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# MULTI-TASK LEARNING AND THE REORGANIZATION OF WORK

¾ FROM TAYLORISTIC TO HOLISTIC ORGANIZATION ¾

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**Abstract:** The paper analyzes an important aspect of the contemporary reorganization of work within firms: the shift from “Tayloristic” organization (characterized by specialization by tasks) to “holistic” organization (featuring job rotation, integration of tasks and learning across tasks). We examine four driving forces behind this restructuring process: advances in production technologies promoting technological task complementarities, advances in information technologies promoting informational task complementarities, changes in worker preferences in favor of versatile work, and advances in human capital that make workers more versatile. Our analysis can also help explain the recent widening of wage differentials and disparities in job opportunities, not only between occupational, educational, and industry groups, but also within these groups.

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## 1. Introduction

The past decade has witnessed a constellation of fundamental changes in production technologies, the nature of physical and human capital, and ideas about how to organize firms. This development has set in motion a process of restructuring the organization of work in many firms of the advanced industrialized countries. The process has been given considerable attention in the news media and in the business management and sociology literatures,<sup>1</sup> but has received relatively little emphasis in economic theory thus far.<sup>2</sup>

Until recently the evidence for this restructuring process consisted mainly of a large numbers of case studies. Over the past few years, however, a number of systematic, broad-based, empirical investigations have been completed, establishing the quantitative importance of the reorganization process. For a summary of the results of these studies, see Lindbeck and Snower (1999). The precise nature of the reorganization process naturally varies from firm to firm, but the evidence is now sufficiently detailed<sup>3</sup> that it is possible to recognize some prominent central features. These features include an increased role of team work and job

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<sup>1</sup> Examples of studies where this process is described, and sometimes also recommended, are Hammer and Champy (1993), Pfeiffer (1994), Wikström and Norman (1994).

<sup>2</sup> Studies on the implications of this process for economic activities include Appelbaum and Bott (1994), Kremer and Maskin (1996), Mitchell, Lewin and Lowler III (1990), Levine and Tyson (1990) and Piore and Sabel (1984). For an analysis emphasizing the complementarities of different functions in the restructured firms, see Milgrom and Roberts (1990). Their focus of attention differs markedly from ours, however, in that they concentrate on changes in production technology (in terms of the rate of product improvements, processing and delivery time, setup costs, and the like), while we emphasize changes in the nature of work (multi-tasking in particular). Finally, Lindbeck and Snower (1996, 1999) examine the implications of organizational restructuring for wage inequality and centralized bargaining, respectively.

<sup>3</sup> Detailed studies of various European countries include the European Foundation (1997, 1998) and the OECD (1996). The reorganization of work in Nordic countries is examined by NUTEK (1996, 1999). Gallie et al. (1998) present detailed studies of the reorganization of work in the UK, emphasizing the consequences for the efficiency of work, work satisfaction and worker-employer relations. Aoki (1990) documents new forms of work organization in Japan, which in some respects pioneered the process. Osterman (1994) focuses on U.S. manufacturing establishments. Lawler, Mohrman, and Ledford (1992) examine the restructuring process in the Fortune 1000. The existing evidence indicates that the restructuring of work is a quantitatively important phenomenon in many OECD countries.

rotation, a reduction in the number of management levels, continuous learning and development of complementary skills, decentralization of responsibility within firms and direct participation of employees in decision making on multiple fronts. The empirical studies show that the restructuring process is widespread in terms of countries, sectors (encompassing services as well as manufacturing), and firms within sectors. It appears that the various features of this process have a common thread: emphasis on learning multiple tasks, the blurring of occupational barriers, and the use of experience gained at one task to enhance performance at another task. These phenomena are the focus of our paper.

The reorganization process appears to be driven by a variety of inter-related forces. One is the introduction of computerized information and communications systems, which have provided employees with greater access to information about other employees' work within the organization and also made it easier to communicate with others. The new information technology has also given individual employees better information about customers, permitting them to respond better and more rapidly to changing customer needs. Not only have these advances facilitated the decentralization of decision making within firms; it has also enabled employees to become more involved in each other's tasks both within their own teams and in other parts of the organizations. Team work and job rotation, hence multi-tasking, have become important ways of meeting these new demands. Supervision and management control of workers continue to be important, though there is a tendency for such supervision (and the related punishment and reward), to be less detailed, less tied to specific activities pursued by individual workers, and instead more closely associated with post facto performance.<sup>4</sup>

A second driving force is the introduction of flexible machine tools and programmable equipment, which has made the capital stock more versatile, i.e. capable of performing wider spectra of tasks. As a result, the workers cooperating with this capital stock are required to become more versatile as well. In the manufacturing sectors, this development has often reduced returns to scale, lowered setup and retooling costs, permitted shorter production cycles, and faster deliveries. This, in turn, has enabled firms to give customers more individualized treatment. Moreover, greater interaction with customers often implies

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<sup>4</sup> See, for instance, Gallie et al. (1998).

that employees need to exercise social, interactive skills in addition to fulfilling their formal occupational requirements.

