The MIT Press

Skill-Biased Organizational Change? Evidence from a Panel of British and French Establishments
Author(s): Eve Caroli and John van Reenen
Source: *The Quarterly Journal of Economics*, Vol. 116, No. 4 (Nov., 2001), pp. 1449-1492
Published by: The MIT Press
Stable URL: http://www.jstor.org/stable/2696464
Accessed: 28/10/2010 12:27

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at http://www.jstor.org/page/info/about/policies/terms.jsp. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at http://www.jstor.org/action/showPublisher?publisherCode=mitpress.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

The MIT Press is collaborating with JSTOR to digitize, preserve and extend access to *The Quarterly Journal of Economics.*

http://www.jstor.org

SKILL-BIASED ORGANIZATIONAL CHANGE? EVIDENCE FROM A PANEL OF BRITISH AND FRENCH ESTABLISHMENTS*

EVE CAROLI AND JOHN VAN REENEN

This paper investigates the determination and consequences of organizational changes (*OC*) in a panel of British and French establishments. Organizational changes include the decentralization of authority, delayering of managerial functions, and increased multitasking. We argue that *OC* and skills are complements. We offer support for the hypothesis of "skill-biased" organizational change with three empirical findings. First, organizational changes reduce the demand for unskilled workers in both countries. Second, *OC* is negatively associated with increases in regional skill price differentials (a measure of the relative supply of skill). Third, *OC* leads to greater productivity increases in establishments with larger initial skill endowments. Technical change is also complementary with human capital, but the effects of OC is not simply due to its correlation with technological change but has an independent role.

I. INTRODUCTION

Over the past decades, the organization of work inside firms has experienced dramatic changes in most industrialized countries. As distinct from earlier transformations (see Chandler [1962]), recent changes have been characterized by a trend toward less hierarchy and more flexible organizational forms. This move generally involves employees performing a wider range of tasks and being awarded more responsibility.[1] As emphasized by management specialists, organizational changes have led to more workplace decentralization. It is generally believed that these changes require a higher level of human capital from individual workers since they need to deal effectively with increased uncertainty and responsibility. Although there exists a wealth of case studies on such organizational changes, there is little quantita-

* We would like to thank Thomas Coutrot, Thibaut Desjonqueres, Madior Fall, Nathalie Greenan, Francis Kramarz, David Thesmar, and Jean-Marc Robin who provided great help with the data. We are grateful to Edward Glaeser, Lawrence Katz, and one anonymous referee for a great number of helpful comments. In addition, Daron Acemoglu, Philippe Askenazy, Timothy Bresnahan, David Card, Emmanuel Duguet, Richard Freeman, James Heckman, Thomas McCurdy, Stephen Nickell, John Pencavel, Kathryn Shaw, Scott Stern, Mathias Thoenig, and participants in numerous seminars have offered helpful suggestions.

1. For an overview on work restructuring in Europe see European Foundation [1998]. For other developed countries OECD [1999] or Caroli [2001] have surveys. For quantitative evidence see Osterman [1994] for the United States, NUTEK [1999] for Nordic countries, and Coutrot [1996] for France.

© 2001 by the President and Fellows of Harvard College and the Massachusetts Institute of Technology.

The Quarterly Journal of Economics, November 2001

tive evidence across a broad range of establishments. The main purpose of this paper is to provide some econometric evidence on what we term "skill-biased organizational change"—the hypothesis that modern organizational changes are complementary with skilled workers.

Traditionally, economics has tended to treat the internal organization of the firm as a "black box."[2] Yet recently there has been an upsurge of interest into peering into the void. This has appeared in several related literatures. Most influentially, Milgröm and Roberts [1990] provide a systematic theoretical treatment of complementarity in organizations based on the supermodularity properties of profit functions. In a subsequent paper [1995] they model more specifically the clustering of practices resulting from the complementarity between technological innovation, organizational changes directed toward greater functional flexibility, and a higher skill level of the workforce.

The idea that technological change, organizational change, and skills may be joint determinants of firms' performance has been taken up in the empirical debate regarding the so-called "productivity paradox." A commonly cited reason for the apparent failure of huge investments in computers to result in significant increases in productivity (until recently)[3] is that companies lack the necessary organizational structures that facilitate the introduction of new technologies. Without the organizational and skills infrastructure, technology alone is not enough.

Despite these conjectures, the literature on innovation has mainly focused on technical change and its impact upon skills and productivity, and little attention has been paid to organizational change. A host of studies have found evidence for skill-biased technical change, although there is fierce argument over the extent to which the decline in the wage and employment prospects of less skilled workers is due to recent advances in information technologies (e.g., Autor, Katz and Krueger [1998] and Machin and Van Reenen [1998]).[4] In parallel, some theorists argue that the observed upskilling of the within-firm occupa-

2. Of course, the classical tradition of such diverse economists as Adam Smith and Karl Marx placed a great emphasis on organizational matters. Alfred Chandler revived interest in the 1960s. The classical tradition survived in the sociology of organizations, as well as institutional and evolutionary economics.

3. See Brynjolfsson and Yang [1996], for a survey. It may be that the productivity growth of the U. S. economy in the last few years has resolved the paradox, although the jury is still out.

4. Other studies have emphasized the role of trade and labor market insti-

tional structure and rising wage inequality may also have been generated by the recent move toward decentralization in work organization.[5] There is however, little empirical evidence regarding the determinants and consequences of such organizational changes. The reason for this lack of attention is mainly data-driven, as it is extremely difficult to empirically proxy organizational changes. A few papers attempt to analyze correlation patterns of "reorganized" enterprises putting forward a series of common features that include size, product market conditions, technical intensity, and human resource policies.[6] Some others have also focused on the consequences of organizational change for productivity[7] but there have been very few attempts to focus directly on skills. Recent exceptions are Greenan [1996] who examines French firms, and Cappelli [1996] and Bresnahan, Brynjolfsson, and Hitt [2002] who examine U. S. firms. All three papers argue for some complementarity between technological change, organizational changes, and skills. Unfortunately, none of these papers has access to data where it is possible to follow the impact of past incidents of organizational change on future employment and productivity outcomes over a number of years. This is one of the main contributions of the current paper.

This paper provides empirical evidence regarding the relationships between organizational change and skills. We argue that the existence of complementarities between organizational change and skills leads to three empirical predictions: (i) organizational change should be followed by a declining demand for less skilled labor; (ii) falls in the relative cost of skills should increase the probability of organizational change; and (iii) organizational changes should have a larger impact on productivity in workplaces with higher levels of skills. We test (and find support for) each of these predictions in our econometric analysis. We also find some support for skill-biased technical change (stronger in Britain than France), but less robust evidence on complementarity between organizational and technical change.

The paper is organized as follows. Section II presents some

tutions (see Wood [1994] and Di Nardo, Fortin, and Lemieux [1996] for examples of these alternative perspectives).

5. See Aghion, Caroli, and Garcia-Peñalosa [1999] for a survey.

6. See Osterman [1994] on U. S. data, Machin and Wadhwani [1991] and Nickell and Nicolistas [1996] on U. K. data; Coutrot [2000] on French data.

7. Some examples are Ichniowski, Shaw, and Prennushi [1997], Black and Lynch [1997], and Cappelli and Neumark [1999].

theoretical considerations regarding skill-biased organizational change. Section III outlines the econometric model. Section IV discusses the data paying particular attention to how we measure organizational change. The results are presented and discussed in Section V, and some concluding comments are offered in Section VI.

II. Skill-Biased Organizational Change: Some Theoretical Considerations

II.A. Organizational Changes

Recent changes in work organization signal a move away from mass production and bureaucratic controls (the so-called "Taylorist" organizations) toward more flexible forms of organization. New work practices have been introduced, that are often characterized as "high performance" [OECD 1999]. These new forms of organization are very diverse, ranging from Total Quality Management and Just-in-Time to job rotation, team working, and change in job design involving multitasking [Greenan and Mairesse 1999].

One common feature of ongoing organizational changes is that they most often involve some decentralization of authority, in accordance with "lean production" principles [Womack, Jones, and Roos 1991]. New organizations are characterized by a shorter chain of command with some decision-making being transferred downstream. This benefits either individuals themselves or more formal teams of workers. Whatever the precise pattern of delegation, it leads to more responsibility being given to lower level staff. As authority is decentralized, the hierarchical structure gets flatter. Intermediate layers of control atrophy, and communication, hence efficiency, can be improved through delayering [Boyer et al. 1998].

The focus of the paper is on organizational changes as characterized by delegation of responsibility and delayering within organizations, i.e., *decentralization of authority* within firms.

II.B. The Benefits and Costs of Decentralization

A simple theory of new forms of organization considers that there are benefits and costs to decentralization and that the trade-off between both will determine the extent to which firms will introduce organizational changes.

The benefits from decentralization arise from at least four sources. First, decentralizing decision-making reduces the costs of information transfer and communication. In a hierarchical organization, information that has been processed at lower levels of the hierarchy has to be transferred upstream. This induces a cost due to the need that information be codified and then received and analyzed at various levels [Bolton and Dewatripont 1994]. When decision-making is decentralized, information is processed at the level where it is used so that the cost of communication is lower. Second, decentralization increases firms' reactivity to market changes [Thesmar and Thoenig 1999]. One reason for this is that hierarchical organizations are characterized by a high degree of specialization of workers. Any response to market changes involves the coordination of a great number of activities so that overall firm's reaction speed is low. When responsibility is transferred downstream, it is most often delegated to teams of workers, generally involved in multitasking [Lindbeck and Snower 1997]. This allows a quicker reaction to market changes given that coordination involves a limited number of multiskilled workers. A third benefit to decentralization comes from the reduction in the cost of monitoring. This is a consequence of delayering: as intermediate layers of control disappear, the related cost decreases. Finally, decentralization of decision-making may increase productivity through rising job satisfaction. Delegation of responsibility goes along with more employee involvement, greater information sharing and a greater participation of lower level staff [OECD 1999]. To the extent that this leads to job enrichment, organizational changes may make workers more satisfied.

Turning to the costs of decentralization, we highlight four of them. First, costs arise from the risk of duplication of information in the absence of centralized management [Greenan and Guellec 1994]. Workers are now in charge of analyzing new pieces of information. As delegation of responsibility and delayering take place, the risk of replication in information processing increases, both across individuals and across teams. A related risk is that of an increase in the occurrence of mistakes. As specialized monitors disappear, less direct controls are exercised in the course of the production process, and the risk of error is then enhanced. A third cost is due to decentralization making it more difficult to exploit increasing returns to scale [Thesmar and Thoenig 2000]. The reason for this is that as multitasking develops, returns to spe-

cialization decrease so that large-scale production becomes less beneficial. Eventually, decentralization may reduce workers' efficiency if the increase in responsibility that it implies induces rising stress and even increasing occupational injuries [Askenazy, Caroli, and Marcus 2001]. In this case, productivity may be directly affected and reduced through lower job satisfaction.

When confronted with the question of whether to introduce organizational changes, firms will balance the costs and benefits of decentralization. Organizational changes will then be complements to skills to the extent that the latter improve the trade-off between the advantages and drawbacks of the transfer of authority.

II.C. Skill-Biased Organizational Change

There is little theoretical literature on how firms' endowment in skilled labor actually impacts the benefits and costs of decentralization. However, one can put forward three hypotheses. First, skills raise the ability to handle information. Skilled workers are more able to analyze and synthesize new pieces of knowledge so that the benefits of the local processing of information is enhanced when the labor force is more highly skilled [Caroli, Greenan, and Guellec 2001]. At the same time, skilled workers are better at communicating which reduces the risk of duplication of information [Zammuto and O'Connor 1992]. Second, the cost of training them for multitasking is also reduced which enhances firm's reactivity to market changes. Another effect has to do with skilled workers being more autonomous and less likely to make mistakes [Scott 1981]. As a consequence, the potential cost associated with less direct and specialized monitoring is lower when production workers are more highly skilled. Finally, workers who are better educated may be more likely to enjoy job enrichment, partly because they expect more from their job in terms of satisfaction and partly because they may be less subject to work injuries due to a lower rate of mistakes.

