CREATIVE DESTRUCTION AND FIRM ORGANIZATION CHOICE*

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Firms' organizational choices are influenced by external conditions such as the instability of the product market. In order to address this issue in a macroeconomic perspective, we embed the firm's choice of organizational structure in a model of growth through creative destruction, which induces endogenous market volatility. We find that an increasing supply of skill or globalization may increase the rate of creative destruction, the skill premium, and the skilled wages, and it may depress the unskilled wages. We use an original data set to test the empirical relevance of our theory.

I. INTRODUCTION

In order to cope with increasingly unstable product markets and to exploit smaller and more rapidly changing customer niches, many firms in industrialized countries have sought to change their organization since the mid-1970s. In opposition to former work organization, the new organizational paradigm is supposed to achieve greater flexibility, adaptability, and reactivity through decentralized decision making, product-based hierarchy, unwritten rules, and multitasking workers.[1] These organizational changes may have had strong consequences at the macroeconomic level. For example, Piore and Sabel [1984] and Chandler [1990] discuss in their influential contributions the influence of the dominant forms of firms' organization on macroeconomic stability. A more recent empirical literature claims that reorganization

* We thank Daron Acemoglu, Philippe Aghion, Roland Bénabou, Eve Caroli, Daniel Cohen, Bruno Crépon, Antoine d'Autume, Mohamad Hammour, Francis Kramarz, David Margolis, Eric Maurin, John Van Reenen, and Thierry Verdier. This paper also benefited from insightful remarks from one referee and two editors of this *Journal*. Last, we thank participants of various seminars (Ecole Normale Supérieure, Université Paris I, European Economic Association 1998 Conference, and the 1999 Workshop on Income Distribution and Growth at the National Bureau of Economic Research). All remaining errors are ours.

1. A thorough statistical assessment of the extent of these changes is still on the research agenda. However, a recent empirical literature provides evidence that these changes cannot be ignored. In 1992 Osterman [1994] conducted a survey of 694 U. S. firms. He found that in 64 percent of all sectors, firms introduced new working practices concerning at least half of their workforce (for example, 40.5 percent introduced self-directed team working, and 26 percent frequent job rotations). According to a French survey conducted by N. Greenan for the Ministry of Industry, 39 percent of French firms (with more than 50 employees) said to have reorganized between 1988 and 1993 (this rate goes up to 62 percent for firms above 1000 workers). Eighty percent of them aimed at reducing delivery time, while 60 percent wanted to be able to adapt more easily to changes in the production process.

The Quarterly Journal of Economics, November 2000

influences the labor market through a skill upgrading of firms' occupational structures [Caroli and Van Reenen 1999; Bresnahan, 1998]. Furthermore, Goldin and Katz [1998] show that the replacement of unskilled labor by skilled workers and machines began early in the twentieth century. They view this skill upgrading as the consequence of organizational change, mainly driven by technological change.

In this paper we develop a theoretical model to assess the interaction between organizational choice and the macroeconomy. We argue that firms constantly have to adapt to the pace of product market change which implies that organization choices represent a trade-off between *efficiency and adaptability.* In our framework this choice feeds back into the product market by reinforcing its instability. We show that, as a result, the product market alters labor demand by skill through reorganization.

The core mechanism borrows from Piore and Sabel's [1984] insight. We assume that complex organizations can enhance their productive efficiency through the payment of a product-specific sunk cost.[2] As a result, product market instability, by increasing the rate of obsolescence of internal procedures, regulations, and equipment, is an important determinant of organization.[3] This sunk cost modeling strategy is very crude, but it allows us to assess very clearly the macroeconomic impact and determinants of organization choice. It is founded on past developments in the sociology of organizations, where contingency theory [Burns and Stalker 1961] views firms' organizational structures as endogenous to the external environment[4] and in particular to the product

2. In Piore and Sabel's words: "Mass production offered those industries in which it was developed and applied enormous gains in productivity [. . .] But these gains had a price. Mass production required large investments in highly specialized equipment and narrowly trained workers. In the language of manufacturing, these resources were "dedicated:" suited to the manufacture of a particular product—often, in fact to just one make or model. When the market of one particular product declined, the resources had no place to go."

3. Many economists consider available production technology to be the main determinant of organization choice (see, for example, Caroli and Van Reenen [1999]).

4. As Daft [1998] puts it: "When the external environment was stable, the internal organization was characterized by rules, procedures and a clear hierarchy of authority. Organizations were formalized. They were also centralized, with most decisions made at the top. Burns and Stalker called this a mechanistic organization system.

In rapidly changing environments, the internal organization was much looser, free flowing, and adaptative. Rules and regulation often were not written down, or if written down, were ignored [. . .] The hierarchy of authority was not clear. Decision making authority was decentralized. Burns and Stalker used the term organistic to characterize this type of management structure."

market instability. According to this literature, environment matters because there is a fundamental *dilemma* between organization and innovation: larger organizations allow substantial productivity gains (through division of labor, detailed definition of tasks, specially designed hierarchies, and control) but resist implementation of innovations for two reasons. First implementation requires studies and modifications that, *by definition,* complex organization has not been designed to deal with [March and Simon 1958]. Second, large organizations favor collusion between employees, whose rents are endangered when innovations are introduced [Crozier 1963]. Thus, implementation costs are positively correlated with the complexity of organizational design [Perrow 1970].[5]

We use a Schumpeterian growth model à la Aghion and Howitt [1992] where the creative destruction rate provides a natural interpretation for product market instability: each innovation creates a temporary monopoly rent, while destroying the incumbent's market power. Skilled workers participate in production and R&D, while unskilled workers can only produce. Environmental instability is captured by a research sector that sells patents to the producing sector. Just after purchasing a patent, new monopolies can choose between an organization that provides high productivity at the expense of a sunk cost (*mechanistic*), and one that provides low productivity without sunk costs (*organistic*):[6] organizational complexity has an innovation-specific component. Intuitively, the higher the innovation rate in the economy, the shorter the project's life expectancy, and the less the sunk cost of being well organized proves profitable. This is how the macroeconomy affects organizational choice. On the other hand, changes in organizational structure, by changing firms' profitability, patent prices, and research activity, do influence the growth rate of the economy and the wage distribution, so that organizational choices feed back into aggregate variables.

This framework provides a macroeconomic theory of interaction between product market instability and organizational choice. First, it provides a natural macroeconomic foundation for endogenizing segregation by skill. Second, our model provides an

5. In the economic literature this innovation versus organization antagonism has been recently explicitly modeled by Martimort and Verdier [1998] who use developments in agency theory to analyze the relation between creative destruction and firm bureaucratization.

6. This terminology is borrowed from Burns and Stalker's work.

integrated explanation to stylized facts on recent trends of the U. S. labor market [Gottshalk 1997]: an increase in the relative supply of skilled workers, an increase in the skill premium, and a decrease in the unskilled real wage. Third, it predicts that the degree of specialization in production decreases with market size, at odds with standard economic literature (Murphy, Shleifer, and Vishny [1988], for instance). The intuition behind this result is that increased market size generates more product market instability, rendering product-specific specialization less affordable to firms. Finally, we show that the process of globalization, when arising largely between *similar* countries, is more likely to have strong consequences for a firm's organization and labor demand by skill because of increased competition.

Our model thus suggests that recent shifts in skilled labor demand must have been related to rising product market turbulence. The second part of the paper provides original evidence that this interpretation is empirically relevant. We rely on a French data set that allows us to disentangle functional and skill structure at the firm level between 1984 and 1995. At the aggregate level, we find that half of the increase in skilled labor demand is accounted for by employment reallocation from (unskilled-worker-intensive) production to (skilled-worker-intensive) development and commercialization. Furthermore, we provide evidence of an increase in research and creative destruction since the 1970s, suggesting that product markets have become more unstable. Then, at the firm level, we show that the degree of occupational reallocation depends heavily on various measures of market instability such as the number of researchers and the share of new products in total sales. The main conclusions of the model are thus supported by the data, firms have experienced more product or process turnover, and were thus forced to change their occupational mix from unskilled-intensive production to more skill-intensive customization, design of new products, and trade-related activities.

We see this paper as providing a link between two strands of the literature. The first, seeking an explanation for the dramatic rise of U. S. wage inequality for the past two decades, considers how organizational change feeds back into macroeconomic variables, in particular the wage distribution and growth (Lindbeck and Snower [1997], Acemoglu and Newman [1997], and Acemoglu

[1999] among others).[7] However, none of these models explicitly accounts for product market stability. The second strand of literature emphasizes the relation between uncertainty (technological or creative destruction) and organization [Piore and Sabel 1984; Aoki 1986; Martimort and Verdier 1998]. In this sense, our paper is close in spirit to Galor and Moav [2000], who emphasize that technical change is skill biased in the short run because it renders low skilled know-how obsolete.

This article is organized as follows. Section II is devoted to presenting the model. Section III discusses implications for the wage distribution, economic development, and international trade. In Section IV we provide macroeconomic and microeconometric evidence in line with the predictions of our model. Section V concludes and gives directions for further research.

II. The Model

A. Basic Framework

The framework presented below is in the style of the Schumpeterian growth model developed by Aghion and Howitt [1992] and Grossman and Helpman [1991].