A third force, significant throughout the industrialized world, has been the steady growth of human capital per worker, generated by education systems, vocational training programs and on-the-job training. This growth has taken the form not only of “capital deepening,” in the sense that individual workers have improved their performance of particular skills; it has also involved substantial “capital widening,” i.e. increased ability to perform a variety of skills. This development – and especially the widening of human capital – is permitting firms to reorganize and integrate tasks along the new organizational lines.

A final driving force has been changes in workers’ tastes. As they acquired better general education and wider varieties of skills, many workers have come to prefer jobs that permit the exercise of diverse skills. More and more employees came to resent the monotonous, fragmented jobs of traditional organizations and to prefer more varied, multi-faceted work.

An important consequence of the above changes is that occupational barriers are breaking down. The traditional organizations required employees to have highly specialized skills, appropriate for standardized production processes. Production workers required narrowly defined manual skills, sales people needed social competence, administrative personnel needed organizational and accounting skills, product designers needed creativity, and managers required judgment, initiative, leadership, and coordination skills. It is on account of this specialization that employees could readily be divided into distinct, well-defined occupations, over which the traditional distinctions between “skilled” and “unskilled” workers could be made. In this environment, relatively little attention was given to people’s capacity to acquire and use multiple skills; if a person happened to have more than one occupational aptitude, he generally had to decide which particular one to use and let the rest lie fallow.

In the new types of firms emerging nowadays the traditional separation of roles tends to break down. Workers are often given responsibilities spanning more than one of the traditional occupational groupings. Greater emphasis is now also placed on continuous learning and skill development, all-round knowledge, the potential to acquire multiple skills, and the ability to learn how the experience gained from one skill enhances another skill. The

new forms of work organization are commonly designed to facilitate such “multi-task learning” in order to exploit complementarities among tasks.

It is of course not surprising that the four above-mentioned driving forces – advances in information technologies permitting integration of tasks, increased versatility of capital equipment, “widening” of human capital across tasks, and changes in workers’ preferences in favor of more varied tasks – should lead to the blurring of occupational boundaries and job rotation. But the main point of our analysis is that it provides a theoretical framework within which this association can be rigorously analyzed and thereby becomes straightforward. The analysis focuses attention on aspects of technological change, skill acquisition, and preference changes that have been largely ignored in the mainstream literature. Once we have developed a framework of thought that brings these elements into center-stage, the links between multi-tasking and its determinants are obvious.

The blurring of occupational barriers and the rise of multi-task learning is closely associated with the decentralization of authority within firms. The traditional pyramidal structures in service and manufacturing organizations, in particular large ones, implied that authority flowed from senior executives, down through layers of middle management, to the workers in the various functional departments. This structure is increasingly giving way to flatter organizations in which customer-oriented teams are often given greater authority. Decision making has been moved closer to the people who have the relevant information, much of which is tacit knowledge among front-line workers. The decentralization of decision making often also takes the form of consultation or delegation, or both. On account of the four above-mentioned driving forces underlying the reorganization process, the decentralization of decision making often means that employees perform a wider variety of tasks within their firms than heretofore. For instance, employees often share tasks within teams or combine a core job with other tasks, even sometimes including some managerial or consultative functions (such as participation in so-called “quality circles” or other advisory groups).

A variety of managerial innovations – such as Total Quality Management (TQM), lean production, and just-in-time production<sup>5</sup> – facilitate the decentralization of decision making and learning across tasks. The move towards customer-oriented teams encourages the exploitation of complementarities among tasks, the sharing of tasks within teams, and bringing the decision-making power closer to the people who have the relevant information.

But multi-tasking, job rotation, and the blurring of occupational barriers are not the only consequences of the ongoing reorganization of work. Particularly significant is the expansion in the scope for learning and the returns from it in the new organizational environment. This aspect is our main focus of attention in this paper. The importance of learning makes the decentralization of decision making within firms yet more important, since central management has far less information about workers' learning opportunities and achievements than the workers themselves.