The main conclusion of the foregoing analysis is that a higher skill level of the workforce tends to reduce the costs and increase the benefits of decentralization. In other words, skills appear to complement organizational change. This has three main implications that characterize "skill-biased" organizational change.

(i) Organizational changes lead to skill upgrading within firms. This is due to the fact that the return to new work

practices is greater when the skill level of the workforce is higher.

(ii) All other things equal, a lower price of skilled labor will accelerate the introduction of organizational changes.

(iii) Skill-intensive firms will experience greater productivity growth when introducing organizational changes for the same reason as in (i). This prediction only holds if it is assumed that all firms have not yet implemented the optimal combination of factors. Otherwise, the demand for skills and organizational change (as expressed in (i) and (ii)) would reflect the optimal relationship between both inputs. Following most of the literature on the subject,[8] we assume that choices made by managers are subject to some optimization errors. Either they do not have perfect information nor understanding of the potential benefits to be drawn from organizational changes, or there are some lags or adjustment costs in the implementation of the optimal strategies. In such cases, the production function approach contains additional information.

II.D. The Timing of Organizational Changes

The last issue raised by skill-biased organizational changes is that of its chronology. Why did the move away from a Taylorist organization toward a decentralization of authority take place during the past two decades? The first reason is the increase in the supply of human capital that has occurred in most OECD countries. In France this has been accompanied by falling wage differentials, although in Britain (like the United States) the educational premium fell in the 1970s, but rose in the 1980s. The above theoretical considerations indeed predict that increases in the relative supply of skilled labor should induce firms to introduce organizational changes. A second reason has to do with the development of information and communication technologies (ICTs). The introduction of ICTs reduces the cost of decreasing direct control of workers since it allows for indirect, computer-based monitoring of ex post performance. Moreover, it also reduces the cost of lateral communication among line workers and

8. Black and Lynch [1997] and Cappelli and Neumark [1999] make the same assumption. So do Bresnahan, Brynjolfsson, and Hitt [2002] who extensively discuss this point.

increases their ability to process information [Radner 1993]. This reduces the benefit of hierarchical decision, thus making firms more willing to decentralize authority [Van Zandt 1997].

In this paper we investigate the theoretical implications derived from subsection C. We examine skill-share equations (is there skill upgrading following organizational change?); the determinants of organizational change (do decreases in the relative market price of skills increase the probability of organizational change?); and productivity growth (does organizational change combined with high skills have a particularly strong effect on productivity?). We do this taking into account the possible interaction between technological and organizational changes.

III. Econometric Modeling Strategy

We have constructed two data sets in Britain and France combining information on individuals' skill characteristics and on plant organization. The advantage of using two countries is that if any robust results can be generated in both nations then they are more likely to arise from economic fundamentals than from specific institutional features or peculiarities of one data set.

III.A. The Demand for Skills and Organizational Change

To put these issues in a familiar setting, we consider a translog cost function with the only variable inputs being different types of labor (indexed by skill group f). We assume that there is a factor, K, which will be denoted as "organizational capital" (we discuss the introduction of other types of capital below) and that it is fixed in the short run. We can easily derive a series of f variable cost share equations of the familiar form,

$$(1) \quad S_f = \beta_f + \beta_{ff} \ln W_f + \sum_{g, f \neq g} \beta_{fg} \ln W_g + \beta_{fK} \ln K + \beta_{fY} \ln Y + \omega_f,$$

where S_f is the wage bill share of skill group f, Y denotes value added, W_f is the wage rate of each factor f, and ω_f is an error term. The hypothesis that a skill group is complementary to "organizational capital" is essentially a test that $\beta_{fK} > 0$. Constant returns to scale implies that $\beta_{fK} = -\beta_{fY}$.

There are a large number of econometric problems with estimating equation (1). First, unobserved heterogeneity is likely to be a major problem. For example, establishments' more dynamic managers (per-

manently higher ω_f in the high skill share equation) may find it easier to introduce organizational change and rely less on unskilled employees. For this reason, we estimate the cost share equations in (long) differenced form to remove the correlated fixed effects:

$$(2)\quad \Delta S_f = \beta_{ff}\,\Delta \ln W_f + \sum_{g,f\neq g} \beta_{fg}\,\Delta \ln W_g + \beta_{fK}\,\Delta \ln K + \beta_{fY}\,\Delta \ln Y + \Delta\omega_f,$$

where Δ is the long difference operator.

Second, organization is not the only form of capital of influence on cost shares. Technological change, such as the introduction of new technologies and other forms of information technology are a particular concern. K could be considered as a vector $(K_1, K_2, \ldots)$ of different quasi-fixed factors.[9] In Britain we do not have good measures of the changes in output or the physical capital stock, so we have to assume, after taking out the fixed effects and time dummies, that these are proxied by changes in total employment and industry dummies. In France we measure firm-level capital stocks and value added. For both countries we also consider other variables such as the establishment size, ownership status (e.g., public sector), union power, and demand conditions.[10] Moreover, we compare the wage bill share equations with employment share equations to check that results are being driven by changes in the quantities rather than the factor prices. A third problem is that changes in many of the variables and in particular organizational capital are not observed as continuous variables but rather as qualitative indicators. We treat this as a measurement issue (i.e., $OC = 1$ if there is an organizational change and zero otherwise), but of course there is a deeper issue of whether discreteness is inherent in this form of "capital" where marginal changes may not be possible.

Fourth, and perhaps most importantly, OC is likely to be endogenous [Athey and Stern 1998]. For example, an unfavorable demand shock (negative $\Delta\omega$) can induce a firm to simultaneously lay off unskilled workers and reorganize the company. To try to mitigate these problems, we focus on using lagged values of organizational change. In Britain we have information on the

9. We also consider interactions between these quasi-fixed factors in the result section.

10. We also experimented with measures of Joint consultative committees, financial performance, plant age, pay incentive schemes, gender composition, whether the plant was standing alone or part of a larger group, and many others. See detailed table notes.

change in skill shares between 1984 and 1990, and we regress these on organizational changes introduced between 1981 and 1984. In France we have information on changes in the skill shares between 1992 and 1996, and we regress these against organizational changes occurring between 1989 and 1992. If anything, this should bias us against finding any significant effects of *OC*. Since there are similar issues for the other controls, we also use lagged values of these variables. The shortness of the panel makes it difficult to deal with endogeneity biases using longer lags as instruments, but we report a series of experiments checking the sensitivity of the findings to alternative specifications. Finally, we generally replace the wage terms on the right-hand side of equation (2) with region-year specific dummy variables.

Our basic skill share equations are

$$(3)\quad \Delta S_{fit} = \beta_{fo} OC_{it-1} + \alpha_1 TECH_{it-1} + \beta_{fK} \Delta \ln K_{it} + \beta_{fY} \Delta \ln Y_{it} + \alpha_2' x_{it-1} + \gamma_1' IND_j + \gamma_2' REG_k + u_{fit},$$

where f indexes the skill group, i the establishment, j the industry, k the region, and t the period and where *OC* denotes organizational change. *TECH* denotes technology (see below), K and Y, respectively, denote physical capital and value added, x is a vector of establishment's characteristics and *IND* and *REG* are industry and regional dummies.

III.B. The Determinants of Organizational Change

A second equation of considerable interest has to do with the determinants of organizational change (*OC*). The theories discussed in Section II argue that the supply of skills is a key factor driving *OC*. In particular, if skills are complementary to organizational design, then decreases in the relative cost of skilled workers should make it more likely that an establishment will introduce organizational changes. To investigate these ideas, we estimate "organizational change" probits of the form,

$$(4)\quad y_{it}^* = \alpha(\ln W^{HIGH} - \ln W^{LOW})_{kt} + \beta' x_{it} + \delta' TECH_{it} + \gamma' IND_j + v_{it},$$

where y^* is the propensity to introduce organizational change and

$$OC_{it} = 1 \text{ if } y_{it}^* > 0$$
$$OC_{it} = 0 \text{ otherwise.}$$

ln W^{HIGH} refers to the mean log hourly wage for highly educated individuals in the region k where the establishment is located, and ln W^{LOW} is the mean log hourly wage for less educated individuals. More specifically, ln W^{HIGH} is the average log hourly wage of workers with a A level or college degree in Britain and of workers with a Baccalaureate or college degree in France. Correspondingly, ln W^{LOW} is the average log hourly wage of low education workers (O level or equivalent and below in Britain and some high-school education and below in France). The technology variable *TECH,* establishment characteristics x, and industry dummies *IND* are the same as in the skill share equation.

Grouping the wage differentials by region is natural. Within European countries there are distinct local labor markets due to costs of geographical mobility.[11] Even after correcting the standard errors for cluster level effects (e.g., Moulton [1986]), there may be econometric problems with the skill price variables relating to endogeneity. For example, a shock that increases the proportion of plants in a region introducing organizational change may drive up the wages of skilled workers, pushing the coefficient of interest, α, in a positive direction. Also, if a region has skilled workers of above average ability, measured wage differentials will be higher, and organizational change more likely. This will again bias our estimated α. Since we believe the true value of the coefficient to be negative, both of these endogeneity problems will cause a bias toward zero, making it harder to reject the hypothesis that "cheap skills" have no effect on organizational change. The empirical section will consider a variety of approaches to dealing with this problem including the use of regional fixed effects and alternative measures of relative supply (proportion of educated individuals in a region).

III.C. Productivity and Organizational Change

In addition to the wage bill share equations and the *OC* equation, there are several other equations that could be investigated.[12] Of most interest is direct evidence of complementarity from the production function. We are interested in the interac-

11. About 3 percent of U. S. households change their region of residence in a year, compared with 1 percent in Britain, France, and Germany [OECD 1990, Table 3.3].

12. The technology choice equation has been analyzed in Britain in some detail in previous work (e.g., Chennells and Van Reenen [1997]). We present some results in Table VI.

tions between skills, technology, and organizational change. In France we estimate long-differenced production functions (1992–1996) whose most general form is

$$\begin{aligned}(5)\quad \Delta \ln Y_{it} = {} & \lambda_0 \Delta \ln K_{it} + \lambda_1 \Delta \ln L_{it} + \lambda_2 OC_{it-1} + \lambda_3 SKILLS_{it-1} \\ & + \lambda_4 TECH_{it-1} + \lambda_5 (OC * SKILLS)_{it-1} \\ & + \lambda_6 (SKILLS * TECH)_{it-1} + \lambda_7 (OC * TECH)_{it-1} \\ & + \lambda_8' z_{it-1} + e_{it},\end{aligned}$$

where Y is value added, K is capital, L is labor, $SKILLS$ indicates labor quality, and z_{it-1} a set of other lagged controls. We are particularly interested in the signs of the interaction terms. For example, if OC is more productive when introduced in skill-rich plants, we expect $\lambda_5 > 0$. We also present models where we estimate separate production functions for the plants exhibiting organizational change allowing all the coefficients in (5) to differ with OC status. Unfortunately, the statistical authorities have not yet matched in investment and value added in the British establishment data, so equation (5) is estimated for France only.

IV. Data

IV.A. British Data

The data that we use come from several databases, as it is necessary to combine information on organizational change, establishment characteristics, and skills. Information on organizational practices is very rare. One rich source of detailed establishment level data is the British Workplace Industrial Relations Survey (WIRS). It consists of a cross section of over 2000 British establishments in 1984 and 1990. This has been extensively used by labor economists to examine the effects of the structure of industrial relations on economic outcomes, such as the size of the union wage markup (e.g., Stewart [1990]). There are a number of questions in WIRS which relate to organizational change in 1984 and a limited follow-up in 1990 which asks more basic information. In both surveys, senior managers have been asked the following question: *Would you look at this card and tell me which, if any, of these changes you have made during the last three years directly affected the jobs or working practices of the manual workforce.*

A. *The introduction of new plant, machinery or equipment that includes new micro-electronic technology (TECH > 0)*
B. *The introduction of new plant, machinery or equipment not including new micro-electronic technology (CC)*
C. *Substantial changes in work organization or working practices not involving new plant, machinery or equipment (OC)*

[Underlining in original].