There exist two types of labor, skilled and unskilled, whose exogenous supplies are H and U, respectively. A representative consumer optimizes her intertemporal utility:

$$U_t = \int_t^{\infty} \ln (C_s) e^{-\rho(s-t)}\, ds, \tag{1}$$

where C_t is an index of consumption at date t and ρ is the subjective rate of time preference. Financial markets are assumed to be perfect. If we define E_t as aggregate spending, straightforward dynamic utility maximization yields $\dot{E}_t/E_t = (r_t - \rho)$. We then normalize agreggate spending to 1, which ensures that $\forall t, r_t = \rho$. The consumption index is a function of a continuum of goods $i \in [0;1]$, subject to quality improvements through innovations. It is given by

$$\ln C_t = \int_0^1 \ln (\lambda^{s(i)} \cdot c_t(i))\, di, \tag{2}$$

where $\lambda > 1$, $s(i)$ denotes the number of innovations experienced

7. Another literature attributes temporary increases in wage inequality to the diffusion of a new technology (see Helpman and Trajtenberg [1994]).

by good i since the beginning of time and $c_t(i)$ is the quantity of good i consumed at date t. Under this specification the demand faced by sector i is given by

$$x_t(i) = 1/p_t(i). \tag{3}$$

Research laboratories produce innovations according to a Poisson process θ, using skilled labor only.[8] Since the set of sectors is of measure 1, θ is both the aggregate research effort and the flow probability that a given sector receives an innovation. In this activity, research technology is of constant returns; that is, for a given lab i, $\theta_i = h_i^{RD}/b$, where h_i^{RD} is the number of employed researchers. We assume, for the sake of simplicity, that innovations cannot be perfectly directed toward one particular sector: hence, while searching, a given lab does not know which sector its innovation will be designed for. Summing over labs[9] yields an aggregate production of innovations:

$$b\theta = h^{RD}.$$

Once found, patents are sold by laboratories to an infinite number of potential final good producers; hence a successful lab can capture the whole value of patent exploitation.[10]

It must be noted that people working in the R&D sector need not be thought of as being researchers only. "R&D" refers to all workers whose job is to create and exploit temporary rents, and as such includes not only engineers and product designers who create improved versions of existing products, but also marketing departments and salesmen who spot new needs, help to design customized products, and work at recovering market share [Stalk and Webber 1993; Daft 1998].

In each sector i, risk-neutral producers use both skilled and unskilled labor according to a constant returns technology $y = a \cdot (h)^{\alpha} \cdot (u)^{1-\alpha}$, where a is the *endogenous* level of productivity (see below) and h and u are the number of skilled and unskilled workers, respectively. Different patent owners in sector i compete in price to sell their good to the consumer. As is standard in this

8. The only assumption needed in order to establish our results is that R&D technology is more skill intensive than the productive sector. This assumption is made just to simplify the calculations.

9. We are assuming independence between the different processes here.

10. As in most Schumpeterian growth models, the producing monopoly chooses to invest nothing in research because the efficiency effect is strictly dominated by the replacement effect. This point can be easily shown in our context of Bertrand competition.

literature, in equilibrium, only one supplier actually produces: the one with the highest quality to price ratio. Note here that given the Cobb-Douglas specification, the unit cost function of a firm is given by

$$UC(a,w_s,w_u) = uc(w_s,w_u)/a, \tag{4}$$

where $uc(w_s,w_u) = \alpha^{-\alpha}(1-\alpha)^{1-\alpha} \cdot w_s^{\alpha} \cdot w_u^{1-\alpha}$ and (w_s,w_u) are the wages of skilled and unskilled workers, respectively.

Once the firm has bought the patent, an innovation-specific production process needs to be implemented. Just after the purchase of the patent, the firm can choose between two production technologies: one with a high productivity $\overline{a}$ which entails an innovation-specific sunk cost C,[11] or one with a low productivity $\underline{a}$, not incurring any fixed cost.

This assumption can be viewed, as in Murphy, Shleifer, and Vishny [1989], as the choice between a production technology with Increasing Returns to Scale (IRS) when the firm pays the sunk cost, and one with Constant Returns to Scale (CRS). From the point of view of the organization of production, the CRS firm is less efficient because it makes little use of labor division, therefore losing gains from specialization. Also, different production units may suffer from coordination failures due to a lack of centralization. According to Demsetz [1997], externalities between these units are not internalized enough by the management: bottlenecks, excess inventories, and inefficient resource (labor, capital) allocation to the different tasks may occur. Alternatively (or additionally), the CRS firm can be thought of as a firm investing little in innovation-specific capital goods. On the other hand, the IRS firm makes intensive use of innovation-specific machines, relies on an extensive division of labor, with very precisely defined tasks and a structured hierarchy; it therefore achieves a higher degree of efficiency at producing, but incurs coordination costs as in Becker and Murphy [1992].

As stated above, this paper emphasizes the innovation-specific nature of coordination costs. The detailed definition of

11. We assume that C is "wasted money:" the lost returns do not show up in other general equilibrium equations. C can also be viewed as an opportunity cost of wasting time in adapting a complex organization to the new process. Our results would be qualitatively unchanged under the assumption that C is a nominal sunk cost which corresponds to the consumption of final goods (see Appendix 1 for more details). We also investigated the case where C corresponds to additional labor consumption: depending on the skill intensity of C with respect to the skill intensity of the production process, our results would be weakened or enhanced (we thank Roland Bénabou for drawing our attention to this point).

tasks and design of an appropriate organization needed to organize the division of labor, the definition of relations between production units, the scheduling of tasks, the design of an appropriate hierarchy, and the purchase of "dedicated" equipment are all, to some extent, up-front innovation-specific costs associated with a more efficient use of production (mostly unskilled) workers. The central assumption here is thus that production (mostly unskilled) labor is complementary to an organizational structure that entails an innovation-specific sunk cost.

B. Competition at the Microeconomic Level

We first perform a partial equilibrium analysis, in order to uncover the determinants of firms' organizations at the sectorial level. So, in this subsection we take the product market rate of creative destruction, θ, as given (θ is indeed set at the macroeconomic level[12]). For the sake of simplicity, we omit here the sectorial subscript i.

First, consider a firm that has just purchased a patent and has to decide on its production technology. Its main competitor (the most up-to-date incumbent) has productivity a_{-1}. Once the new entrant has chosen technology a, firms in the sector will engage in Bertrand competition. In the absence of capacity constraints, the producer providing the highest quality price ratio will serve the whole demand, adjusting its price such that its less efficient competitors make negative profits. Thus, the new entrant[13] will crowd the incumbent out of the market if

$$\lambda a > a_{-1}.$$

Hence, the new entrant will always make positive profits, until another innovation comes out. The entrant's expected value of profits is thus given by

$$V(a;a_{-1},\theta) = \frac{(1 - a_{-1})/\lambda a}{r + \theta} - C \cdot \mathbb{I}_{\{a=\overline{a}\}}, \tag{5}$$

where $\mathbb{I}_{\{a=\overline{a}\}}$ is an indicator function.

12. This stems from our assumption that a lab cannot direct its innovations toward a given sector. In making this assumption, we rule out the strategic interaction whereby a firm deters further innovations in its own sector, by influencing the future incumbent's value and research activity.

13. We make the simplifying assumption that the quality improvement is large enough to compensate the possibility that the new entrant has chosen a less productive production technology than the incumbents. In other words, we allow a workshop to be able to crowd out a Tayloristic factory. This assumption could be relaxed without altering the main results, although at the cost of some complications and a lot of expository complication.

For a given θ, the entrant's reaction function is easily computable:

$$a^*(a_{-1},\theta) = \begin{cases} \underline{a} \text{ if} & \theta > a_{-1} \cdot \dfrac{\Delta a}{\overline{a}\underline{a}\lambda C} - r \\ \overline{a} \text{ if} & \theta < a_{-1} \cdot \dfrac{\Delta a}{\overline{a}\underline{a}\lambda C} - r \end{cases},$$

with $\Delta a = \overline{a} - \underline{a}$. For a given θ, the entrant's optimal technology will be more efficient when the incumbent is more efficient; i.e. there is a strategic complementarity between both competitors. In economic terms, this means that if the other firm's productivity is low, the competitive drawback of not being efficient is less than the sunk cost of specialization.

Second, if the rate of creative destruction is large enough, the CRS technology will always be preferred. Indeed, since the innovation life cycle ($=1/\theta$) is short, the firm is better off adopting the CRS organization than paying the innovation-specific sunk cost associated with a more efficient production process: this effect, at the heart of Piore and Sabel's [1984] view of flexible specialization, is the direct consequence of the macro-level externality R&D exerts on the firm's choice of organizational structure. Indeed, an increase in the rate of destruction decreases the marginal return to being efficient. This externality will play an important role in the general equilibrium analysis.

In this paper we consider only the symmetric equilibria. We thus arrive at the following straightforward proposition.

PROPOSITION 1. (Characterization of the possible equilibria).

1. All firms choosing $\underline{a}$ is an equilibrium if and only if

$$\theta > \frac{\Delta a}{\lambda C \overline{a}} - r = \underline{\theta}.$$

In what follows, we call this the CRS equilibrium.

2. All firms choosing $\overline{a}$ is an equilibrium if and only if

$$\theta < \frac{\Delta a}{\lambda C \underline{a}} - r = \overline{\theta}.$$

In what follows, we call this the IRS equilibrium.

Hence, the characterization of sectorial equilibrium depends on the rate of creative destruction. This is a direct consequence of the externality that R&D exerts on a project's discounted rate of return. Moreover, the strategic complementarity mentioned above is strong enough to ensure the existence of multiple equilibria for intermediate values of θ, since $\underline{\theta} < \overline{\theta}$ for all parameter values.