We will distinguish between two broad types of learning: “intra-task” and “inter-task” learning. *Intra-task learning* is learning-by-doing in the traditional sense (Arrow (1962)): the more time a worker spends at a particular task, the more skillful he becomes at performing that task, and thus the greater his productivity from this activity. *Inter-task learning*, on the other hand, arises when a worker can use the information and skills acquired at one task to improve his performance at other tasks. Much of this inter-task learning takes place through job rotation within and between teams of workers in production, management, marketing, etc. However, inter-task learning may also be important among tasks that have traditionally been separate within firms. For instance, when a worker is involved in sales, he gains information about customer preferences that can be put to use if he is engaged in consultative groups or the provision of ancillary services to the customers (such as repairing or advice giving). Furthermore, when a worker is involved in production, he gains information about technological processes that can be useful if he contributes to organizational improvements or perhaps even product development. The business administration literature (cited above) provides a wealth of examples: information

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<sup>5</sup> An important objective of lean production and just-in-time production is that they expose the precise points in organizational networks where production problems, bottlenecks, and delivery delays arise, thereby enabling at these employees to tackle these deficiencies in a decentralized manner.

gained through marketing may be applicable to product design, information gained on the production line may be useful in product development or in training of new recruits or in devising appropriate accounting procedures, and so on.

The tasks over which job rotation, multi-tasking, and learning occur are here interpreted in a wide sense. They cover not only formal occupational functions, but also the exercise of social skills, communication with fellow employees and customers, collaborative skills, judgement, initiative, and creativity. In what follows, the traditional producer organizations – in which workers specialize heavily by tasks – will be called “Tayloristic.”<sup>6</sup> The new, integrated organizations – heavily reliant on job rotation, decentralization of decision making, and inter-task learning – will be called “holistic.”<sup>7</sup> It is important to note that our distinction between Tayloristic and holistic organizations rests on the degree of task specialization among workers, not specialization in production among firms. These two types of specialization need not proceed in tandem; quite on the contrary, many reorganized firms engage in multi-tasking while focusing more narrowly on their “core competences” in production.

There is a large literature, following the path of Adam Smith, on the determinants of specialization of work in society, but little of it has focused on the features described above. Much of the recent literature on the organization of work within firms (e.g. Becker and Murphy (1992), Bolton and Dewatripont (1994), and Yang and Borland (1991)) concentrates on the returns to specialization vis-à-vis the costs of coordinating the activities of different workers. In this context, falling costs of communication (due to improvements in information technologies) lead to *greater* specialization among employees within firms, not more multi-tasking. Others (e.g. Holmstrom and Milgrom (1991)) have examined how the choice of tasks within teams depends on the remuneration system and the measurability of task performance. Rosen (1983) has shown that individuals specialize their investment in skills when there are increasing returns to human capital utilization and that non-specialization occurs when the costs of investment in different types of skills are non-separable.

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<sup>6</sup> A term in honor of Frederick Taylor (1911), the pioneer of scientific management of firms.

<sup>7</sup> In making this distinction, our aim is to focus on broad, overall trends in the organization of work. There are of course counterexamples, involving increasing task specialization, such as much research and much medical and legal practice.

None of these contributions, however, explain organizational changes associated with *reductions* in the degree of labor specialization within firms or plants, and a blurring of occupational boundaries. Our analysis does so by examining task coordination and specialization on an *intra-personal* level (one individual performing one or more tasks) rather than on an *inter-personal level* (a group of people performing a broader or narrower range of tasks). Furthermore, our analysis examines the determinants of firms' incentives to restructure their organizations of work in favor of multi-tasking or job rotation.

The rest of the paper is organized as follows. Section 2 analyzes the trade-off between the returns from specializing at a task and the returns from exploiting the complementarities between tasks. This analysis is embedded in a model of a profit maximizing firm. Section 3 examines how such a firm decides on its organization of production and work. In this context, Section 4 investigates how the restructuring process is driven by changes in physical capital, information technology, workers' preferences, and human capital. Finally Section 5 concludes.

## **2. The Firm's Decision Making Problem**

In deciding whether workers are to specialize or perform multiple tasks,<sup>8</sup> employers face a tradeoff between two sets of returns: (i) "returns from specialization," whereby a worker's productivity at a particular task increases with his exposure to that task, and (ii) "returns from task complementarities," whereby his activity at one task raises his productivity at another task.