If managers answered "yes" to *C* (note that they could answer "yes" to any or all of *A, B,* or *C*) the establishment was coded to have *OCMAN* = 1. An identical question was asked for nonmanual workers[13] (*OCNMAN*). We created the variable *OC* = 1 if there was either manual or nonmanual organizational change. In 1990 the *OCMAN* question was identical. For nonmanual workers the question was phrased slightly differently in 1984 as it applied to "office workers," whereas in 1984 it applied to any nonmanual employees (for more details see the Data Appendix).

There are two main advantages of using these data. First, organizational change is clearly distinguished from technical change (question A) and physical investment (question B). The different types of change often occur in the same plants (see Appendix 2). Second, there is a time series element to the data including both a repeated cross section, and a panel for a subsample of the establishments. On the negative side, the WIRS questions are asked of a very specific group of employees—senior managers. This could generate a bias with managers being, for example, overoptimistic about the performance of the firm. However, detailed comparisons between their answers and those given by a workers' representative to identical questions in WIRS have revealed substantial agreement as to the occurrence of an organizational change [Millward 1993].

A second source of measurement difficulty regards the nature of organizational change. Our focus is on organizational changes that imply some delegation of responsibility and delayering within organizations. Is our measure broadly capturing these notions? Fortunately, in 1984 managers were asked

13. A "manual worker" is a production worker, and a "nonmanual worker" a nonproduction worker.

TABLE I
WHAT IS ORGANIZATIONAL CHANGE IN BRITAIN?

OC affecting nonmanuals				*OC* affecting manuals			
A. Have more or less responsibility?							
More	Same	Less	D/K	More	Same	Less	D/K
0.462	0.465	0.029	0.045	0.328	0.571	0.064	0.036
B. Have to work at a more or less skilled level?							
More	Same	Less	D/K	More	Same	Less	D/K
0.504	0.431	0.039	0.026	0.298	0.551	0.110	0.042
C. Effect on range of tasks performed							
Wider	Same	Narrower	D/K	Wider	Same	Narrower	D/K
0.625	0.281	0.058	0.03	0.395	0.450	0.133	0.020
D. Have more interesting or less interesting jobs to do?							
More	Same	Less	D/K	More	Same	Less	D/K
0.639	0.235	0.058	0.070	0.369	0.473	0.101	0.057
E. What happened to staffing or manning levels?							
More	Same	Less	D/K	More	Same	Less	D/K
0.092	0.554	0.346	0.007	0.112	0.417	0.461	0.009

These are the answers given by senior managers to various questions on the effects of organizational change asked in the 1984 WIRS. The questions were only asked if some organizational change had taken place over the past three years. The answers to the questions read as follows. For question A 46.2 percent of managers in the whole sample say that workers (as a whole) had more responsibility following *OC* (that mainly affected nonmanuals). 46.5 percent say responsibility has remained the same, and 2.9 percent say it has decreased. D/K = don't know or not answered. There are 413 (436) observations for the nonmanual (manual) responses.

in more detail what the change actually involved. The answers are tabulated in Table I. Although in many cases the change in organization did not involve any change in responsibility, when it did so a substantial fraction of organizational changes lead to more responsibility (almost half of all incidents for nonmanuals and about a third for manuals). There were practically no examples of *OC* leading to decreases in responsibility. Reading down the table, it also appears that organizational change is more likely to be associated with a widening range of more interesting tasks performed by workers. Downsizing (employment falls) generally follows organizational change.

Overall then, although the measure is far from perfect, it does seem to broadly capture the type of organizational changes that we consider important from a theoretical perspective. Perhaps the most relevant part of Table I however, is the question relating directly to the effect of organizational change on the skill level in the establishment (row B). It shows that managers were

far more likely to state that organizational change increased, rather than decreased, the level of skill requirements.[14]

A variety of indicators are used to control for technical change (see the Data Appendix for details). First, we use the question on advanced technical change asked at the same time as the *OC* question. We define a binary variable ($TECH > 0$) indicating whether new technologies have been introduced in the establishment over the last three years. There is information on the proportion of workers who were using microelectronic technologies in the establishment if there was some technical change (*TECH*). In addition to this variable we also include the change in the proportion of workers in the two-digit industry using microelectronic technologies between 1985[15] and 1990 (ΔIND_TECH) and a variable indicating whether a plant introduced (or removed) microcomputers in the 1984–1990 period ($\Delta COMP$). Technical and organizational changes often occur together. For example, in 1984, 18 percent of workers were using new technology (*TECH*) in plants that introduced *OC,* compared with only 10 percent of workers in plants that had not introduced *OC* (see also in Appendix 2). Although our first-order concern is that any effect we identify is not merely proxying for unmeasured technical change, we also investigate interactions between technical change and *OC* in the results section.

The second data source we use is the GHS (General Household Survey). This contains information on earnings as well as education and occupation. It is the closest equivalent in Britain to the U. S. Current Population Survey. Using the GHS, we calculated the region-year specific weekly earnings for each of the six occupational skill groups used in the analysis and used these to calculate the wage bill shares. We also calculated mean log hourly wages by education group focusing on two groups—highly educated people with college degrees or *A* levels and low educated people being all others (roughly, O levels/GCSEs and below).

14. It should be noted that these results are not driven by the fact that some plants experiencing organizational change also experienced technical change. Conditioning on the establishments which had organizational but not technical change we find that 56 (25) percent increased responsibility compared with 3 (2) percent who decreased following nonmanual (manual) *OC.* The equivalent figures for skills are 38 (22) percent increase versus 5 (6) percent decrease; for range of tasks: 63 (37) percent wider versus 5 (10) percent narrower; for manning levels 16 (11) percent more versus 35 (28) percent less.

15. We did not have data on this variable in 1984.

IV.B. French Data

Information about organizational changes is more abundant for France than for Britain.[16] We use the REPONSE (Relations Professionnelles et Négociations d'Entreprise) survey that was explicitly devised with reference to the British WIRS. Twenty-five hundred establishments were surveyed with senior managers being asked questions about industrial relations and organization in 1992. The question on work organization related to the previous three years.

For any of the organizational methods I will mention, would you tell me whether it is already implemented, in the process of being so, being considered or not even thought of, in your establishment?

One of these methods is specifically *delayering*[17]—removing one or more managerial levels, which is very close to the theoretical concept we are trying to measure. Whenever the manager answered that delayering was already implemented or in the process of being so, the establishment was coded as having $OC = 1$ for this method. The main advantage of using these data is the similarity of the WIRS and REPONSE surveys. Both are establishment based, designed to be nationally representative, and contain similar control variables that can be introduced in the regressions. A detailed study carried out by Coutrot [1996] shows that delayering leads to more autonomy being awarded to workers. We also consider some of the other organizational variables—Just-In-Time production, Quality Circles, and Total Quality Management.

The REPONSE survey does not include data on occupational structure. In order to examine employment changes over time, we drew on another survey of employment structure in France, the ESE, which is a stratified random sample of French establishments. About half of the REPONSE establishments that continuously existed between 1992 and 1996 were matched to the

16. Available data sets include "TOTTO" dealing with work organization and technique, conducted by the French Ministry of Labor in 1993, "Changements Organisationnels dans la Production" conducted by the Ministry of Industry in 1993, and "Changements Organisationnels et Informatisation" conducted by the Ministry of Labor in 1997 that both focus on organizational change (see Greenan and Mairesse [1999]).

17. The exact phrasing is "Raccourcissement de ligne hiérarchique, c'est-à-dire suppression d'un niveau hiérarchique intermédiaire."

ESE (1360 plants).[18] The ESE breaks the workforce down into five occupational categories (unskilled manuals, skilled manuals, clerical workers, technicians/middle managers, and senior managers).

In REPONSE, managers are asked about whether a number of new technologies are present in the establishment—robots, micro- and mainframe computers, and numerically controlled machinery. If any of these were present, the managers were asked to estimate what proportion of different skill groups was using them. We use the occupational proportions coupled with this measure to construct *TECH,* an indicator of the proportion of workers using new technologies in the establishment.

The third French data set is the Enquête Emploi (EE), an annual survey of individuals conducted by the French National Statistical Agency, INSEE. The EE is a 1/300 sample of the French population containing information about education levels, occupations, wages, region, industry, and employment status. We define as educated those workers with a college degree or any baccalaureate. All others are considered as low educated. We compute weekly earnings for five occupational groups that we use to calculate wage bill shares. We also compute relative log hourly wages of the higher to the lower educational group at the level of 21 regional cells.

Finally, we needed to obtain data on capital stock and value added. This comes from the Bilans Industriels et Commerciaux database (BIC) containing firm-level information on the historical value of the capital stock, value added, and other information.[19] It is a major advantage having a panel of quantitative measures of firm production activities matched with detailed information on organization in all sectors of the economy. There are very few data sets with this property (examples focused on manufacturing include Black and Lynch [1997] and Cappelli and Neumark [1999] for the United States and Nickell [1996] for Britain).

A number of descriptive statistics are contained in Appendixes 1 and 2. Appendix 1 displays the means of variables from the cross sections in both countries. In Britain organizational

18. Failed matches are due to incomplete sampling and closures between 1992 and 1996.

19. Since BIC data relate to firm-level information rather than plant-level information, we aggregate over the plants when running the production functions (weighting by total employment in 1992). There are very few firms that have more than one plant in REPONSE—only about eight in the final sample.

change affects a substantial proportion of establishments in our sample, and this proportion rose over time. Similarly, new technologies have spread. We also see many of the well-known trends in the British economy—deunionization, downsizing, and privatization.

The proportion of educated workers has risen in both countries (e.g., from 36 percent to 40 percent in the United Kingdom). Consistent with our view of local labor markets, there is a negative correlation between the proportion of highly educated workers in a region and educational wage premiums. In the United Kingdom the correlation is $-.245$, and in France the correlation is $-.256$.

There has been upskilling in both countries. In the United Kingdom the wage bill share of the most skilled group (managers) rose by 3.7 percentage points, and the share of the least skilled group (unskilled manual workers) declined by 1.2 percentage points. In France the share of the most skilled group rose by 1.2 percentage points, and the least skilled group fell by 2.6 percentage points. In both countries the fortunes of the unskilled were much worse when plants introduced organizational change. In the United Kingdom there was an average fall of 2.4 percentage points in plants experiencing *OC* compared with only 0.4 percentage points in those that did not have *OC*. In France the difference is even more marked: -3.4 percent versus -0.2 percent. Although this is consistent with managerial answers in Table I, we have to be cautious about attributing this correlation to "skill-biased organizational change." Appendix 2 presents the correlation matrix between *OC,* technical change, skills change, capital investment, and employment growth. With only one exception (technology and skills in France) there are positive correlations between *OC,* technical change, and skills. The next section essentially probes whether the skills-*OC* relationship is robust when we control for these (and other) variables.

