0.316 (0.129)	-
Heterogeneity (H_l^G) (90 th – 10 th percentiles)	-	0.540 (0.325)	-	-	-	0.659 (0.312)
Frontier (99 th percentile)	-	-	-0.051 (0.073)	-	-0.204 (0.073)	-0.156 (0.073)
Establishment age < 5 years	-	-	-	-0.076 (0.115)	-0.099 (0.116)	-0.123 (0.114)
5 ≤ Est. age < 10 years	-	-	-	0.086 (0.081)	0.055 (0.089)	0.049 (0.089)
10 ≤ Est. age < 20 years	-	-	-	-0.127 (0.077)	-0.164 (0.076)	-0.173 (0.075)
Many competitors	-	-	-	-	0.127 (0.082)	0.150 (0.078)
Few competitors	-	-	-	-	0.210 (0.070)	0.228 (0.065)
No competitors	-	-	-	-	<i>ref</i>	<i>ref</i>
Other firm and industry controls	no	no	no	no	yes	yes
Industry dummies	yes (64)	yes (64)	yes (64)	yes (64)	yes (64)	yes (64)
Observations	236	236	236	236	236	236

NOTES: All coefficients are marginal effects from probit maximum likelihood estimation. Robust standard errors corrected for arbitrary variance-covariance matrix at the four-digit industry level in parentheses. Data are from the 1998 British Workplace Employee Relations Survey (WERS); they include manufacturing establishments only. Dependent variable is a dummy variable indicating whether “Establishment’s manager is able to make decisions on which staff to recruit without consulting Head Office”. Heterogeneity and frontier are averaged between 1994 and 1997. All regressions include a control for employment size (current, lagged one year and lagged five years), the proportion of young workers (under 20 years old), the proportion of older workers (aged over 50 years old), the proportion of unskilled manual workers and the proportion of part-time workers. See text for variable definitions.