The returns to specialization are well known and may be viewed as the result of intra-task learning. The returns from task complementarities, on the other hand, have received much less attention thus far. They may be divided into what we will call "technological" and "informational" task complementarities.

The *technological task complementarities* are captured by the cross-partial derivatives between different types of labor services in the production function: just as labor and capital may be complementary in the production process, so different occupational

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<sup>8</sup>Note that the gains from multi-tasking by a worker are analogous to the economies of scope arising when a firm produces several different products (See Baumol, Panzer, and Willig (1982).)

types of labor may be complementary as well. To take a trivial example, the productivity of managers is enhanced by the services of their secretaries, and the managers do not themselves have to perform secretarial tasks for this complementarity to arise.

The *informational task complementarities* are the outcome of inter-task learning. Analytically, these complementarities may be captured by letting a worker's human capital at one task depend on his activity at other tasks.<sup>9</sup> For example, a worker within a team may become more skillful in a specific task when he learns related tasks within his team. His ability to perform a specific task may also be enhanced by learning tasks within quite different parts of the firms.

Clearly, both the returns to specialization and the informational task complementarities manifest themselves only with the passage of time. For simplicity, however, our analysis covers only a single time period, and thus the length of this period must be taken as sufficiently long for these returns to be able to manifest themselves.

Consider a firm that produces its output through two tasks, 1 and 2.<sup>10</sup> The firm's employees can be divided into two homogeneous groups:<sup>11</sup> "type-1 workers," whose skills give them a comparative advantage at task 1, and "type-2 workers," with a comparative advantage at task 2.<sup>12</sup>

Although the returns to specialization and the returns to informational task complementarities may not be straightforward to identify in practice, it is nevertheless convenient to represent them be separate variables. We let the type-1 worker's returns to specialization ( $s_i$ ,  $i=1,2$ ) at each task depend positively on the fraction  $t$  of time devoted to that task:  $s_1 = s_1(t)$  and  $s_2 = s_2(1-t)$ ,  $s_1', s_2' > 0$ . Furthermore, the greater is the fraction of the type-1 worker's time devoted to the task  $i$ , the more information he gains about this task and consequently the more productive he becomes at task  $j$ ,  $j \neq i$ . Thus the

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<sup>9</sup> Thereby the informational task complementarities give leverage to the technological task complementarities.

<sup>10</sup> These tasks could cover a vast array of complementary tasks, such as different types of production work or participation in quality circles, the supervision and training, etc.

<sup>11</sup> It is however worth noting that in practice most outputs require the performance of many tasks and multi-taskers usually perform only a few of these tasks in varying combinations.

<sup>12</sup> We will define comparative advantage formally once we have specified the workers' productivities.

informational task complementarity, resulting from the type-1 worker's inter-task learning, may be expressed as  $c_1 = c_1(1-t)$  and  $c_2 = c_2(t)$ ,  $c_1', c_2' > 0$ . Specifically,  $c_1$  is the worker's ability to increase his productivity at task 1 through time spent  $(1-t)$  on task 2, and  $c_2$  is his ability to increase his productivity at task 2 through time spent  $(t)$  on task 1.

These returns to specialization and returns to informational task complementarities will be viewed as determinants of the type-1 worker's productivity. In particular, let  $e_1$  and  $e_2$  stand for the type-1 worker's "efficiency units of labor" per hour at tasks 1 and 2, respectively. We portray these efficiency units as the sum of the associated returns to specialization and returns to informational task complementarities:<sup>13</sup>

$$\begin{aligned} e_1 &= s_1(t) + c_1(1-t) = e_1(t) \\ e_2 &= s_2(1-t) + c_2(t) = e_2(t) \end{aligned} \tag{1a}$$

Similarly, let the type-2 worker's returns to specialization ( $S_i$ ,  $i=1,2$ ) at each task depend positively on the fraction  $T$  of time devoted to that task:  $S_1 = S_1(1-T)$  and  $S_2 = S_2(T)$ ,  $S_1', S_2' > 0$ . Moreover, let this worker's informational task complementarity at one task depend positively on the fraction of time devoted to the *other* task:  $C_1 = C_1(T)$  and  $C_2 = C_2(1-T)$ ,  $C_1', C_2' > 0$ . Let  $E_1$  and  $E_2$  be the efficiency units of each type-2 worker at the two tasks. Then the type-2 worker's "efficiency units of labor" per hour are expressed as the sum of the associated returns to specialization and returns to informational task complementarities:

$$\begin{aligned} E_1 &= S_1(1-T) + C_1(T) = E_1(T) \\ E_2 &= S_2(T) + C_2(1-T) = E_2(T) \end{aligned} \tag{1b}$$

In sum, we may think of the time allocations  $t$  and  $T$  as generating human capital in type-1 and type-2 workers (respectively), and this human capital contributes to the workers' efficiency units of labor via the returns to specialization and the returns to informational task complementarities.