V. Results

V.A. Organizational Change and Changes in Skill Structure

Considerable recent effort has been directed at examining the effect of technology on enterprise skill structure (e.g., Doms, Dunne, and Troske [1997]). In the first part of this subsection, we examine the impact of organizational changes that have been

TABLE II

CHANGES IN WAGE BILL SHARES IN BRITAIN: EFFECTS OF ORGANIZATIONAL AND TECHNOLOGICAL CHANGE

	1984–1990 Change in wage bill share of:					
Mean of dependent variable	−.012	−.001	−.014	−.005	−.005	.037
	Unskilled manuals	Semi-skilled manuals	Skilled manuals	Clerical workers	Supervisors & foremen	Managers & technical staff
A. Basic controls						
OC	−0.047	−0.001	0.014	0.025	0.015	−0.005
	(0.018)	(0.018)	(0.016)	(0.019)	(0.008)	(0.021)
B. Basic controls and technology						
OC	−0.049	0.001	0.022	0.025	0.013	−0.012
	(0.018)	(0.019)	(0.016)	(0.019)	(0.008)	(0.021)
TECH	0.032	−0.021	−0.060	−0.056	−0.003	0.108
	(0.038)	(0.040)	(0.035)	(0.040)	(0.017)	(0.044)
ΔIND_TECH	−0.028	−0.006	−0.076	0.050	0.056	0.004
	(0.050)	(0.052)	(0.045)	(0.053)	(0.023)	(0.058)
ΔCOMP	−0.023	0.004	−0.009	−0.019	0.010	0.037
	(0.014)	(0.014)	(0.012)	(0.014)	(0.006)	(0.016)
C. Extended controls and technology						
OC	−0.056	−0.000	0.029	0.028	0.009	−0.010
	(0.019)	(0.020)	(0.017)	(0.020)	(0.008)	(0.022)
TECH	0.041	−0.033	−0.050	−0.063	−0.004	0.110
	(0.039)	(0.041)	(0.036)	(0.041)	(0.018)	(0.046)
ΔIND_TECH	−0.004	−0.013	−0.080	0.029	0.054	0.014
	(0.050)	(0.053)	(0.046)	(0.053)	(0.023)	(0.059)
ΔCOMP	−0.019	0.002	−0.009	−0.023	0.010	0.039
	(0.014)	(0.015)	(0.013)	(0.015)	(0.006)	(0.016)

Standard errors are in parentheses. Each column presents the results from a separate regression where the left-hand-side variable is the change in the wage bill share between 1984 and 1990 of the indicated skill group. Each panel (A,B,C) corresponds to a different specification. *OC* indicates whether the plant introduced organizational change between 1981–1984. Basic controls include ten regional and nine industry dummies, the change in the log of total employment in the establishment between 1984–1990, and the 1984 share of all skill groups. Technology controls are the average proportion of workers using microelectronic technologies introduced in the establishment over the period 1981–1984 (*TECH*), the change in the average proportion of workers using microelectronic technologies in the two-digit industry between 1985–1990 (*ΔIND_TECH*), and the change in a dummy indicating whether plants had microcomputers (*ΔCOMP*)). Extended controls include the 1984 values of union recognition, financial performance above/below average, U. K. ownership, presence of Joint consultative committee, and lagged size of the establishment. Estimation by weighted OLS—the weights are establishment size and sampling frequency. The number of observations is 378 in all panels.

introduced by U. K. establishments in the 1981–1984 period on the subsequent evolution of skill structures in the 1984–1990 period within the same establishments. Table II reports the results using the WIRS panel to estimate the effects of *OC* introduced between 1981–1984 on the change in the wage bill shares. The first panel (A) presents the conditional correlation between

OC and the change in skill proportions (each column summarizes the results from a separate OLS regression). The only additional controls are the change in total firm size (change in log employment 1984–1990), the initial proportion of the six skill groups in 1984,[20] and a set of regional and industry dummies. The second panel (B) includes the three technology variables, and the third panel (C) includes a full set of conditioning variables.[21]

It is clear that *OC* is associated with a significant shakeout of the least skilled group—unskilled manual workers. Across all specifications there is a negative and significant effect of past organizational change on the change in the wage bill share of unskilled manuals. It is less clear, however, which other groups are increasing their proportions at the expense of the least skilled.

Panel B includes the three controls for technical change. Unsurprisingly, we find evidence for skill-biased technical change at the establishment level (e.g., Haskel and Heden [1999]). The proportion of workers using microelectronic technologies in the establishment (*TECH*) and the computer introduction variable, $\Delta COMP$ have a positive and significant effect on the share of highly skilled workers. The introduction of computers in the plant is also associated with a fall in the proportion of unskilled manuals. The *OC* effect on the least skilled group persists conditional on these variables. Panel C saturates the model by including an extensive list of establishment level controls including financial performance, unionization, size, and ownership and demand variables. The negative effect of *OC* is quite robust to these controls. Including the introduction of new plant and machinery (*CC*) as an additional variable was insignificant in all of the regressions.

Table III considers various robustness tests. An important criticism of the results is that managers may interpret large employment changes as organizational change. Since many of the employment shifts over this period were to reduce unskilled workers, it could be argued that we are merely picking up an identity with the regressions. The force of this criticism is miti-

20. This was to control for the fact that organizational change may be less likely in plants with few skilled workers, and these establishments could have shrunk more rapidly over this period. The *OC* effects are quite robust to the exclusion of these initial conditions.

21. Note that we have conditioned on having nonmissing observations on all the variables to keep the sample size stable across the table. The results are quite robust if we use the larger sample for the specifications with fewer variables (see the working paper version—Caroli and Van Reenen [1999]).

TABLE III

CHANGES IN WAGE BILL SHARES IN BRITAIN: ROBUSTNESS TESTS

	1984–1990 Change in wage bill share of:					
Mean of dependent variable	−.012	−.001	−.014	−.005	−.005	.037
	Unskilled manuals	Semi-skilled manuals	Skilled manuals	Clerical workers	Supervisors & foremen	Managers & technical staff
A. Extended controls and technology						
(i) *OCNMAN*	−0.072	−0.028	0.048	0.029	0.008	0.015
	(0.021)	(0.022)	(0.019)	(0.022)	(0.009)	(0.024)
(ii) *OCMAN*	−0.035	0.024	0.006	0.040	−0.004	−0.032
	(0.023)	(0.024)	(0.021)	(0.021)	(0.009)	(0.023)
B. Technology * *OC* interaction (Extended controls)						
OC	−0.065	−0.040	0.048	0.052	0.007	−0.002
	(0.025)	(0.027)	(0.023)	(0.027)	(0.012)	(0.030)
TECH	0.031	−0.049	−0.028	−0.030	0.004	0.072
	(0.048)	(0.051)	(0.044)	(0.051)	(0.022)	(0.056)
ΔIND_TECH	0.046	−0.069	−0.112	0.055	0.046	0.034
	(0.056)	(0.059)	(0.051)	(0.059)	(0.025)	(0.065)
ΔCOMP	−0.031	−0.006	0.003	−0.020	0.009	0.045
	(0.015)	(0.016)	(0.014)	(0.016)	(0.007)	(0.018)
*OC * TECH*	0.038	0.050	−0.071	−0.093	−0.021	0.098
	(0.077)	(0.081)	(0.070)	(0.081)	(0.035)	(0.090)
*OC *_IND_TECH*	−0.198	0.249	0.123	−0.118	0.037	−0.093
	(0.104)	(0.110)	(0.096)	(0.111)	(0.047)	(0.122)
*OC * ΔCOMP*	0.053	0.040	−0.053	−0.014	0.005	−0.030
	(0.032)	(0.034)	(0.030)	(0.034)	(0.015)	(0.038)
C. Change in employment share (Extended controls and technology)						
Mean of dependent variable	−0.018	0.005	−0.009	−0.005	−0.001	0.026
OC	−0.073	0.010	0.030	0.026	0.009	−0.003
	(0.024)	(0.023)	(0.019)	(0.019)	(0.007)	(0.019)

Standard errors are in parentheses. Specifications are based on Table II. Each panel (A,B,C) corresponds to a different specification. The left-hand-side variable is the change in the wage bill share between 1984 and 1990 of the indicated skill group except in row C where the dependent variable is the change in employment share of the indicated skill group. *OC* indicates whether the plant introduced organizational change between 1981–1984. *OCMAN* = 1 when the organizational change mainly affected manual workers; *OCNMAN* = 1 when *OC* mainly affected nonmanual workers. Basic controls include ten regional and nine industry dummies, the change in the log of total employment in the establishment between 1984–1990, and the 1984 share of all skill groups. Technology controls are the average proportion of workers using microelectronic technologies introduced in the establishment over the period 1981–1984 (*TECH*), the change in the average proportion of workers using microelectronic technologies in the two-digit industry between 1985–1990 (*ΔIND_TECH*), and the change in a dummy indicating whether plants had microcomputers (*ΔCOMP*)). Extended controls include the 1984 values of union recognition, financial performance above/below average, U. K. ownership, presence of Joint consultative committee, and lagged size of the establishment. Estimation by weighted OLS—the weights are establishment size and sampling frequency. Observations are 376 in panel A(i), 348 in panel A(ii), and 378 in panels B and C.

gated by our use of lagged *OC* and also by the fact that managers seemed to understand the difference between employment changes and organizational changes (see Table I). Nevertheless, we attempted to address the problem empirically in several different ways. First, we used the fact that managers were asked to distinguish between organizational changes primarily affecting manual workers (*OCMAN*) and nonmanual workers (*OCNMAN*). If we are merely picking up some kind of identity, then one would expect the downward bias on the *OC* term in the unskilled manual equation to be much larger for *OCMAN* than *OCNMAN*. In Table III we therefore use *OCNMAN* and *OCMAN* as explanatory variables in separate regressions (they are quite highly correlated, so including them together in the same equation results in collinearity problems). It is clear from panel A that *OCNMAN* has the strongest negative effect on the demand for unskilled workers and not *OCMAN,* as would be the case if we were picking up some form of identity.

Second, to check that our *OC* results are not simply downsizing in disguise, we split the sample into those plants where total employment shrank 1984–1990 ("downsizers") and those where it rose. In fact, the negative *OC* effects on the unskilled were stronger in the growing plants (coefficient of −.072 with standard error of .032) than in the shrinking plants (−.021 with a standard error of .035). Finally, we also looked at another, more specific indicator of *OC*. A question (only asked in 1984) directly asks managers whether they have made any changes to increase employee involvement. Although this is much more specific than the main *OC* question, the pattern of results using this question instead of the *OC* question were similar.[22]

Interactions between *OC* and the different technology indicators were also included in the skill share equations. A representative example is in panel B of Table III. As can be seen, there is little consistent pattern. For example, in the unskilled manual share equations the interaction of $OC * \Delta IND_TECH$ is negative as expected, but the interactions between $OC * \Delta COMP$ and $OC * TECH$ are perversely positive. However, none of these are

22. "Has the management made any changes in the last 4 years with the aim of increasing employees' involvement in the operation of the establishment?" Forty-three percent answered "yes." The coefficient (standard error) of the involvement variable in the unskilled workers equation was −.030(.015) in panel A, −.032(.015) in panel B, and −0.031(0.016) in panel C of Table II. It was insignificant in all other skill share equations.

significant at the 5 percent level. Similar ambiguity holds for France below.

The impact of *OC* appears to be mainly driven by employment shifts rather than wage changes, as we would expect from theory. This is illustrated for the most general model in panel C of Table III. All results are robust to including a variety of other variables including a measure of outsourcing, two-digit industry dummies, hourly wage terms,[23] and different treatment of outliers.[24]

Table IV holds the results on the effects of organizational change on wage bill shares for France. The table is similar in structure to the U. K. results in Tables II and III except we have only five occupational groups for France as opposed to six for Britain.[25] It is remarkable that across all three specifications we also identify a significant and negative effect of *OC* on the change in the wage bill share of unskilled manuals as we found in Britain. The strongest positive effect of managerial delayering appears to be on the skilled manual workers, a pattern that was not so clearly present in Britain (where the signs were generally positive but insignificant). Another difference is that we cannot identify any significant effects for the technology variable in France (although the sign is negative for the least skilled). The technology variables are less rich in France than in Britain (for example, we have only cross-sectional information). Nevertheless, other authors have argued that the evidence for skill-biased technical change is weaker for France than for other countries (e.g., Goux and Maurin [2000]).

For France we also have information on changes in capital intensity that we include in panel D. There is some evidence for capital-skill complementarity in that establishments who in-

23. We obviously drop the regional dummies when including the regional hourly wage terms. The own price elasticities were −1.07, −4.06, −3.40, −2.04, −.964, −0.85 for unskilled, semi-skilled, skilled, supervisors, clerical workers, and managers, respectively.