C. General Equilibrium

In what follows, we restrict ourselves to the study of stationary symmetric equilibria; that is, the organizational structure is the same in all sectors. Since potential innovation buyers compete à la Bertrand to buy the patent, its price is exactly the value of the firm. We get, from equation (5),

$$V(\theta) = \frac{1 - 1/\lambda}{r + \theta} - C\,\mathbb{I}_{\{a=\overline{a}\}} \tag{6}$$

$$a = \overline{a} \quad \text{if} \quad \theta < \overline{\theta} \quad \text{and} \quad a = \underline{a} \quad \text{if} \quad \theta > \theta. \tag{7}$$

Note that this value function depends on the firm's organizational choices by way of the sunk cost C, and not through the firms' productivity levels a. This is because, in equilibrium, only relative productivities matter.[14] Consequently, for a given θ, the patent value is unambiguously higher in the CRS equilibrium than in the IRS one.

Free entry in R&D equalizes the costs and the benefits of the activity. Thus,

$$bw_s = V(\theta). \tag{8}$$

Labor market clearing conditions are given by the following sets of equations:

$$H = b\theta + \alpha/\lambda w_s, \tag{9}$$

$$U = (1 - \alpha)/\lambda \cdot w_u. \tag{10}$$

Hence, the full characterization of the steady state general equilibrium is given by equations (6)–(8) and (9)–(10).

The right-hand side of equation (9) represents skilled labor demand expressed in terms of θ and w_s. By using equations (6)–(8), we may express this demand in terms of θ alone (as shown in Figure I). When all firms use an IRS production technology, the supply of skilled workers needed to achieve a given rate of creative

14. This is particulary obvious under Bertrand competition. Nevertheless, Our results would continue to hold in any general equilibrium model, where demand depends on relative prices (perfect competition with vintage capital as in Aghion and Howitt [1994], or monopolistic competition as in Romer [1990]).

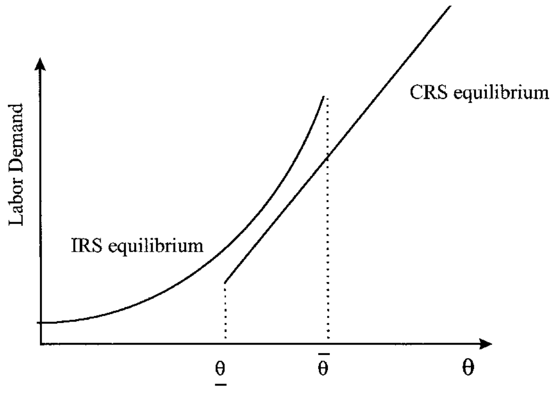

FIGURE I
Aggregate Labor Demand in CRS and IRS Equilibria

destruction θ is larger, as production is more efficient, and therefore employs more of them. This is why the labor demand curve in the IRS regime lies above the CRS one. Thus, strategic choice of organizational structure renders labor demand nonmonotonic, and for intermediate values of the skilled labor supply, the horizontal supply curve intersects the demand curve twice.

PROPOSITION 2. Description of Equilibria: $\exists(\underline{H},\overline{H})$ such that $\underline{H} < \overline{H}$ and

1. if $H \le \underline{H}$, then the economy is IRS in all sectors;
2. if $H \ge \overline{H}$, then the economy is CRS in all sectors;
3. if $\underline{H} \le H \le \overline{H}$, both equilibria coexist.

This result highlights the key role of a second strategic complementarity that arises in general equilibrium through the R&D sector. Indeed, let all other firms choose to be CRS. As noted above, this common strategy raises their value, and hence R&D's marginal productivity (recall that the labs' expected flow of profits is given by $(V/b) \cdot h^{RD}$),[15] which in turn raises R&D's output, i.e., the growth rate θ. But from Proposition 1 we know that a higher rate of creative destruction generates an externality on the sectors' choices, rendering more likely the existence of a CRS equilibrium.

In summary, the externality that firms' decisions impose on

15. Note that this effect is robust to a Decreasing Returns to Scale specification of the R&D technology: $\theta = l^{\alpha}/b$.

R&D, and the feedback effect of the level of R&D activity on both organizations' comparative advantages, combine to form a strategic complementarity in general equilibrium. This complementarity, along with the sectorial one highlighted in the preceding subsection are responsible for the coexistence of IRS and CRS equilibria at the macro level.

III. Discussion

A. Equilibrium Switch

In this section we aim to investigate the pure effect of a change in organizational structure. In order to do this, we compare the features of both equilibria for a given labor supply $H \in [\underline{H};\ \overline{H}]$. This allows us to abstract from supply effects. We present comparative statics results when *Reorganization* occurs; i.e., when the economy switches from an IRS to a CRS equilibrium.

Production in the CRS equilibrium is less "skill consuming" (the CRS labor demand curve lies below the IRS one in Figure I): θ is unambiguously larger in the CRS equilibrium than in the IRS equilibrium. As discussed above, for a given θ, project values are higher if all firms choose the CRS organization because nobody pays for the sunk costs, while all firms have the same productivity. This ensures that the flows of profits are not lower than in the IRS equilibrium. As a result, R&D's productivity is higher, as is R&D's demand for skilled labor and hence θ. In other words, firms' reorganizations, by increasing the price of patents, tend to create a bias toward R&D activity and innovation.

RESULT 1. The rate of creative destruction is higher in the CRS equilibrium ($\theta_{CRS} > \theta_{IRS}$), and the stock market value of a firm is higher ($V_{CRS} > V_{IRS}$).

The flow of output in equilibrium is given by

$$X = a \cdot U^{1-\alpha},(H - b\theta)^{\alpha}. \tag{11}$$

As outlined above, skilled workers move from production to R&D as firms reorganize; at the same time, firms' reorganization reduces productivity ($\underline{a} < \overline{a}$). Hence, the production flow is unambiguously lower in the CRS equilibrium for two reasons. First, productivity goes down. Second, R&D becomes comparatively more productive, attracting more skilled workers, which leaves fewer skilled workers in the productive sector.

RESULT 2. The production level is lower in the organistic (CRS) equilibrium ($X_{CRS} < X_{IRS}$).

One might argue that our results are inconsistent with the fact that after reorganization, firms often see a massive increase in their labor productivity (see Askenazy [1998] for the United States). However, standard measures of productivity are obtained by dividing value added by the number of workers. An equivalent measure in our framework would be obtained by multiplying the number of projects undertaken in a year by their values and dividing by the workforce. In the CRS equilibrium we thus expect firms to undertake more projects (since their life cycle is shorter) that have larger values, and to use fewer employees. Hence, in our model, we would expect the empirical measure of productivity to rise when the economy switches from the IRS to the CRS equilibrium. To sum up, IRS firms have a higher "static" productivity ($\underline{a} < \overline{a}$), while CRS firms have a higher productivity in a dynamic sense and they also undertake more projects.

The change of equilibrium affects the real wage distribution through three channels. First, since the production process is less efficient, the supply of the final good goes down, which raises its price. As a result, this "disorganization" effect depresses real wages for both types of labor. Second, as skilled workers leave production for research, the marginal gain of hiring production workers goes down. Third, demand for labor in R&D is higher, which boosts the skilled wage. This "innovation push" effect has no direct effect on the unskilled wage. Channels 2 and 3 combine into what we called above the "segregation effect;" as a result of widespread reorganization, skilled workers leave the less skill-intensive activity to join the more skill-intensive one. This result is consistent with the theory and evidence presented in Kremer and Maskin [1995], although the source of segregation here is a change in equilibrium, rather than a change in labor force composition. However, we show below that a change in labor force composition can be at the origin of this shift in organizational and technological paradigm, thereby reconciling our results with those of Kremer and Maskin.

A switch from an IRS to a CRS equilibrium thus yields an unambiguous decrease in the unskilled real wage, while the skilled wage may increase if the "innovation push" effect dominates the "disorganization" effect. To summarize, both types of workers suffer from the lower productivity of the production sector, but the improved profitability of R&D can outweigh this lower productivity for skilled workers. The "ever-changing" economy, which emphasizes reactivity and cheap implementation of short-lived innovations, harmful to the unskilled, who have a lower productivity, but it can benefit the skilled, who participate in making the inventions (the "noise").

Next, we measure inequality as the skilled/unskilled wage ratio. We show in the appendix that the CRS equilibrium is associated with more inequality and a higher skill premium:

$$\frac{w_s}{w_u} = \left(\frac{\alpha}{1-\alpha}\right) \cdot \frac{U}{H - b\theta}. \tag{12}$$

RESULT 3. Wage inequality, as measured by the skill premium, is higher in the CRS equilibrium $(w_s/w_u)_{CRS} > (w_s/w_u)_{IRS}$ than in the IRS equilibrium.

Since innovations in this model appear through quality, and not productivity, output and real wages are stationary. However, the instantaneous utility at date τ is given by

$$u(\tau) = \theta \cdot \ln \lambda \cdot \tau + \ln X.$$

Hence, the utility level is increasing in τ, through successive improvement of the final goods' qualities. By considering preferences instead of output, we again find a positive effect of innovation on both skilled and unskilled workers. Although the real wages of unskilled workers are decreasing, their instantaneous utility increases faster after reorganization, at least in the long run.

B. Skilled Workers and Retooling

According to Goldin and Katz [1998], the fact that a change in organizational structure and the installation of new machines require skilled labor, is the source of skill complementarity. In this section we discuss briefly, in a partial equilibrium context, the implications of this assessment in our framework.

Consider an extension of our model where the innovation-specific sunk cost is $\overline{C}$ units of skilled labor for a *mechanistic* organization and $\underline{C}$ units of skilled labor for an *organistic* organization, and $\overline{C} > \underline{C}$. Aggregate demand for skill is now composed of demand for producers, researchers, and people who can install new equipment (retoolers). Let us consider a shift from the mechanistic equilibrium to the organistic one.

The effects on the first two components of skill demand have already been discussed above. This is why we focus on the last component, the demand for retoolers, which is equal to θC. In the organistic equilibrium, demand for retoolers decreases (C goes down). But, as θ increases, firms need to retool more often, which increases demand for installation. The consequence of an equilibrium shift on demand for skilled installers is thus ambiguous, but if the latter effects dominates, increased product market instability is even more favorable to skilled workers because of increased frequency of retooling.