24. We also reran the specifications by robust regression to ensure that the results were not driven by outliers. The coefficient (standard error) on *OC* in the unskilled manual models of Table II, panel C, was −.012(.006). The other coefficients were −0.007(.007), 0.006(.006), −.011(.010), .002(.004), −.010(.013) for semi-skilled manuals, skilled manuals, clerical workers, supervisors, and managers, respectively. Dropping the 10 percent of smallest plants made little difference to the results. The coefficient (standard error) on *OC* in the unskilled manual share equation was −.047(.021) in Britain and −.019(.008) in France.

25. The covariate set in the "extended" model differs slightly between countries due to data availability. For example, there are no questions on foreign ownership and financial performance in REPONSE.

TABLE IV

CHANGES IN WAGE BILL SHARES IN FRANCE: EFFECTS OF ORGANIZATIONAL CHANGE (DELAYERING) AND TECHNICAL CHANGE

	1992–1996 Change in wage bill share of:				
Mean of dependent variable	−.026	0	−.008	.022	.012
	Unskilled manuals	Skilled manuals	Clerical workers	Middle Managers & Technicians	Senior managers
A. Basic controls					
OC	−0.015	0.017	−0.002	0.003	−0.003
	(0.007)	(0.009)	(0.004)	(0.005)	(0.004)
B. Basic controls + technology					
OC	−0.015	0.016	−0.001	0.003	−0.002
	(0.007)	(0.009)	(0.004)	(0.006)	(0.004)
TECH	−0.001	0.015	−0.007	0.006	−0.013
	(0.014)	(0.018)	(0.008)	(0.011)	(0.008)
C. Extended controls + technology					
OC	−0.016	0.016	−0.003	0.003	−0.001
	(0.007)	(0.009)	(0.004)	(0.006)	(0.004)
TECH	−0.002	0.015	−0.005	0.005	−0.012
	(0.014)	(0.018)	(0.008)	(0.011)	(0.008)
D. Capital/value added (Extended controls + technology)					
OC	−0.019	0.015	−0.003	0.006	0.001
	(0.007)	(0.009)	(0.004)	(0.006)	(0.004)
log (*K*/value added)	−0.044	0.028	−0.010	−0.002	0.029
	(0.025)	(0.031)	(0.013)	(0.020)	(0.014)
E. Technology * *OC* interaction (Extended controls + technology + *K*/value added)					
OC	−0.034	0.034	0.005	−0.011	0.006
	(0.013)	(0.016)	(0.007)	(0.010)	(0.007)
OC * *TECH*	0.034	−0.042	−0.017	0.037	−0.012
	(0.023)	(0.029)	(0.012)	(0.018)	(0.013)
F. Change in employment shares (Extended controls + technology + *K*/value added)					
Mean of dependent variable	−.020	.003	−.007	.011	.013
OC	−0.021	0.016	−0.004	0.007	0.002
	(0.008)	(0.009)	(0.005)	(0.005)	(0.005)

Standard errors are in parentheses. Each column presents the results from a separate regression where the left-hand-side variable is the change in the wage bill share between 1992 and 1996 of the indicated skill group (except row F where the dependent variable is the change in the employment share of the skill group). *OC* indicates whether the plant introduced organizational change—delayering—between 1989–1992. Basic controls include twelve industry and eleven regional dummies, a dummy for proximity to the German border, the initial 1989 proportion of all skill groups, and the change in the log of total employment in the establishment between 1989 and 1992. Technology controls include the proportion of workers using new technologies in the establishment over the period 1989–1992 (*TECH*). Extended controls are the following establishment characteristics dated 1989: plant employment size, demand conditions, the existence of a union representative at the plant level, and a public sector dummy. Panel D adds changes in log (capital/value added). Panel E has the interaction between *OC* and the *TECH* variable in the most general specification including extended controls, technology and (capital/value added). The specification in panel F is equivalent to that in D except the dependent variable is the change in the proportion of the skill group in total employment, rather than changes in the wage bill share. All estimations by weighted OLS—the weights are establishment size and sampling frequency. The number of observations in all panels is 515.

crease their capital intensity also tend to increase their skill intensity. There is a significant and positive coefficient on capital intensity in the equation for the most skilled group and a negative (but only weakly significant) association for the least skilled group. Most importantly for our purposes, the *OC* effect is robust to this extra control.[26]

We included an interaction of *OC* and *TECH* in panel E. Similarly to the United Kingdom, there was no clear pattern. The variable was insignificant for all groups except for the second highest skill group (middle managers and technicians) where the combination of technical and organizational change was associated with significant skill upgrading. As with the United Kingdom, the regional wage terms were not significant.

The criticism that the results are merely reflecting the fact that managers perceive delayering as the same as reduction of the least skilled is highly unlikely as the delayering question refers to changes in management functions. Thus, any measurement biases are likely to result in underestimating the effects of organizational change on reducing the demand for the least skilled.

Overall then, the French results on changes in the skill structure appear to broadly corroborate the U. K. results, despite covering a more recent time period, being a larger sample, and having a rather different measure of organizational change. Turning to the size of the coefficients, the heads of the columns in Table IV show that the wage bill share of unskilled manuals fell by 2.6 percentage points in our data in France. Using an *OC* coefficient of −.016 (Table IV, panel C) and a mean value of *OC* of .52 (Appendix 1), this implies that 32 percent of the fall in the wage bill proportion of unskilled manuals in France could be "accounted" for by *OC*. In the United Kingdom we "overexplain" the fall in unskilled. The unskilled manuals share fell by 1.2 percentage points in the United Kingdom. Using a coefficient estimate of −.056 (Table II, panel C) and a mean of .38 (Appendix 1), we account for 177 percent of the change. Although we must approach these calculations with caution, the effects of organiza-

26. These results are robust to including the growth in value added as an additional variable. *OC* coefficient is −.019 with a standard error of .007 in the unskilled manual skill share regression.

tional change appear important in an economic as well as a statistical sense.[27]

V.B. The Determination of Organizational Change

The next equation of interest is the organizational change equation. Table V summarizes the results for Britain and France. In Britain we pool the two cross sections in 1984 and 1990 and include a set of covariates.[28] The only difference between columns (1) and (2) is that the latter includes a control for technical change.[29] In column (1) higher wage inequality is associated with a significantly lower probability of organizational change. Our interpretation of this is that cheap skills are beneficial to the introduction of organizational change. A relative shortage of educated workers in the local labor market drives up relative wages and makes the introduction of organizational change (which is skilled labor intensive) more expensive. Column (2) shows that technical change is strongly correlated with *OC* as was suggested by the descriptive statistics. Nevertheless, the skill price variables remain negative and significant at conventional levels.

Turning to the other variables, larger plants tended to experience more *OC,* as did those who faced changes in demand conditions. Unionization and public sector status are positively correlated with organizational change (see below for discussion). There is a concave relationship between average age in the region and organizational change reaching a maximum at 35 years of age, the sample mean.[30]

The next columns in Table V examine the organizational

27. Given the different definitions of *OC* and skills across countries, one should be wary about reading too much into these numbers. Nevertheless, the larger impact of *OC* in the United Kingdom may be related to the more dramatic change in industrial relations during the Thatcher period. There were a series of legal changes dramatically weakening the power of labor unions in the 1980s who were traditionally resistant to organizational change. There was no parallel weakening in France. Some evidence for this comes from the fact that the largest falls in employment and unskilled workers occurred in unionized establishments which experienced *OC* (see Machin and Wadhwani [1991] for more on this argument).

28. Pooling has the advantage of generating some extra variation in the relative wage variable. The restriction of pooling the two years (with a time dummy) was not statistically rejected by the data. For column (1) an F-test of the null that all the coefficients were stable over time had a p-value of 0.13.

29. We use a dummy variable ($TECH > 0$) as it can be defined consistently over the two years. The continuous variable ($TECH$) is only available for 1984.

30. The age variables were insignificant in France. Other demographic variables such as gender or relative age by education group were also insignificant.

TABLE V

DETERMINANTS OF ORGANIZATIONAL CHANGE IN BRITAIN AND FRANCE

	Britain		France	
Mean of dependent variable	.432	.432	.524	.524
	(1)	(2)	(3)	(4)
	OC	*OC*	*OC*	*OC*
Regional relative wage	−0.893	−0.683	−1.122	−1.165
(high-low education)	(0.285)	(0.210)	(0.629)	(0.602)
TECH > 0		0.165		
		(0.021)		
TECH				0.190
				(0.081)
Log (Employment size)	0.095	0.076	0.042	0.038
	(0.016)	(0.017)	(0.022)	(0.023)
Demand rise	0.089	0.077	−0.047	−0.047
	(0.032)	(0.033)	(0.051)	(0.051)
Demand fall	0.108	0.105	0.034	0.032
	(0.031)	(0.032)	(0.063)	(0.064)
Public firm	0.185	0.171	−0.108	−0.098
	(0.070)	(0.069)	(0.076)	(0.078)
Union recognition	0.024	0.015		
	(0.030)	(0.028)		
Union representative			−0.012	−0.008
			(0.058)	(0.058)
Union density			−0.172	−0.167
			(0.122)	(0.120)
Foreign owned	−0.001	−0.010		
	(0.038)	(0.034)		
Log (Capital)			0.026	0.017
			(0.023)	(0.024)
Log (Value added)			0.007	0.011
			(0.030)	(0.031)
Industry dummies (Britain: 9, France: 12)	Yes	Yes	Yes	Yes
Time dummies (1)	Yes	Yes	N/a	N/a
Observations	1674	1674	1014	1014
Log likelihood	−943.6	−927.5	−619.4	−614.7
Pseudo R^2	0.161	0.176	0.114	0.121

Standard errors (adjusted for clustering on region) are in parentheses. These are the marginal effects from a probit Maximum Likelihood regression. All estimates are weighted by establishment size and sampling frequency. All specifications control for average individual age and age squared in the region. The dependent variable in columns (1) and (2) is a dummy for whether the establishment has introduced *OC* affecting either manuals or nonmanuals in Britain over the past three years. In Britain the regional relative wage is computed as the average log hourly wage of workers with high education (A levels or college degrees) relative to that of lower educated workers in the region where the plant is located (ten regions in Britain). Specifications in columns (1) and (2) pool the data for 1984 and 1990. Controls include employment size three years previously, dummies for demand changes (no change as the omitted case), a dummy for the public sector, union recognition, foreign ownership, a dummy for the presence of a Joint consultative committee, industry dummies, and a time dummy for 1990. In column (2) the controls are the same plus a dummy for whether the plant has introduced new technologies over the previous three years (*TECH* > 0). In France, the dependent variable is a dummy for whether the plant had introduced delayering (*OC*) between 1989–1992 in columns (3) and (4). The regional relative wage is computed as the average log hourly wage of workers with a Baccalaureate or any college degree relative to lower educated workers in the region where the plant is located (21 regions in France). In column (3) the control variables include plant size, a dummy for the public sector, the existence of a union representative at the plant level, union density, the log of the stock of capital and value added, industry dummies, and a dummy for proximity to the German border. In column (4) controls are the same plus the proportion of workers using new technologies in the plant (*TECH*).

change equation for France. As with Britain, larger, more high-tech establishments are more likely to introduce organizational change. Union strength and being in the public sector appear to have a negative correlation with *OC* although the marginal effects are not significant at conventional levels. This difference between France and Britain (where the marginal effects were positive) is probably because of the substantial changes in the unionized and public sectors stimulated by deregulation in the 1980s in Britain under Mrs. Thatcher (see Machin and Wadhwani [1991], for example). Being unionized or state owned generally retards the probability of organizational change, but when incumbents in these plants are being weakened by legislative changes (as in the 1980s in Britain) these plants can experience the most dramatic organizational restructuring.

Most importantly, relative wages by education group also exhibit a negative correlation with *OC* in France even after controlling for these other variables. The association is significant at the 10 percent level.

Table VI presents a variety of robustness checks on the main results (we use the specifications in columns (1) and (3) of Table V for these checks). First, in Britain we break *OC* into whether it mainly affected manuals (row 1) or nonmanuals (row 2). Relative wages are significantly associated with both types of *OC,* although the marginal effect is stronger on manual *OC* than on nonmanual *OC.* Second, we also considered the impact of relative wages on technical change. In the United Kingdom (row 3), as the theory of skill-biased technical change would predict, higher skill prices significantly reduce the probability of technical change. The marginal effect in France is also negative (row 4), but insignificant.

The next three rows of Table VI attempt to mitigate potential endogeneity problems. In row 5 we replace the level of relative wages by long differenced (1984–1990) relative wages in the 1990 cross section.[31] The marginal effect of the growth terms (−1.26) is actually higher, although less well determined, than simply using

31. This can only be done for Britain in 1990 because of the inconsistency in the U. K. hourly wage series prior to 1984 and in France prior to 1990. When we used the 1990–1992 relative wage difference in France the marginal effect was .165(.466). This perverse positive and insignificant association is also found in the United Kingdom if we use short two-year differences (1988–1990). The marginal effect is 0.002 with a standard error of 0.209. This is likely to be because of a low signal to noise ratio in these higher frequency changes.

TABLE VI

ROBUSTNESS OF ORGANIZATIONAL CHANGE EQUATIONS

Row	Equation	Experiment	Marginal effect of relative wage (s.e.)
1.	*OCMAN,* 1984 and 1990 pooled (Britain)	*OCMAN* as dependent variable	−1.003 (.383)
2.	*OCNMAN,* 1984 and 1990 pooled (Britain)	*OCNMAN* as dependent variable	−0.707 (.349)
3.	*TECH* > 0, 1984 and 1990 pooled (Britain)	Technical change dummy as the dependent variable	−1.745 (.383)
4.	*TECH* > 0, 1992 (France)	Technical change dummy as the dependent variable	−0.017 (.568)
5.	*OC,* 1990 (Britain)	Use growth of relative regional wages (1984–1990) instead of level of relative wages	−1.263 (0.705)
6.	*OC,* 1990 (Britain)	Lagged (1988) relative wage differential	−0.478 (.225)
7.	*OC,* 1992 (France)	Lagged (1990) relative wage differential	−0.861 (.492)
8.	*OC,* 1984 and 1990 pooled (Britain)	Proportion of educated in region-industry cell instead of relative wage	0.305 (0.368)
9.	*OC,* 1992 (France)	Proportion of educated in region-industry cell instead of relative wage	0.996 (0.603)
10.	Just-in-time, 1992 (France)	Replace the dependent variable by a dummy for Just-in-time.	−1.108 (0.602)

Standard errors (adjusted for clustering on region) are in parentheses. Specifications are based on those in Table V. Controls are identical to Table V, column (1) for Britain and column (3) for France. Row 1 uses *OC* affecting manuals as the dependent variable, and row 2 uses *OC* affecting nonmanuals. Rows 3 and 4 use a dummy for whether advanced technical change had been introduced in the previous three years as the dependent variable. Row 5 replaces the level of relative wages with the growth of relative wages. Rows 6 and 7 use wages lagged two years. Rows 8 and 9 use the proportion of workers instead of relative wages. Row 10 replaces delayering with Just-in-time as the *OC* measure. Unless otherwise stated, column 3 contains the marginal effects of relative wage terms (and associated standard errors adjusted for clustering on region) from a probit Maximum Likelihood regression. All estimates are weighted by establishment size and sampling frequency. All specifications control for regional average age and age squared in the region. In Britain the regional relative wage is computed as the average log hourly wage of workers with high education (A levels or college degrees) relative to that of lower educated workers in the region where the plant is located (ten regions in Britain). For Britain the controls include employment size three years previously, dummies for demand increases (no change as the omitted case), a dummy for the public sector, union recognition, foreign ownership, a dummy for the presence of a Joint consultative committee, industry dummies, and a time dummy. In France, *OC* is measured over 1989–1992. The regional relative wage is computed as the average log hourly wage of workers with a Baccalaureate or any college degree relative to lower educated workers in the region where the plant is located (21 regions in France). For France the control variables include plant size, a dummy for the public sector, the existence of a union representative at the plant level, union density, the log of the stock of capital and value added, industry dummies, and a dummy for proximity to the German border.

the 1990 values (in the 1990 cross section the marginal effect was −1.11 with a standard error of 0.58). In rows 6 and 7 we use relative wages two years earlier instead of contemporaneous relative wages. The variable is still significant (at the .05 level in Britain and at the .10 level in France), although the marginal effects are smaller in both countries.

As an alternative measure of the supply of skills, we constructed the relative quantities in each country. Similarly to Moretti [1999] we calculated the proportion of workers who had high levels of education in an industry-regional cell. This was then used as an alternative to the relative wage terms[32] (rows 8 and 9). Regions with greater proportions of educated workers were more likely to have experienced organizational change, although the correlation is insignificant in Britain and only significant at the 10 percent level in France. Moretti finds that higher levels of human capital in a city increase the propensity of U. S. plants to adopt new technologies. These results are consistent with our own since organizational change and technical change are so often found together. Finally, Row 10 repeats the baseline with another measure of organizational change in France—Just-in-Time. Relative wages appear to have a (weakly) significantly negative effect on this measure of OC.[33]

A large number of other specification tests were also performed on the *OC* equations. First, it may be that wage relativities are low in some regions not because of skill abundance, but because of institutional constraints on the wages of less skilled workers (e.g., the French minimum wage was high over this period). Consequently, we included relative unemployment rates in some specifications—these were always insignificant. Second, several other measures of product market competition were included to examine whether product market competition stimulated organizational innovation.[34] Mostly, these were uninformative. There was some evidence that falling prices (in the plant's three-digit industry) stimulated more *OC* in the early 1980s in Britain (when the economy experi-

32. Note that we are able to control for regional fixed effects as we have variation across industries within a region. We use one-digit industries.

33. There were no significant effects on other measures of *OC* such as Total Quality Management or quality circles. Nor were any of these ever significant in the skill share equations.

34. Measures included import prices, concentration indices, and the manager's assessment of the number of competitors faced by the establishment.

TABLE VII
FIRM-LEVEL PRODUCTION FUNCTIONS FOR FRANCE 1992–1996

Change in Value added 1992–1996 (annualized mean = .01)						
					$OC = 1$	$OC = 0$
	(1)	(2)	(3)	(4)	(5)	(6)
ln(Capital)	0.226	0.227	0.233	0.232	0.237	0.227
	(0.080)	(0.080)	(0.081)	(0.082)	(0.140)	(0.094)
ln(Labor)	0.879	0.875	0.888	0.889	0.807	0.817
	(0.097)	(0.096)	(0.100)	(0.100)	(0.155)	(0.130)
Lagged variables						
OC	0.017	0.037	0.034	0.022		
	(0.012)	(0.016)	(0.017)	(0.030)		
OC *% Unskilled		−0.114	−0.125	−0.115		
		(0.057)	(0.059)	(0.062)		
% Unskilled	−0.031	0.030	0.101	0.097	−0.118	0.026
	(0.029)	(0.043)	(0.051)	(0.052)	(0.054)	(0.038)
TECH			0.019	0.008	−0.022	−0.020
			(0.031)	(0.038)	(0.042)	(0.029)
TECH *% Unskilled			−0.161	−0.166		
			(0.104)	(0.105)		
OC * *TECH*				0.022		
				(0.045)		
Quality circles			0.015	0.014	0.021	0.023
			(0.015)	(0.015)	(0.029)	(0.015)
Industry dummies (12)	no	no	yes	yes	yes	yes
Regional dummies (11)	no	no	yes	yes	yes	yes
Other controls	no	no	yes	yes	yes	yes
Observations	289	289	289	289	141	148
R^2	0.406	0.414	0.540	0.541	0.623	0.549

Standard errors are in parentheses. These are long-differenced specifications. Value added, capital, and labor are annualized changes 1992–1996. Organizational change (*OC*), the proportion of workers using new technologies in the establishment over the period 1989–1992 (*TECH*) and a dummy for quality circles (Quality circles) are measured over 1989–1992. The proportion of unskilled workers (% Unskilled) is measured as of 1992. Other controls are changes in demand, a public sector dummy, the existence of a union representative at the plant level, union density, and a dummy for proximity to the German border. Estimation by OLS. All estimates are weighted by establishment size and sampling frequency.

enced a major recession), but there were no significant effects in the late 1980s nor in France.

V.C. Organizational Change and Firm Productivity

The third implication of the hypothesis that skills and *OC* are complementary relates to firm productivity. Table VII contains estimates of firm production functions for France. The dependent variable is the growth of annualized log value added between 1992 and 1996. In the first column we include our measure of *OC,*

the 1992 proportion of unskilled manual workers[35] and the growth of labor and capital. The conventional factors take their expected signs with coefficients close to their share in value added which is reassuring since differencing is likely to exacerbate measurement error [Griliches and Mairesse 1997]. One cannot reject the hypothesis of constant returns to scale in labor and capital (p-value on F-test = .191). Organizational change is positively correlated with productivity growth, although the linear *OC* coefficient is insignificantly different from zero at conventional levels.

The second column includes the critical interaction term between skills and *OC*. According to this column, establishments with no unskilled manual workers who introduced organizational changes had additional growth in value added of 3.7 percent a year. The unskilled intensive plants were much less likely to benefit from organizational changes, however, as the interaction term is negative and significant. For plants where more than 32 percent of employees were unskilled manual workers, there is actually a negative effect of *OC* (only 31 establishments in our sample fell into this low-skill and some *OC* category). This result is in line with those in the literature on high performance work practices. This underlines the fact that new work practices raise productivity only in firms that already have complementary assets or characteristics. Black and Lynch [1997] underline the importance of unionization, and Cappelli and Neumark [1999] that of profit sharing in order for firms to fruitfully exploit new work practices. In a similar way, we only find a positive and significant impact of organizational change in plants that initially have a highly skilled labor force.[36]

The third column includes our technology variables, their interactions with *OC* and a set of other lagged controls (unions, public sector, size in 1992, demand changes 1989–1992, and regional and industry dummies). The *TECH* * *%UN-*

35. We focus on this group because of the evidence from the skill share equation that this group suffered the most from organizational change.

36. Instead of including skills measured continuously, we also experimented with making them discrete. A monotonic relationship still held. For example, we discretized unskilled proportion into four bands: −ZERO; 0–10 percent, 10–30 percent, and >30 percent. We then included these linearly and interacted them with *OC*. The coefficients (standard errors) on the interaction with the most skilled plants (*OC* * *ZERO*) was .068(.029). On the other skill groups (going down in skill level) they were .030(.020) for *OC* * 10; −0.005(.029) for *OC* * 10–30 and −.015(.025) for *OC* * > 30.

SKILLED interaction is negative, consistent with skill-biased technical change, but is insignificant. It is possible that *OC* is introduced in plants which have higher trend in productivity growth (cf. Ichniowski, Shaw, and Prennushi [1997]), so to control for this we included the 1989–1992 growth in value added (instrumented with the level of value added in 1989). The variable was insignificant (0.094 with a standard error of 0.215).

The fourth column presents the empirical counterpart to equation (5) where we include an additional interaction of *OC* and technology.[37] This variable is positive as expected, but is not significant at conventional levels. Finally, in the sixth column we estimate the most general model, splitting the sample and allowing all the coefficients to vary by *OC* status. The unskilled proportion is negative and significant for plants who experienced *OC* and positive (but insignificant) for plants who did not experience *OC*.[38]

Taking the results in Table VII as a whole, it is clear that there is evidence for skill-biased organizational change. The evidence for other complementarities is weaker, but this is partly due to collinearity between skills, *OC,* and technology in the data (as one would expect since these practices are clustered).[39]

A similar exercise is not possible in Britain because WIRS lacks information on value added and investment. We did examine the part of the 1984–1990 panel that includes the firms who closed down before 1990. This is a rather extreme measure of plant performance. There does not appear to be a significant relationship between organizational change, skills, or their interactions and the probability of plant closure (the strongest predictor is actually establishment size: larger plants are far more likely to survive than smaller plants). This does not give support to the idea of a complementarity between the two types of changes and a rather extreme measure of performance. On the

37. We experimented with also including the changes in the skill shares, but they were not significant (e.g., when included in column (5) F-test = 0.68).