C. Market Size and Organizational Change

Our model is also able to shed new light on the relation between market size and the degree of division of labor. To illustrate this point, we assume in the following sections that the number of sectors is of measure N. θ is now the flow probability that a given sector receives an innovation (the relevant measure of creative destruction). $\Theta = N\theta$ is the aggregate research effort. All equations are unchanged, except (9).

$$H/N = b\theta + \alpha b(r + \theta)/(\lambda - 1 - C\lambda(r + \theta) \cdot \mathbb{1}_{\{a=\bar{a}\}}). \tag{13}$$

Thus, the choice of the organizational structure depends on the sectorial θ, which is in turn determined by the ratio H/N.

In what follows, we call an expansion of market size, an equiproportional increase in both labor supplies H and L. In our framework, if N remains fixed, this expansion is favorable to the CRS equilibrium (Proposition 1), where firms adopt a constant return to scale production organization, relative to an IRS organization. Should we be surprised by this result?

According to conventional wisdom since Adam Smith, the degree of labor division in the economy is limited by the size of the market. This implies that larger markets will have more competitive IRS firms, because IRS firms more efficiently exploit increasing returns to scale through division of labor. This is not the case in our model since a larger market here stimulates the R&D activity and shortens the product life cycle. This renders fixed costs unsustainable, and therefore CRS firms are more efficient. This mechanism can be related to the argument suggested by Becker and Murphy [1992]. They argue that coordination costs within the firm exert a constraint on the degree of labor division that is more stringent than market size.

This market size effect on growth is standard in models with imperfect competition. However, Jones [1995] challenges this mechanism and empirically shows that there is no correlation between growth and market size. Young [1998] provides a theoretical framework which allows him to purge Schumpeterian models of this pure market size effect. He proposes a model of growth in which both vertical and horizontal differentiation are allowed, but horizontal differentiation does not benefit from intertemporal spillovers.

Young's argument suggests a deeper interpretation of the effects of market size on the division of labor. Since an equiproportional expansion of labor supply should increase the number N of commodities available in the economy in the long run, R&D should remain unchanged, and the choice of organizational structure should be the same before and after an expansion of size (H/N is constant in equation (13)). But the story is quite different in the short run. Young does not consider explicitly the transition dynamics after a market expansion (in his model, the economy immediately reaches the steady state equilibrium). But, if we think of N as a stock variable and θ as a forward one, N increases continuously just after an increase in market size whereas θ jumps directly to a higher value and then relaxes. In this case, instability should temporarily increase and may compel the firm to switch to a CRS organization. We may thus expect some hysteresis along the transition path; if firms choose a CRS organization because of the temporary increase in θ, they may remain CRS despite the decline in θ that occurs through increasing horizontal differentiation. In sum, if one believes in the hysteresis effect, market size may have a long-run effect on organizational choice, and therefore on the degree of labor division (see Figure II), even though it has no long-run effect on R&D activity.

D. Increase in the Skilled Labor Force

Autor, Katz, and Krueger [1998] have documented how the U. S. college premium sharply increased in the 1980s, while the college educated share of the workforce also steadily increased over the period. In addition, Askenazy [1999] shows that among those U. S. sectors that have reorganized, most did so in the

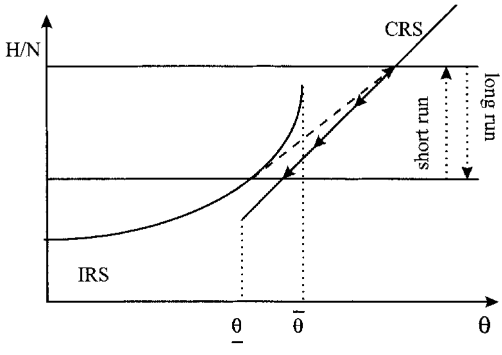

FIGURE II
Short-Run and Long-Run Effects of a Larger Market Size

mid-1980s. Our model provides a new perspective for understanding these facts.

In order to restrict our attention to pure composition effects in the labor force, we suppose (in the spirit of Young [1998]) that $N = U + H$. An increase in the share of skilled labor may shift the economy to the CRS equilibrium (equation (13) and Proposition 2). This has two effects on wage inequality. First, inequality is reduced through lowering the skilled wage. This is a standard supply effect. Second, if the skilled labor supply hits the upper bound $\overline{H/N}$, firms face an economywide organizational change. As a result of this effect, the skill premium rises (see the preceding section). As an example, Figure III shows the case where both the supply and organizational change effects are at work, but where the latter outweighs the former.

Our model is thus able to generate a comovement between the share of skilled labor and the skill premium. The intuition behind this outcome lies in the possibility that an increase in skilled labor supply can induce more than its own demand. This feedback of supply into demand has been ignored by economic theory until recently. There is now a small, but growing, body of literature dealing with these issues. To our knowledge, the first paper exhibiting these features is Acemoglu [1998a]. He models an economy where firms post vacancies, choosing in a first step the quantity of capital associated with each job. Then they search for workers to fill the vacancies. Labor supply is composed of two types of workers: productive (skilled) and less productive (unskilled). If the supply of skills is scarce, firms will fill their

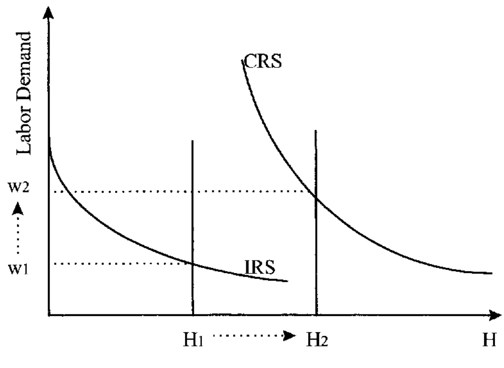

FIGURE III
Increase in Skilled Labor Supply and Equilibrium Shift

vacancies with the first worker they find. In equilibrium, all posted vacancies will be associated with the same quantity of capital, since ex ante discrimination is not profitable for firms: this is his pooling equilibrium. On the other hand, if the supply of skills is abundant, it will be profitable for firms to create both highly capital-intensive vacancies, designed for skilled workers exclusively, and jobs associated with low capital, for unskilled workers. In this separating equilibrium, skilled wages will be higher, and unskilled wages lower. In this model, matching externalities along with hold-up effects, make the expected marginal return to capital depend on labor force composition.

Our story is quite different. It results from the combination of two features. First, a CRS economy has a lower demand for unskilled labor in production, since it does not invest in the sunk cost. Second, the CRS economy actually has a higher demand for skilled workers in research. Hence, the economy reacts to a larger supply of skilled workers by creating even more skilled jobs in R&D, and by destroying unskilled jobs in production.

E. Economic Integration

The discussion above suggests that our model can provide some insights into the labor market consequences of international trade between similar countries. Consider the economic integration of two countries (1 and 2). Suppose that the skill endowments of these countries are identical, $U_1 = U_2$ and $H_1 = H_2$, so that, after integration, neither country will opt for complete specialization. The number of goods in each country is $N_i = U_i + H_i$. We consider two cases according to the degree of overlap between commodity markets of both countries (see Grossman and Helpman [1991, Chapter 9] for a detailed discussion).

At one extreme (case A), both countries produce goods that are completely different. The number of sectors in the integrated (relative to autarky) economy increases to $(N_1 + N_2) = (U_1 + U_2 + H_2 + H_2)$; aggregate research effort Θ also rises. But the rate of creative destruction θ within each sector does not change, since the share of skilled labor remains constant (equation (13)). This case corresponds to a pure composition effect, in which integration alters neither economic turbulence nor the choice of organizational structure.

In the opposite case (case B), both economies produce exactly the same goods before integration. The number of sectors in each country remains unchanged after integration. However, *the rate* of creative destruction θ rises, and the integrated economy may shift from the IRS to the CRS equilibrium. As a result, firms change organizational structure, and inequality rises. Case B is an example of a pure size effect.

In this discussion we treated the number of sectors as exogenous. If we let N adapt to market size as we did above, our analysis suggests that the size effect should temporarily dominate in the short run (and possibly also in the long run if we believe in the hysteresis effect), and economic integration between developed countries may create markets that are more turbulent, in which firms are forced to reorganize.

IV. Empirical Evidence

The supply of educated workers has been increasing sharply for the past 30 years in most OECD countries [Autor, Katz, and Krueger 1998]. Our model suggests that this change in the supply of skilled labor may have affected relative demand for skill from firms, because product markets may have become too unstable to support the previously dominant organizational structure. Therefore, our setup provides a natural framework for interpreting recent trends in OECD labor markets.

In this section we provide empirical evidence that these predictions of our model are consistent with recent data. At the macroeconomic level, we show that skill upgrading of jobs from 1984 to 1995 in the French economy is the result of a reallocation from functions related to production to functions related to commercialization, customization, and design of new products.[16] In addition, there is macroeconomic evidence that creative destruction on the product market has become more active.

At the firm level, we find a significant correlation between employment reallocation (away from production-related activities) and different indicators of creative destruction on the product market.