38. A three-way interaction between *OC, TECH,* and unskilled proportion was also insignificant.

39. For example, if we drop the *OC* * Unskilled interaction from this column, the *TECH* * *UNSKILLED* variable becomes significant, taking a coefficient of −.228 and a standard error of .100. The *OC* * *TECH* interaction rises to a coefficient of .049 with a standard error of .042.

positive side, it does mean that survivor bias is unlikely to be a major problem in our results.

VI. Conclusions

This paper has examined the relationship between skills and organizational change. This is a subject that is the object of much speculation, but where there is a dearth of econometric analyses. Our results are easy to summarize. First, British and French establishments that introduced organizational changes were significantly more likely to reduce their demand the most for unskilled workers than those that did not. Second, the probability of introducing changes in organization, such as delayering of hierarchies, is depressed by shortages of skilled workers (as proxied by educational wage differentials) in both countries. Third, in France at least, the introduction of organizational change in skill-intensive firms leads to significantly faster productivity growth than the introduction of organizational change in unskilled-intensive firms. Taken together, these findings do suggest that there is something in the notion of "skill-biased organizational change."

The results presented here are part of a small but growing literature that tries to econometrically examine the relationship between skills, organization, and technology. Using establishment level panel data from different countries is, we believe, an advance over existing work.

Where do we go from here? One issue that we would like to focus on in more detail is the role of product market competition in stimulating organizational change. To the extent that there are some exogenous changes in the competitive environment facing firms, we may be able to identify more closely the link between competition and productivity growth stressed by many authors [Nickell 1996; Porter 1990].

Another important issue is whether organizational factors really do have an independent influence on firm's productivity and demand or whether they are just part of the transmission mechanism between technological change and outcomes. If we had better measures of technical progress, then organizational factors, per se, may be unimportant. Our prejudice is that this is not the case and managers do face real choices in what organizational strategies to pursue. Nevertheless, the usual call for improved data is certainly true in the area of technol-

ogy and organization. We were not able to identify strong complementarities between organizational and technical change, although we believe that they exist. Better measures of both aspects of the workplace (such as the IT capital stock used by Bresnahan, Brynjolfsson, and Hitt [2002]) would certainly help.

Finally, the debate over the deteriorating position of low paid workers has tended to stress the role of technology, trade, and labor supply. We would emphasize that understanding the changing wage and employment position of the less skilled is intimately tied with the evolution of organizational forms. An important avenue for future research is to tie down the extent to which the declining fortunes of the unskilled are really linked to managerial innovations in the organization of work.

Data Appendix

A. Overview of the Data Sets

Britain

The Workplace Industrial Relations Survey (WIRS) is a survey covering a stratified random sample of over 2000 British establishments with at least 25 employees. Larger plants are oversampled with a known sampling weight. It has been conducted in 1980, 1984, 1990, and 1997. There is a panel element of 537 establishments between 1984 and 1990. Some of these were mismatched, so we keep only the subsample of plants that the data collectors recommend were good matches. A Senior Manager answers the main survey.

The General Household Survey (GHS) has been conducted since 1971. There are about 20,000 individuals in the survey in each year. The earnings question in GHS relates to usual gross earnings, and hours relate to typical weekly hours. There is a break in the hours series in 1983 so we could only calculate hourly wages from 1984 and after. The lowest level of aggregation we can obtain is based on ten regions (London and South-East, Scotland, Wales, East Anglia, North-West, North, South-West, Yorkshire, East Midlands, West Midlands).

GHS also contains the three-digit Classification of Occupations (1980) which we use to create occupational categories

matched to the six WIRS skill groups (see Chennells and Van Reenen [1998] for details). GHS also contains detailed information on highest educational qualification that we use to construct two groups. Highly educated individuals are all those who have at least one A level or higher qualification (e.g., college degree). All others are in the low group.

FRANCE

Relations Professionelles et Négociations d'Entreprise (REPONSE) was carried out in 1992 and was modeled on the British WIRS (see Coutrot and Malan [1996]). Twenty-five hundred establishments were surveyed with senior managers being asked questions about industrial relations and organization in 1992. Only establishments belonging to firms with more than 50 employees were sampled. Larger plants are oversampled with a known sampling weight. One difference in sample structure from the British WIRS is that REPONSE does not include any public sector employees (except workers in state-owned industries). This is why there is a higher proportion of public sector employees in Britain in Appendix 1 (35 percent in Britain compared with 17 percent in France). We could find no significant difference in the main results from our regressions when we dropped the public sector employees from the sample.

L'Enquête sur la Structure des Emplois (ESE) is a stratified random sample of French establishments. About half of the REPONSE establishments that continuously existed between 1992 and 1996 were matched to the ESE (1360 plants). Failed matches are due to incomplete sampling and closures between 1992 and 1996. The ESE breaks the workforce down into five occupational categories (unskilled manuals, skilled manuals, clericals, middle managers, and senior managers).

The Enquête Emploi (EE) is an annual survey of individuals conducted by the French National Statistical Agency, INSEE. The EE is a 1/300 sample of the French working population (about 60,000 households) based on a three-year rotating panel containing information about education levels, region, industry, and employment status. We define as educated those workers with a college degree or baccalaureate. All others (with BEP, CAP, and below) are considered as low educated. The EE has a consistent monthly earnings series from 1990 onwards (it was grouped into bands prior to this

date), and we combine this with usual weekly hours to construct an hourly wage.

As with the British data, we compute relative wages at the level of regional cells, although unlike WIRS we can disaggregate further into 21 regions.[40] This is useful as we only have a single cross section, whereas we can pool the U. K. regions across years to get twenty region-year observations. We also aggregated French regions into eleven "zones" to conduct robustness tests. We do so on a geographical basis so that Nord-Pas de Calais is matched with Picardie, Aquitaine with Midi-Pyrénées, Auvergne with Limousin, and so on. The only region that is not reaggregated to a higher level is Ile-de-France.

The Bilans Industriels et Commerciaux (BIC) is a firm-level database with information on the historical value of the capital stock, value added, total wages, and other information. Since ESE and REPONSE relate to plant-level information rather than firm-level information, we aggregate over the plants when running the production functions (using total plant employment in 1992 as the aggregation weight).

B. Technology Questions

Britain

Managers were asked:

Would you look at this card and tell me which, if any, of these changes you have made during the last three years directly affected the jobs or working practices of the manual [non-manual] workforce?

The introduction of new plant, machinery, or equipment that includes new micro-electronic technology.

If this question was answered in the affirmative (either for manuals or nonmanuals), we defined the variable ($TECH > 0$). In the 1984 WIRS only, managers were then asked to estimate the proportion of workers who were using the new technology (in manufacturing) or were affected by the technology (in nonmanufacturing). Given that we know the proportions of manual and nonmanual workers, we can calculate a continuous variable

40. These regions are Alsace, Aquitaine, Auvergne, Bourgogne, Bretagne, Centre, Champagne-Ardennes, Franche-Comté, Ile-de-France, Languedoc-Roussillon, Limousin, Lorraine, Midi-Pyrénées, Nord-Pas de Calais, Basse Normandie, Haute Normandie, Pays de la Loire, Picardie, Poitou-Charentes, Provences-Alpes-Côte-d'Azur, Rhône-Alpes.

proxying the proportion of the plant's workers using new technology (*TECH*). In 1990 we only have the binary indicator $TECH > 0$. In specifications where we pool across years (such as the *OC* probits) we just use $TECH > 0$ as it is available across years.

IND_TECH. We estimate the proportion of individuals who are using any new technologies at work (including computers) from aggregating up individual level data on computer use to the two-digit industry level (51 sectors) from the British Social Attitudes Survey (BSAS) in 1985 and 1990. We then calculate the change in this proportion (ΔIND_TECH) between 1985 and 1990 (BSAS did not ask this question in 1984).

$\Delta COMP$. There are questions relating specifically to the use of computers in the workplace in WIRS 1984 and 1990. We created a binary dummy equal to unity if a workplace had any microcomputers. We then took the difference of this binary indicator between 1984 and 1990 in the panel.

FRANCE

Managers are asked about whether a number of new technologies are present in the establishment—robots, microcomputers and mainframe computers, numerically controlled machinery. If any such technologies were present, managers were asked to estimate what proportion of each of four different skill groups were using these technologies. We then use the skill proportions coupled with this measure to construct *TECH,* an indicator of the proportion of workers using new technologies in the establishment.

C. Skills and Wages

The main measure we use of relative supply is the log hourly wages of highly educated workers compared with the log hourly wages of less educated workers in the region. First, we take the individual microdata and calculate the log hourly wages for each person between the ages of 18 and 60. We remove individuals with hourly wages below £0.50 and above £200 per hour in both countries. We then take the average of these log wages by education group (high and low) by region and year. Our regional relative wage variable is then simply the mean log hourly wage of the highly educated minus the mean log hourly wage of the less educated.

This variable is contemporaneously dated (i.e., 1984 in the 1984 cross section, etc.). Ideally, we would use lagged relative

wages in the *OC* equations. This was not possible in the 1984 *OC* equation in the United Kingdom as the hourly wage series is only available from 1984 onwards (see above). In France the hourly data are consistently defined from 1990 onwards. We experiment with lagged wages for the 1990 British cross section and for France in Table VI.

In regions where there is a larger proportion of educated individuals in the population of working age (whether employed or not), the lower is the relative skill premium in both countries (correlation of -0.245 in Britain and -0.256 in France).

In France neither REPONSE, nor ESE, nor BIC have wages by skill group at the establishment level. In Britain, WIRS does have some establishment level information, on wages but we did not use these data because (a) they are not available for all skill groups (e.g., managers); (b) it was only asked if there was a minimum of 25 individuals in the particular skill group in 1990; (c) they are banded; (d) they relate to the median, not mean wage. Instead, we use the individual data to estimate the weekly earnings by occupation by region by year. These regional wage rates are used to weight the occupational skill numbers to construct establishment-specific wage bill shares.

Various descriptive statistics are contained in Appendixes 1 and 2.

APPENDIX 1: MEANS OF VARIABLES IN CROSS SECTIONS

Variable	United Kingdom 1984		United Kingdom 1990		France 1992	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
OC—Delayering	—	—	—	—	0.524	0.498
OC—manual	0.323	0.468	0.430	0.495	—	—
OC—nonmanual	0.223	0.435	0.447	0.497	—	—
OC—either manual or nonmanual	0.380	0.485	0.487	0.500	—	—
TECH, % workers using new technologies	0.123	0.225	—	—	0.184	0.299
TECH > 0—manual	0.328	0.470	0.345	0.476	—	—
TECH > 0—nonmanual	0.624	0.472	0.613	0.487	—	—
COMP, microcomputer in plant	0.242	0.429	0.623	0.485	—	—
IND_TECH, percentage of workers using new technologies in industry (1985 and 1990)	0.448	0.232	0.550	0.273	—	—
Union recognition	0.801	0.400	0.677	0.470	—	—
Union representative	—	—	—	—	0.661	0.473
Union density	—	—	—	—	0.150	0.191
Quality circles	—	—	—	—	0.724	0.447
Just-in-time	—	—	—	—	0.384	0.466
Size (total employees)	102.2	239.1	93.2	224.7	84.22	219.1
Demand rise	0.622	0.485	0.627	0.484	0.513	0.500
Demand fall	0.105	0.307	0.127	0.334	0.234	0.424
Joint consultative committee	0.551	0.498	0.446	0.497	—	—
Foreign ownership	0.066	0.248	0.123	0.328	—	—
Public sector	0.437	0.496	0.353	0.478	0.171	0.376
Percent highly educated (college Degrees/A level or Bac)	0.359	0.099	0.398	0.110	0.261	0.125
% Degrees	0.066	0.049	0.063	0.046	0.134	0.080
% A levels/Bac	0.293	0.080	0.335	0.092	0.126	0.061
% O levels/BEPC + CAP/BEP	0.214	0.059	0.281	0.071	0.413	0.060
% No qualification	0.427	0.094	0.320	0.078	0.326	0.107
Regional relative wages (mean log high educated hourly wage versus mean log low educated hourly wage)	0.490	.048	0.505	.035	0.417	.038
Average age in region	34.24	1.038	35.49	.769	36.064	0.468

All variables are weighted by WIRS/REPONSE sampling weights and plant employment (except for employment size variable).