A. The Data

The data set we use comes from a French survey of the structure of employment in firms (Enquête sur la Structure des Emplois, INSEE). Details concerning the data are provided in Appendix 2. All sectors are covered except for Household Services and Nontraded services (Education and Health Care). The data represent 60,000 firms per year, from 1984 to 1995. It is an unbalanced panel, since many firms enter and exit the data set year. At the firm level, the data provide variables measuring total employment in terms of workers (TOT), sector of activity (four digits-SECT) and the share of employment in each of the following five functions: *development of new products* (DNP: R&D, marketing), *commercialization of existing products* (CO: sales, advertising, technical sales involving in customization, purchasing), *production* (PR: engineers, technicians, blue-collar workers), *logistics* (LO: drivers, maintenance workers, cleaners) and *administration* (AD: managers, corporate lawyers, accountants, other employees). We also know the share of skilled workers employed in each function.[17]

Our data make a clear distinction between function and skill at the firm level. To our knowledge, the literature on occupations and skills tends to use individual data (U. S. census data have been used in this context by Katz and Murphy [1992], Goldin and Katz [1995, 1998], and Murphy and Welch [1993]). On the other hand, existing firm data (such as those used by Berman, Bound, and Griliches [1994]) only have the blue-/white-collar classification, which mixes skill and occupation. Our data set, providing

16. The theoretical counterpart of this reallocation is the shift of skilled employment from production to R&D, as would be predicted by a change in equilibrium.

17. As explained in Appendix 2, the skill measure is derived from the detailed French socioprofessional classification, which allows us to disentangle skill from occupation for each job type at the firm level.

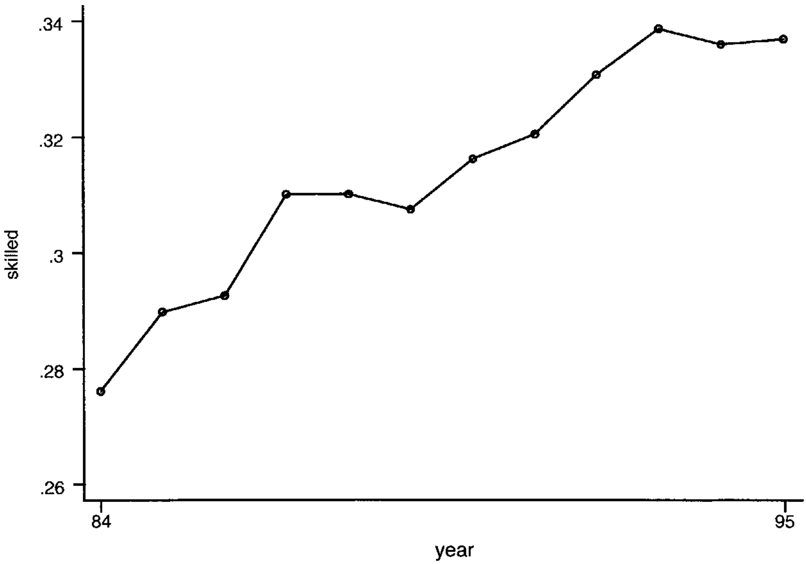

FIGURE IV
Share of Skilled Jobs in France: 1984–1995
Source Enquête Structure des Emplois (1984–1995).

information on both skill and function at the firm level, allows us to deal more easily with labor demand issues.[18]

B. Macroeconomic Evidence

Figure IV plots the share of skilled jobs in aggregate employment from 1984 to 1995. Over this period, France has seen a skill upgrading of jobs of the same magnitude as found in other OECD countries [Machin and Van Reenen 1998]. In our panel the total increase in the share of skilled workers over the period is 5.8 percent, equivalent to an average increase of 0.5 percent per year.

Table I displays aggregate function shares and skill intensities across years. We see that production is the largest and most unskilled labor-intensive function. Development and commercialization are the two smallest functions, but together account for 23

18. We show below that the recent evolution in the skill structure of French employment exhibits similar trends as other OECD countries. For this reason, if France behaves like the rest of the world on the skill dimension, then our empirical analysis should be informative for other developed economies (under the assumption that organizational change is pervasive to some extent).

TABLE I
DESCRIPTIVE STATISTICS ON OCCUPATIONAL STRUCTURE

Function	Adminis-tration	Commercial-ization	Produc-tion	Logis-tics	Devel-opment
Share in total employment (%)					
1984	18.5	11.4	51.6	13.7	4.90
1995	18.0	15.4	44.4	14.7	7.50
Share of skilled workers (%)					
1984	35.7	55.8	14.8	15.5	100
1995	43.7	54.3	17.2	15.9	100

Source. Employment structure survey [ESE 1984, 1995].
All French Establishments of more than twenty employees except in Household Services, Health Care, and Education. Employment is measured in terms of distinct individuals. Skill measure is derived from the detailed French socioprofessional classification and depends on education level and experience.
All numbers are percentage point changes.

percent of aggregate employment in 1995; at the same time they represent the most skill intensive jobs.

How have the shares of different functions varied with time? Their evolutions are plotted in Figure V. A large employment reallocation from production toward development and commercialization (the most skill intensive functions) took place from 1984 to 1995 in the French economy. Indeed, the share of production workers decreased by 7 percent, while that of development and commercialization workers increased by 6.5 percent over the

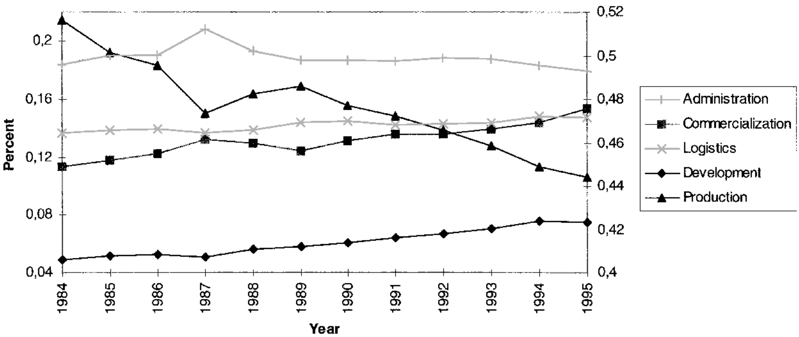

FIGURE V
Occupation Shares in France
Source Enquête Structure des Emplois.

Note. Right axis for Production, Left axis for Administration, Logistics, Development, and Commercialization. Shares are computed by dividing the aggregate number of workers in a given function by the sample labor force.

same period. This reallocation is comparable in size to the aggregate skill upgrading of jobs.

In sum, we see a large employment shift from production (an unskilled-labor-intensive function) to skilled functions, whose main purpose is to reap market share through the design of new products, as well as by customizing and selling them. Consistent with our model, the French economy seems more and more involved in the Schumpeterian process of creative destruction and management of change, and less and less in actual production. The increase in the share of functions related to commercialization and development is consistent with the secular trend in U. S. occupations described in Goldin and Katz [1995]. However, since they cover the 1900–1940 period, they also witness an increase in the share of "operatives," consistent with the diffusion of mass production during that period.

Now consider the contribution of functional reallocation to skill upgrading. Functional reallocation seems to be a major component of the economy's aggregate skill upgrading. To see this, we follow the methodology introduced by Berman, Bound, and Griliches [1994] and decompose aggregate skill upgrading into two parts. Let H be the total number of skilled jobs and N be total employment. Let n_i be employment and h_i be the number of skilled jobs in sector i. Then

$$\frac{H}{N} = \sum_{i=1}^{M} \frac{h_i}{n_i} \cdot \frac{n_i}{N}.$$

Taking first differences with respect to time yields

$$\Delta\frac{H}{N} = \sum_{i=1}^{M} \Delta\frac{h_i}{n_i} \cdot \frac{\overline{n_i}}{N} + \sum_{i=1}^{M} \frac{\overline{h_i}}{n_i} \cdot \Delta\frac{n_i}{N},$$

where Δ represents the time difference operator, and the upper bar denotes the intertemporal mean.

In this approach, aggregate skill upgrading can be decomposed into 1) a move toward more skill intensive sectors (Between component) and 2) an upgrading of skills within each sector (Within component). Using U. S. sectoral data, Berman, Bound, and Griliches [1994] find that the between component is negligible when compared with the within term, regardless of the level of aggregation. Berman, Bound, and Machin [1998] present similar evidence for other OECD countries. Both studies infer from these regularities that specialization due to international trade cannot

TABLE II
SECTORIAL REALLOCATION AND SKILL UPGRADING

Years	84–90	90–95	84–95
D(Skilled)	4.02	2.06	6.08
Between sector	0.42	−0.03	0.09
Within sector	3.60	2.09	5.09

Source. Employment structure survey [ESE 1984, 1990, 1995].

All French Establishments of more than twenty employees except in Household Services, Health Care and Education. Employment is measured in terms of distinct individuals. Skill measure is derived from the detailed French socioprofessional classification and depends on education level and experience. The table variables refer to the Berman, Bound, and Griliches [1994] decomposition. The percentage increase in skilled employment (D(Skilled)) in the sample is equal to the sum of two terms. The first is the sum of net percentage increases in each sector's employment, weighted by this sector's share of skilled workers in employment (Between sector). The second term is the sum of sectorial increases in skilled employment, weighted by each sector's share in total employment (Within sector). To define sectors, we used a two-digit classification (70 sectors).

All numbers are percentage point changes.

be held responsible for the observed widespread skill upgrading of jobs, and that pervasive Skill Biased Technical Change remains the best alternative explanation.

Table II gives the within-between sector decomposition of the aggregate skill upgrading, from 1984 to 1995, and on two five-year subperiods, using our French enterprise data. We use two-digit sector classifications.[19] The between term is almost negligible, suggesting that the sectorial reallocation has little explicative power with regard to the aggregate skill upgrading of French jobs over the period 1984–1995.[20] Our results are thus consistent with what has been found in the two papers cited above; on the skill dimension, French data exhibit the same regularities as displayed by other countries.