APPENDIX 2: CORRELATION MATRIX BETWEEN ORGANIZATIONAL CHANGE (*OC*), TECHNICAL CHANGE (*TECH*), AND SKILLS

A. BRITAIN

	OC (organizational change introduced between 1981 and 1984)	*TECH* (percentage of workers using new technology introduced between 1981 and 1984)	Δ*SHARE* −Change in unskilled manual wage bill share 1984–1990	*CC* (some investment in plant or machinery not incorporating microelectronic technology 1981–1984)
OC	1			
TECH	.175	1		
Δ*SHARE*-unskilled	−.053	−.019	1	
CC	.386	.181	.053	1
Employment growth 1984–1990	−.097	−.009	.063	−.098

B. FRANCE

	OC (delayering 1989–1992)	*TECH* (percentage of workers using new technology in 1992)	Δ*SHARE* −Change in unskilled manual wage bill share 1992–1996	Log(*K*/*L*) Capital-labor ratio in 1992
OC	1			
TECH	.130	1		
Δ*SHARE*-unskilled	−.093	.056	1	
Log(captial/labor)	.079	.255	−.051	1
Employment growth 1992–1996	−.108	−.053	.116	−.067

These are the correlation matrices for key variables. *CC* = conventional change, new plant and machinery not involving microelectronics. Data from the panel data sets in both countries are weighted by sampling probability and establishment size. There are 395 observations in Britain and 713 in France.

LABORATOIRE D'ÉCONOMIE APPLIQUÉE, INSTITUT NATIONAL DE LA RECHERCHE AGRONOMIQUE, AND CENTRE D'ÉTUDES PROSPECTIVES D'ÉCONOMIE MATHÉMATIQUE APPLIQUÉES A LA PLANIFICATION

DEPARTMENT OF ECONOMICS, UNIVERSITY COLLEGE LONDON, AND INSTITUTE FOR FISCAL STUDIES

REFERENCES

Aghion, Philippe, Eve Caroli, and Cecilia Garcia-Peñalosa, "Inequality and Economic Growth: The Perspective of the New Growth Theories," *Journal of Economic Literature,* XXXVII (1999), 1615–1660.

Askenazy Philippe, Eve Caroli, with Vincent Marcus, "New Organizational Practices and Working Conditions: Evidence from France in the 1990s," CEPREMAP Working Paper, No. 0106, 2001.
Athey, Susan, and Scott Stern, "An Empirical Framework for Testing Theories about Complementarity in Organizational Design," NBER Working Paper No. 6600, 1998.
Autor, David, Lawrence Katz, and Alan Krueger, "Computing Inequality: Have Computers Changed the Labor Market?" *Quarterly Journal of Economics,* CXIII (1998), 1169–1213.
Black, Sandra, and Lisa Lynch, "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity," NBER Working Paper No. 6120, 1997.
Bolton, Patrick, and Mathias Dewatripont, "The Firm as a Communication Network," *Quarterly Journal of Economics,* CIX (1994), 809–839.
Boyer, Robert, Elsie Charron, Ulrich Jurgens, and Stephen Tolliday, *Between Imitation and Innovation. The Transfer and Hybridization of Productive Models in the International Automobile Industry* (Oxford: Oxford University Press, 1998).
Bresnahan, Timothy, Erik Brynjolfsson, and Lorin Hitt, "Information Technology, Workplace Organization and the Demand for Skilled Labor: Firm Level Evidence," *Quarterly Journal of Economics,* CXVII (2002), forthcoming.
Brynjolfsson, Erik, and Shinku Yang, "Information Technology and Productivity: A Review of the Literature," *Advances in Computers,* XLIII (1996), 179–214.
Cappelli, Peter, "Technology and Skill Requirements: Implications for Establishment Wage Structures," *New England Economic Review* (1996), 139–154.
Cappelli, Peter, and David Neumark, "Do 'High Performance' Work Practices Improve Establishment-Level Outcomes?" NBER Working Paper No. 7374, 1999.
Caroli, Eve, "New Technologies, Organizational Change and the Skill Bias: What Do we Know?" in Pascal Petit and Luc Soete, eds., *Technology and the Future Employment of Europe* (London: Edward Elgar, 2001).
Caroli, Eve, Nathalie Greenan, and Dominique Guellec, "Organizational Change and Skill Accumulation," *Industrial and Corporate Change,* X (2001), 481–506.
Caroli, Eve, and John Van Reenen, "Skill Biased Organizational Change?" Couverture Orange CEPREMAP No. 9917, 1999.
Chandler, Alfred, *Strategy and Structure. Chapters in the History of the Industrial Enterprise* (Cambridge: MIT Press, 1962).
Chennells, Lucy, and John Van Reenen, "Technical Change and Earnings in British Establishments," *Economica* LXIV, (1997), 587–604.
Chennells, Lucy, and John Van Reenen, "Establishment Level Earnings, Technology and the Growth of Inequality: Evidence from Britain," *Economics of Innovation and New Technology,* V (1998), 139–164.
Coutrot, Thomas, "Les Nouveaux Modes d'Organisation de la Production: Quels Effets sur l'Emploi, la Formation, l'Organisation du Travail?" *Données Sociales,* INSEE (1996), 209–216.
——, "Innovations et Gestion de l'Emploi," *Premières Synthèses DARES* (2000).
Coutrot, Thomas, and Anna Malan, "L'Enquête REPONSE: Bilan critique d'une operation nouvelle," *Travail et Emploi,* LXVI (1996), 7–17.
Di Nardo, John, Nicole Fortin, and Thomas Lemieux, "Labor Market Institutions and the Distribution of Wages, 1973–1992: A Semi-Parametric Analysis," *Econometrica,* LXV (1996), 1001–1044.
Doms, Mark, Timothy Dunne, and Kenneth Troske, "Workers, Wages, and Technology," *Quarterly Journal of Economics,* CXII (1997), 253–290.
European Foundation for the Improvement of Living and Working Conditions, *Direct Participation and Organizational Change* (Dublin: European Foundation, 1998).
Goux, Dominique, and Eric Maurin, "The Decline in Demand for Unskilled Labor: An Empirical Analysis Method and its Application to France," *Review of Economics and Statistics,* LXXXII (2000), 596–607.
Greenan, Nathalie, "Progrès Technique et Changements Organisationnels: leur

Impact sur l'Emploi et les Qualifications," *Economie et Statistique,* CCXCVIII (1996), 35–44.
Greenan, Nathalie, and Dominique Guellec, "Co-ordination within the Firm and Endogenous Growth," *Industrial and Corporate Change,* III (1994), 173–197.
Greenan, Nathalie, and Jacques Mairesse, "Organizational Change in French Manufacturing: What Do we Learn from Firm Representatives and from their Employees?" NBER Working Paper No. 7285, 1999.
Griliches, Zvi, and Jacques Mairesse, "Production Functions: The Search for Identification," in Scott Ström, ed., *Essays in Honour of Ragnar Frisch,* Econometric Society Monograph Series (Cambridge: Cambridge University Press, 1997).
Haskel, Jonathan, and Ylva Heden, "Computers and the Demand for Skilled Labour: Industry and Establishment Panel Evidence for the UK," *Economic Journal,* CIX (1999), 68–79.
Ichniowski, Casey, Kathryn Shaw, and Giovanna Prennushi, "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines," *American Economic Review,* LXXXVII (1997), 291–313.
Lindbeck, Assar, and Dennis Snower, "Reorganization of Firms and Labor Market Inequality," *American Economic Review,* LXXXVII (1997), 315–321.
Machin, Stephen, and John Van Reenen, "Technology and Changes in Skill Structure: Evidence from Seven OECD Countries," *Quarterly Journal of Economics,* CXIII (1998), 1215–1244.
Machin, Stephen, and Sushil Wadhwani, "The Effects of Unions on Organizational Change and Employment," *Economic Journal,* CI (1991), 835–854.
Milgröm, Paul, and John Roberts, "The Economics of Modern Manufacturing: Technology, Strategy and Organization," *American Economic Review,* LXXX (1990), 511–528.
Milgröm, Paul, and John Roberts, "Complementarities and Fit. Strategy, Structure, and Organizational Change in Manufacturing," *Journal of Accounting and Economics,* XIX (1995), 179–208.
Millward, Neil, "Personnel Management and Technical Change: The Findings from the WIRS Series," in John Clark, ed. *Human Resource Management and Technical Change* (London: Sage, 1993).
Moretti, Enrico, "Workers' Education, Externalities and Technology Adoption: Evidence from Plant-Level Production Functions," University of California, Berkeley, Center for Labor Economics Working Paper No. 21, November 1999.
Moulton, Brent, "Random Group Effects and the Precision of Regression Estimates," *Journal of Econometrics,* XXXII (1986), 385–397.
Nickell, Stephen, "Competition and Corporate Performance," *Journal of Political Economy,* CIV (1996), 724–746.
Nickell, Stephen, and Daphne Nicolistas, "Does Doing Badly Encourage Innovation?" London School of Economics, Center for Economic Performance Discussion Paper, 1996.
NUTEK, *Flexibility Matters: Flexible Enterprises in the Nordic Countries* (Stockholm: Swedish National Board for Industrial and Technical Development, 1999).
OECD, *Employment Outlook* (Paris: OECD, 1990).
——, *Employment Outlook* (Paris: OECD, 1999).
Osterman, Paul, "How Common Is Workplace Transformation and Who Adopts it?" *Industrial and Labor Relations Review,* XLVII (1994), 173–188.
Porter, Michael, *The Competitive Advantage of Nations* (London: Macmillan, 1990).
Radner, Roy, "The Organization of Decentralized Information Processing," *Econometrica,* LXI (1993), 1109–1146.
Scott, Walter, *Organizations: Rational, Natural and Open Systems* (Englewood Cliffs, NJ: Prentice-Hall, 1981).
Stewart, Mark, "Union Wage Differentials, Product Market Influences and the Division of Rents," *Economic Journal,* C (1990), 1122–1137.
Thesmar, David, and Mathias Thoenig, "Choix d'Organisation dans un Environnement Instable: Une Analyse Macroéconomique," *Revue Economique,* L (1999), 393–403.

Thesmar, David, and Mathias Thoenig, "Creative Destruction and Firm Organization Choice," *Quarterly Journal of Economics,* CXV (2000), 1201–1237.
Van Zandt, Timothy, "Decentralised Information Processing in the Theory of Organizations," in Murat Sertel, ed., *Contemporary Economic Development Reviewed, Volume 4: The Enterprise and its Environment* (London: Macmillan, 1997).
Womack, James, Daniel Jones, and Daniel Roos, *The Machine that Changed the World* (New York: Rawson, 1991).
Wood, Adrian, *North-South Trade, Employment and Inequality: Changing Fortunes in a Skill Driven World* (Oxford: Clarendon Press, 1994).
Zammuto, Raymond, and Edward O'Connor, "Gaining Advanced Manufacturing Technologies Benefits: The Roles of Organization Design and Culture," *Academy of Management Review,* XVII (1992), 701–728.