The prediction of our model is that functional, instead of sectorial, reallocation should have taken place, as a result of increased creative destruction. Table III provides the between-within function decomposition of the skill upgrading: although we have only five functions, the functional reallocation explains more than half of the aggregate skill upgrading in France. Note that the contributions of production, development, and commercialization are large: reallocation (the between term) takes place from

19. Berman, Bound, and Griliches' study involves a classification of 29 sectors. Our two-digit NAF classification provides us with 70 sectors. A similar decomposition performed on a more disaggregated classification did not change the result.

20. Also note that between-within firm decomposition also yields a negligible between firm reallocation.

TABLE III
FUNCTIONAL REALLOCATION AND SKILL UPGRADING

Years	84–90	90–95	84–95
D(skilled)	4.02	2.06	6.08
Between function			
Administration	0.10	−0.29	−0.17
Commercialization	0.98	1.25	2.21
Production	−0.62	−0.56	−1.16
Logistics	0.12	0.04	0.16
Development	1.17	1.42	2.60
Total	1.76	1.88	3.65
Within function			
Administration	1.04	0.43	1.45
Commercialization	0.07	−0.29	−0.19
Production	0.97	0.17	1.12
Logistics	0.17	−0.11	0.06
Development	.	.	.
Total	2.25	0.19	2.43

Source. Employment structure survey [ESE 1984, 1990, 1995].

All French establishments of more than twenty employees except in Household Services, Health Care, and Education. Employment is measured in terms of distinct individuals. Skill measure is derived from the detailed French socioprofessional classification and depends on education level and experience. The table variables refer to a variant of the Berman, Bound, and Griliches [1994] decomposition. The percentage increase in skilled employment (D(skilled)) in the sample is equal to the sum of two terms. The first is the sum of net percentage increases in each function employment weighted by this function's share of skilled workers in employment (Between function). The second term is the sum of increases in skilled employment within each function, weighted by this function's share in total employment (Within function). Recall that functions are decomposed into five categories, while sectors are decomposed into 70 categories.

All numbers are percentage point changes.

production to development and commercialization. The within production and within administration terms are also quite large, suggesting that skill-biased technical change may be taking place mainly within these two functions.

To sum up, the extent of this functional reallocation from production to development and commercialization is quantitatively important, in that it accounts for almost half of the economy's aggregate skill upgrading.[21] Murphy and Welch [1993] find similar results: they estimate, under particular elasticity assumptions, that a shift in occupations is responsible for one-third of the increase in demand for skilled labor in the U. S. economy between 1950 and 1990.

Finally, our theory predicts that economywide reorganization

21. This methodology is purely descriptive; strictly speaking, these results cannot be interpreted without strong assumptions on the different elasticities of substitution of the underlying production function (for a more structural analysis, see Maurin and Thesmar [1999]).

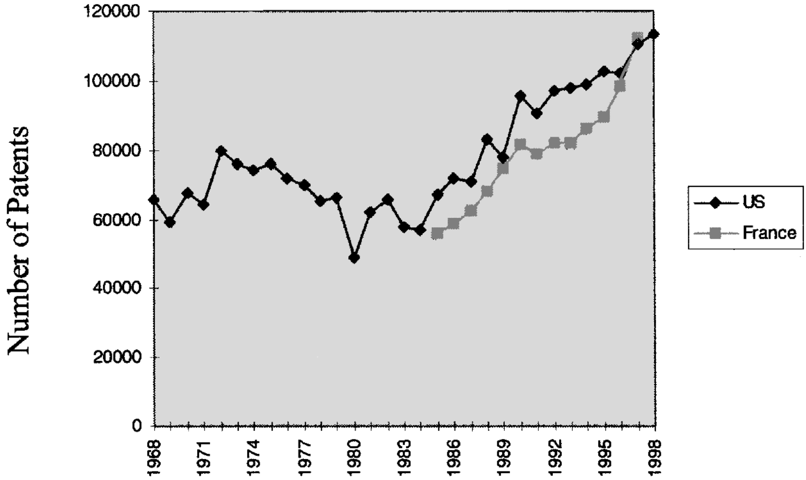

FIGURE VI
Patents Applied for in France and Patents Granted in the United States
Source Patent Offices, France and the United States.

should result in a rise in the rate of creative destruction. According to our results mentioned above, the share of total employment devoted to development of new products (through R&D and Marketing) rose from 4.9 percent to 7.5 percent (a 50 percent increase in twelve years). Similar evidence is provided by Machin and Van Reenen [1998]: they note that, between 1973 and 1989, the share of value added devoted to R&D in seven OECD countries (Japan, United States, United Kingdom, France, Germany, Denmark, and Sweden) has increased by between 45 and 100 percent.

A consequence of this dramatic rise is a larger patenting rate. Figure VI shows the number of patents granted by the U. S. patent office since 1968, along with the number of patents applied for in France since 1985. In both countries we see a twofold increase between 1980 and 1998, a sign of a dramatic acceleration in patenting activity in the past two decades. Although patenting rate is a crude proxy for innovative activity, this pattern suggests a substantial increase in the rate of creative destruction.[22]

Furthermore, Gottschalk and Moffit [1994], using the PSID

22. According to Griliches [1990], the decrease in patents granted during the 1970s is mainly the consequence of a smaller budget for printing the approved patents at the U. S. patent office. However, as can be seen in Figure VI, the subsequent rise (from 1980 onward) in patent approval largely surpasses the number of patents granted in 1970, the peak year before the decline.

data, show an increase in earnings fluctuations and job turnover from the 1970s to the 1980s. This suggests increasing job creation and destruction during the period; however, evidence from plant-level data on this point remains mixed. In our context, we do not believe that firm-to-firm job reallocation is the relevant counterpart to our creative destruction rate since product or process innovations within the firm do not systematically yield worker replacement. Our point is rather that frequent innovations compel firms to change their functional mix, shifting employment toward more skill intensive product development and commercialization. Greenwood and Jovanovic [1999] directly measure product market instability as the share of market value accounted for by firms entering and exiting 30 product specific markets. Using this measure, they find that the rate of turnover has risen from 3 percent in the early 1970s to 6 percent in the late 1980s.

C. Microeconomic Evidence: Creative Destruction and Organization

Complementarity between production workers and an innovation-specific sunk cost (corresponding to organizational complexity) is the key mechanism in this paper. A direct, testable implication of this assumption is that firms in sectors experiencing more creative destruction should, in principle, hire fewer production workers. If our theory is correct, we should therefore observe a negative correlation between worker allocation to production and relevant measures of product market instability in our enterprise data.

As noted above, the most relevant proxies for creative destruction have to do with innovation. Relations between innovation and the share of blue-collar workers have been previously investigated in the skill-biased technical change literature, although the data available so far lack a proper distinction between function and skill, and are most often aggregated to the sectorial level. For example, Machin and Van Reenen [1998] find that the relative demand for white-collar workers is positively related to existing capital and R&D expenditures, using two-digit sectorial data in a panel of OECD countries. Dunne, Haltiwanger, and Troske [1996] find similar results using plant-level U. S. data between 1972 and 1988. These results can be interpreted as a negative relation between product turnover (development of new products) and production employment's share (blue-collar workers) at the firm level. However, the predictions of our model concern the total share of production (both skilled and unskilled) workers. Since our data set allows us to disentangle more accurately function from skill, this section thus seeks to establish the nature of the relation between the share of employment devoted to production and product turnover at the firm level.

In what follows, we use the share of production employees (both skilled and unskilled) within the firm (PR) as our empirical measure of what we called "production workers" in our model.[23] We use two different measures of creative destruction. The first is the ratio of products less than three years old in total sales (NPR); this represents the rate of product turnover. In order to reduce measurement error, this variable is discretized into four categories (less than 10 percent, 10–30 percent, 30–70 percent, and more than 70 percent). The second empirical counterpart for creative destruction is (more classically) the number of researchers.

To begin, we restrict our attention to firms that were active between 1986 and 1990. We regressed the average share of production workers (PR) over the period on our measure of product turnover. Given that the new product ratio (NPR) is taken from a separate survey (the Enquête Innovation), the restriction of a balanced panel of firms present in both surveys reduces the number of available observations to 11,233. Model 1 regresses PR on three indicator variables representing the categories of NPR, while model 2 controls for total employment and sector. Both models are estimated by OLS with White [1980] correction for arbitrary heteroskedasticity. The results are given in Table IV; the reference category for NPR is having less than 10 percent of new products in total sales. A firm in the 10–30 percent category has on average a lower (by five points) share of production workers. For the category more than 70 percent, the difference amounts to 9 percent. All results are highly significant; there is a strong negative correlation between product turnover and the allocation of employment to production.

The second regression takes the number of workers devoted to the function *development of new products* as a regressor (DNP: R&D and marketing) instead of the rate of product turnover. In order to avoid spurious correlation between the dependent variable and the regressor, we replaced PR by the share of production

23. Alternative regressions, using production and administrative workers ($PR + AD$) yield qualitatively similar results, and are available from the authors upon request.

TABLE IV
INNOVATION TURNOVER AND FUNCTION REALLOCATION

Share of production workers	Model 1	Model 2
Share of new products in total sales (86–90)		
Between 10 and 30%	−0.05	−0.05
	(11.44)	(10.88)
Between 30 and 70%	−0.07	−0.06
	(9.54)	(8.82)
More than 70%	−0.09	−0.08
	(5.31)	(4.9)
Employment (1e-6)	—	−3.58
		(1.57)
Observations	11233	11233
R^2	0.02	0.06

Source. Enquête Innovation and Enquête Structure des Emplois (balanced panel).
The dependent variable is the average of the 1986 and 1990 shares of production workers.
The equations are estimated through OLS with White [1980] correction for arbitrary heteroskedasticity.
Model 2 includes the total employment and fifteen sectorial dummies as additional regressors.

workers in total employment excluding development of new products. In this regression we use the full, unbalanced panel of firms, although we require that a firm does not disappear and later reappear in the data set. This leaves us with 568,146 observations between 1984 and 1995. Model 1 regresses PR on DNP lagged by one period, while model 2 adds total employment (TOT) as a second regressor. In both cases, the estimation includes firm-specific fixed effects. Finally, in order to control for long-term trends, models 3 and 4 perform the same regression using five-year differences. As shown in Table V, all models (except model 3, which is rejected by the data) exhibit a negative relation between development effort and the share of production workers.

V. CONCLUDING REMARKS

This paper is motivated by the observation that the organization structures of firms in all OECD industries experienced extensive mutations since the 1970s. In a model of Schumpeterian growth, where production is less skill intensive than research, we allow patent owners to choose an optimal organizational structure in response to volatility in the economic environment. The microeconomic analysis highlights the importance of product market instability (rate of creative destruction) on a firm's choice of organization. A general equilibrium framework reveals that firms'

TABLE V
DEVELOPMENT EFFORT AND FUNCTION REALLOCATION

Share of production	Model 1	Model 2	Model 3	Model 4
Total employment (1e-6)	—	6.86	—	7.05
		(28.34)		(8.56)
DNP (1e-6)	−5.66	−13.9	13.4	−41.1
	(3.08)	(7.47)	(0.42)	(4.93)
Observation	568146	568146	238932	238932
Fisher statistic	106.6	106.79	0.18	36.8

Source. Enquête Structure des Emplois.
Note. DNP corresponds to the number of workers in the function *Development of New Products* (R&D and marketing).
Models 1 and 2 use lagged conception employment. They are estimated by OLS with firm-specific effects.
Models 3 and 4 use long differences (five years). They are estimated by OLS.
t-statistics are in parentheses.

organizational decisions could feed back into aggregate instability. These two externalities combine to generate a macroeconomic complementarity, so that mass production itself reinforces the stability of product markets. Thus, multiple equilibria (mass production/organistic firms) coexist for certain parameter values.

Our findings mostly deal with the interaction between the labor market, equilibrium choices of organization, and aggregate product market instability. Comparative statics show that an increase in the size of the skilled labor force can shift the economy into a zone where both equilibria coexist, and possibly to the zone where only the CRS (organistic) equilibrium exists. This possible equilibrium shift yields an increase in aggregate instability and wage inequality. Furthermore, unskilled wages temporarily drop, while skilled wages jump. Economic integration with similarly skill endowed countries is shown to have the same effects, at least in the short run.

Our conclusions are consistent with recent waves of firm reorganizations, past labor market mutations in several OECD countries (the United States, the United Kingdom, Australia), and an increase in the college enrollment rate. The view expressed in this paper is that there is no obvious reason why technical progress should be more skilled biased than it was 50 years ago. However, we argue that a move toward more decentralization and horizontal communication in the organization of firms intrinsically favors skilled labor to the disadvantages of the unskilled.

The second part of this paper is devoted to an analysis of firms' organizations by way of their functional structures. We show that our assumption that organizational complexity induces an innovation-specific sunk cost is consistent with the firm-level data. Firms that experience more product turnover or that innovate more tend to have a smaller share of production workers. At the macroeconomic level, we witness a massive shift from unskilled labor-intensive functions like production to skill-intensive ones like R&D, Marketing, and Sales Related Activities, which have the goal of designing and customizing new products, and increasing market shares. Moreover, we provide evidence that innovative activity is increasingly intense, in particular over the past twenty years. The evidence thus provides us with a picture consistent with the model: firms experienced more product turnover, and were thus compelled to change their functional mix toward more "flexible functions," which required more skilled workers.

Appendix 1: General Equilibrium Derivation

Unlike the text, where the sunk cost C is assumed to be wasted, this appendix provides calculations assuming that the sunk cost corresponds to consumption of final goods. In this case, we show that the effects highlighted in the text are enhanced.

In all sectors, the choice of organizational structure is symmetric. As patent buyers compete à la Bertrand to buy the patent, its price is exactly the value of the firm. We get from (5): $V(\theta) = 1/r + \theta(1 - 1/\lambda) - C\mathbb{1}_{\{a=\overline{a}\}}$. We then assume that the nominal sunk cost C corresponds to consumption in terms of final goods. More precisely, we suppose that each firm must expend C in buying a composite good Z_C, where $\ln Z_C = \int_0^1 \ln z_c(i)di$. This corresponds to consumption of each final good i of the form, $z_c(i) = C/p(i)$. At each date t, a fraction θ of all firms choose to be organized in a CRS or IRS way. Thus, for each good i the demand due to sunk costs is equal to $\mathbb{1}_{\{a=\overline{a}\}} C\theta/p(i)$.

Free entry in R&D equalizes the costs and the benefits. Instantaneous expected benefits are given by $\theta dt \cdot V_{\{o,m\}}(\theta)$, and instantaneous costs are given by $(b\theta)wdt$. We thus obtain $bw_s = V(\theta)$. As the firm's production function is Cobb-Douglas, the cost in terms of skilled labor required to produce one unit is given by $w_s \cdot U_1^s = \alpha C(a, w_s, w_u)$, where $C(\cdot, \cdot, \cdot)$ is the cost function in (4).

Demand (cf. (3)) is $d(i) = x(i) + z_c(i) = (1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta)/p_i$. Hence,

$$\text{(A1)} \quad D_{U^s} = \int_0^1 d(i) \cdot U_1^s \cdot di = \frac{1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta}{p} \cdot U_1^s$$

$$= \frac{1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta}{\lambda \cdot C(a_{\{o,m\}}, w_s, w_u)} \cdot U_1^s = \frac{\alpha}{\lambda \cdot w_s}\left(1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta\right).$$

Labor demand in R&D depends on the speed of innovation and R&D technology: $D_{U^s}^{R\&D} = b\theta$. The skilled labor market clearing condition gives $\alpha/\lambda w_s \, (1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta) + b\theta = U^s$. Plugging in the free entry condition in R&D yields

$$\text{(A2)} \quad H = b\theta + \frac{\alpha b(r + \theta)(1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta)}{\lambda - 1 - \lambda C(r + \theta) \cdot \mathbb{1}_{\{a=\bar{a}\}}}.$$

Unskilled labor demand is obtained in a similar fashion, as

$$\text{(A3)} \quad D_{U^u} = \int_0^1 d(i) \cdot U_1^u \cdot di = \frac{1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta}{p} \cdot U_1^u$$

$$= \frac{1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta}{\lambda \cdot C(a_{\{o,m\}}, w_s, w_u)} \cdot U_1^u = \frac{1 - \alpha}{\lambda \cdot w_u}\left(1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta\right).$$

The unskilled labor market clearing condition is given by $U = 1 - \alpha/\lambda \cdot w_u \, (1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta)$. For any given θ, the right-hand side of equation (A2) is higher in the IRS equilibrium ($\mathbb{1}_{\{a=\bar{a}\}} = 1$). Thus, we have $\theta_{IRS} < \theta_{CRS}$. Output production is given by $X = aU^{1-\alpha} (H - b\theta)^\alpha$. Expenditure E_t and sunk costs are consumed in the final goods sector: $(1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta)E_t = pX$. Thus,

$$\text{(A4)} \quad p_X = \frac{1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta}{a \cdot U^{1-\alpha} \cdot (H - b\theta)^\alpha}.$$

Nominal wages are easily computed:

$$\text{(A5)} \quad w_u = \frac{(1 - \alpha)(1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta)}{\lambda U};$$

$$\text{(A6)} \quad w_s = \frac{\alpha(1 + \mathbb{1}_{\{a=\bar{a}\}} C\theta)}{\lambda(H - b\theta)}.$$

We can then compute real wages and wage premium from (A4), (A5), and (A6).

APPENDIX 2: DATA DESCRIPTION

A. The Employment Structure Survey

This survey concerns all French establishments having more than twenty employees in a given year. It has been conducted each year from 1984 to 1995 (Enquête sur la Structure des Emplois, INSEE). All sectors are represented, although services tend to be underrepresented because of the minimum employment requirement. Each establishment has a SIRET number (twelve-digit identifying number, whose first nine digits identify the firm to which the establishment belongs), its industry (coded in a four-digit number), and employment (number of workers, with a separate figure for male and female employees).

In addition, the establishment is required to provide detailed information about its employment structure. Each job is coded according to the French socioprofessional classification (Classification Socio-Professionelle), which consists of a four-digit number. The interesting feature of this classification is that it gives information on the tasks performed, the sector, and the worker's skill level, in a manner that allows us to easily disentangle these three pieces of information. The first digit represents the skill level of the employees, ranging from 2 to 7 (2–4 = Cadres, 5 = Profession Intermediaires, 6 = Ouvriers/Employés Qualifiés, 7 = Ouvriers/Employés non Qualifiés). This "ladder" is used in collective agreements in order to determine wages. A higher level of education initially takes workers to a higher starting point on the scale (i.e., to a lower figure), and experience then allows them to climb the steps. It is important, however, to note that this digit represents a pure mix of education and experience, and that it contains no task-specific element. Some "Cadres" may be high-ranking directors, while others have no one to supervise (consultants and R&D engineers, for instance); however, the firm has to classify them as cadres in order to give them high wages. Recall that in France, some 85 percent workers are covered by collective agreements. The last three digits provide detailed information about the task that is performed (occupation), and sometimes also on the sector.

B. Our Main Data Set

Our data set consists of the employment structure survey described above for all available years. Establishments were aggregated into firms (all establishments having the same first nine digits in their SIRET identifying number belong to the same firm). Firms operating in household services (restaurants, hotels, etc.) and nontraded services (health care, education, and other public administrations) were then removed from the sample. All other industries (such as corporate services in consulting and telecommunications) belong to our data set: outsourcing of services by manufacturing firms should thus remain within the scope of our study. At this point, we have a twelve-year unbalanced panel of some 60,000 firms per year. Each firm that has at least one establishment with twenty or more employees in a year during our sample window is present in the data at least once. However, note that the data set may not provide us with each firm's total employment, since only these establishments with more than twenty employees are obligated to answer the survey.

Each annual observation of each observed firm provides the number of employees for each four-digit value of the socioeconomic classification. The first digit is aggregated in two skill groups (2–5, and 6–7), hereafter called "skilled" and "unskilled." The next three digits (those detailing the task performed) are aggregated into five "functions." The first one is "Administration," and consists of corporate lawyers, accountants, secretaries, clerks, and other workers dealing with the firm's general administration. The second one is "Commercialization of Existing Products," which includes salesmen, advertisers, commercial engineers who customize products, etc. Next comes "Production": operatives, supervisors, technicians, and production engineers belong to this function. "Logistics" contains all employees dealing with transportation, repair, and cleaning. Finally, "Development of New Products" includes research engineers, technicians working with them, as well as marketers and designers.[24]

To summarize, our data set is an unbalanced panel of French firms of the 1984–1995 period; attrition is endogenous (firms may leave the panel for endogenous reasons), but this does not fundamentally affect our analysis, which remains descriptive. At

24. Note that "Development of New Products" only has skilled employees, because the first digits of the PCS classification in this function range from 2 to 5 (Cadres and Techniciens) only. Forming skill groups on a different basis (Cadres as skilled and Techniciens-Ouvrier-Employés as unskilled), would allow for the presence of both skill levels in each function. However, techniciens' wages are closer to Cadres' wages than Ouvriers-Employés', and they are usually perceived as being closer to the highest skill group. Moreover, the fact that blue-collar workers are mostly male does not preclude that the concepts are similar.

the firm level, the data set provides employment in skill-function cells.[25]

C. Innovation

A separate survey on innovation (Enquête Innovation, SESSI) provides us with the share of new products in total sales. This survey has been conducted in 1990 by the Ministry of Industry on all manufacturing firms of more than twenty employees. Among other questions, firms were asked about the average share of new products in total sales between 1986 and 1990. This variable (NPR) is discretized, in order to reduce measurement error. It takes as the value 0 if new products account for less than 10 percent of sales, 1 if the number is thought to be between 10 and 30 percent, 2 for the 30–70 percent range, and 3 if new products represent more than 70 percent of sales. The survey also asks for the SIREN identifying number (first nine digits of the SIRET), which allows us to merge this information with the main data set. The resulting data set, which is used in subsection III.C only, is thus restricted to manufacturing firms.

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REFERENCES

Acemoglu, Daron, “Changes in Unemployment and Inequality: An Alternative Theory and Some Evidence,” *American Economic Review,* LXXXIX (1999), 1259–1278.
Acemoglu, Daron, and Andrew Newman, “The Labor Market and Corporate Structure,” CEPR Discussion paper No 1708, 1997.
Aghion, Philippe, and Peter Howitt, “A Model of Growth through Creative Destruction,” *Econometrica,* LX (1992), 323–351.
Aoki, Masanao, “Horizontal vs. Vertical Information Structure of the Firm,” *American Economic Review,* LXXVI (1986), 971–983.
Askenazy, Philippe, “The neo-Stakhanovism,” presented at the North American Winter Meeting of the Econometric Society, 1999.
Autor, David, Lawrence Katz, and Alan Krueger. “Computing Inequality: Have Computers Changed the Labor Market?” *Quarterly Journal of Economics,* CXIII (1998), 1169–1214.
Becker, Gary, and Kevin Murphy, “The Division of Labor, Coordination Costs, and Knowledge,” *Quarterly Journal of Economics,* CVII (1992), 1137–1160.

25. In order to check the consistency of our definition of skill with wages, we computed average wages in each function-skill cell from the French Labor Force Survey (which also has the PCS classification). A table (available from the authors) shows that the variability of wages is much larger across skill groups than across functions.

Berman, Eli, John Bound, and Zvi Griliches, "Changes in the Demand for Skilled Labor within U. S. Manufacturing Industries," *Quarterly Journal of Economics,* CIX (1994), 367–398.

Berman, Eli, John Bound, and Stephen Machin, "Implications of Skill-Biased Technical Change: International Evidence," *Quarterly Journal of Economics,* CXIII (1998), 1245–1279.

Bolton, Patrick, and Mathias Dewatripont, "The Firm as a Communication Network," *Quarterly Journal of Economics,* CIX (1994), 809–839.

Bresnahan, Timothy, Erik Brynjolfsson, and Lorin Hitt, "Information Technology, Workplace Organization and the Demand for Skilled Labor: Firm Level Evidence," Stanford University, mimeo, 1998.

Burns, Tom, and Georges Stalker, *The Management of Innovation* (London: Tavistock, 1961).

Caroli, Eve, and John Van Reenen, "Human Capital and Organizational Change: Evidence from British and French Establishments in the 1980s and 1990s," mimeo, University College, London, 1998.

Chandler, Alfred, *Scale and Scope: the Dynamics of Industrial Capitalism* (Cambridge: Harvard University Press: 1990).

Crozier, Michel, *Le Phénomène Bureaucratique* (Paris: Le Seuil, 1963).

Daft, Robert, *Organization Theory and Design* (Saint Paul: West Publishing, 1998).

Demsetz, Harold, "Classical Theory of the Firm: A Quiet Revolution," *American Economic Review,* LXXXVII (1997), 426–429.

Dunne, Timothy, John Haltiwanger, and Kevin Troske, "Technology and Jobs: Secular Changes and Cyclical Dynamics," mimeo, U. S. Census Bureau, 1995.

Galor, Oded, and Omer Moav, "Ability-Biased Technological Transition, Wage Inequality, and Economic Growth," *Quarterly Journal of Economics,* CXV (2000), 469–498.

Goldin, Claudia, and Lawrence Katz, "The Decline of Noncompeting Groups: Changes in the Premium to Education, 1890 to 1940," NBER Working Paper No. 5202, 1995.

Goldin, Claudia, and Lawrence Katz. "The Origins of Technology-Skill Complementarity," *Quarterly Journal of Economics,* CXIII (1998), 693–732.

Gottschalk Peter, "Inequality, Income Growth, and Mobility: The Basic Facts," *Journal of Economic Perspectives,* XI (1997), 21–40.

Gottschalk, Peter, and Robert Moffit, "The Growth of Earnings Instability in the U. S. Labor Market," *Brookings Papers on Economic Activity* (1994), 212–272.

Greenwood Jeremy, and Boyan Jovanovic, *American Economic Review,* LXXXIX (1999), 116–128.

Griliches, Zvi. "Patents Statistics as Economic Indicators: A Survey," *Journal of Economic Literature,* XXVIII (1990), 1661–1707.

Grossman, Gene, and Elhanan Helpman, *Innovation and Growth in the Global Economy* (Cambridge: MIT Press, 1991).

Helpman, Elhanan and Manuel Trajtenberg, "A Time to Sow and a Time to Reap: Growth Based on General Purpose Technologies," CIAR Discussion paper No. 32, 1994.

Jones, Charles, "Time Series Tests of Endogenous Growth Models," *Quarterly Journal of Economics,* CX (1995), 495–525.

Katz, Lawrence, and Kevin Murphy, "Changes in Relative Demand, 1963–1987: Supply and Demand Factors," *Quarterly Journal of Economics,* CVII (1992), 36–78.

Kremer, Michael, and Eric Maskin, "Segregation by Skill and the Rise in Inequality," NBER Working Paper No. 5718, 1995.

Lindbeck, Assar, and Dennis Snower, "Reorganization of Firms and Labor-Market Inequality," *American Economic Review,* LXXXVII (1997), 315–321.

Machin, Steve, and John Van Reenen, "Technology and Changes in Skill Structure: Evidence from Seven OECD Countries," *Quarterly Journal of Economics,* CXIII (1998), 1215–1244.

March, James, and Herbert Simon, *Organization* (New York: Wiley, 1958).

Martimort, David, and Thierry Verdier, "Monopolies Life Cycle, Bureaucratization, and Schumpeterian Growth," mimeo, DELTA, 1998.

Maurin, Eric, and David Thesmar, "Changes in the Functional Structure of Firms and the Demand for Skill," mimeo, CREST, 1999.

Murphy, Kevin, Andrei Shleifer, and Robert Vishny, "Industrialization and the Big Push," *Journal of Political Economy,* XCVII (1989), 1003–1026.
Murphy, Kevin, and Finis Welch, "Inequality and Relative Wages," *American Economic Review,* LXXXIII (1993), 104–109.
Perrow, Charles, *Organizational Analysis: A Sociological View* (London: Tavistock, 1970).
Piore, Michael, and Charles Sabel, *The Second Industrial Divide* (New York: Basic Books, 1984).
Osterman, Paul, "How Common Is Workplace Transformation and Who Adopts It?" *Industrial and Labor Relations Review,* XLVII (1994), 173–188.
Romer, Paul, "Endogenous Technical Change," *Journal of Political Economy,* XCVIII (1990), 71–102.
Stalk, George, and Alan Webber, "Japan's Dark Side of Time," *Harvard Business Review,* LXXI (1998), 93–102.
White, Halbert, "A Heteroskedasticity Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity," *Econometrica,* XLVIII (1980), 817–838.
Young, Alwyn, "Growth without Scale Effects," *Journal of Political Economy,* CVI (1998), 41–63.