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<sup>13</sup> Specifying the efficiency units in terms of the *sum* is a reasonable simplification in the context of our two-task model. Here it is always possible to express the  $s_i$  and  $c_i$  functions,  $i=1,2$ , so that their sum yields the efficiency units of labor. (Similarly for the  $S_i$  and  $C_i$  functions,  $i=1,2$ .) When there are more tasks, however, complementarities and

Let  $n$  and  $N$  be the number of type-1 and type-2 workers employed, respectively. Then the total labor services in efficiency units devoted to tasks 1 and 2 may be expressed as<sup>14</sup>

$$\begin{aligned} I_1 &= e_1(\mathbf{t}) \cdot \mathbf{t} \cdot n + E_1(T) \cdot (1-T) \cdot N = \Lambda_1(\mathbf{t}, T; n, N) \\ I_2 &= e_2(1-\mathbf{t}) \cdot (1-\mathbf{t}) \cdot n + E_2(T) \cdot T \cdot N = \Lambda_2(\mathbf{t}, T; n, N) \end{aligned} \quad (2)$$

Observe that when a type-1 worker increases the time ( $\mathbf{t}$ ) spent at task 1, there are three effects on type-1 labor services ( $I_1$ ):

- (i) a direct, positive effect in terms of labor time ( $\mathbf{t} \cdot n$  increases);
- (ii) a positive effect via the returns to specialization ( $s_1(\mathbf{t})$  increases); and
- (iii) a negative effect via the returns from informational complementarities ( $c_1(1-\mathbf{t})$  falls).

(Similarly for the type-2 worker.)

The firm's production function is

$$q = f(\Lambda_1(\mathbf{t}, T; n, N), \Lambda_2(\mathbf{t}, T; n, N)) \quad (3)$$

where  $q$  is the firm's output,  $f_i > 0$ ,  $f_{ii} < 0$  ( $i = 1, 2$ ) and  $f_{ij} > 0$  ( $i = 1, 2$  and  $j \neq i$ ). The technological task complementarities may be depicted in terms of the positive cross-partial derivatives:  $f_{ij}$ ,  $i = 1, 2$  and  $j \neq i$ .

Let the firm's real labor costs be  $wn + WN$ , where  $w$  and  $W$  are the real wages of the type-1 and type-2 workers, respectively. For simplicity, but without any substantive loss of generality, we assume that these wages are the reservation wages of these workers (i.e. the wages that make them indifferent between employment and leisure). Furthermore, we suppose that the workers have preferences regarding the organization of work. If workers prefer specialized to versatile work, then their reservation wage achieves a maximum at  $\mathbf{t} = 1/2$  (when they devote equal amounts of time to both tasks); if they prefer versatile work, then their reservation wage attains a minimum at  $\mathbf{t} = 1/2$ . So, provided that the wage

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substitutabilities among different returns to specialization and returns to informational task complementarities may preclude the above simplification.

<sup>14</sup> We introduce  $L_1$  and  $L_2$  just for expositional simplicity: in the analysis below, the change in labor services as a function of the time allocation ( $\partial I_1 / \partial \mathbf{t}$ ,  $\partial I_2 / \partial \mathbf{t}$ ) will be specified in terms of the  $L_1$  and  $L_2$  functions (rather than in terms of the  $e_1$  and  $e_2$  functions).

depends positively on the reservation wage, we specify that  $w = w(\mathbf{t})$ ,  $w'(1/2) = 0$ ; and if the workers prefer specialization, then  $w'' < 0$ , whereas if they prefer versatility, then  $w'' > 0$ .

The firm's profit is

$$\mathbf{p}(\mathbf{t}, T, n, N) = f(\Lambda_1(\mathbf{t}, T; n, N), \Lambda_2(\mathbf{t}, T; n, N)) - w(\mathbf{t})n - W(T)N \quad (4)$$

The comparative advantage of the type-1 workers is mirrored in the following condition:

$$\begin{aligned} & f(\Lambda_1(1, T; n, N), \Lambda_2(1, T; n, N)) - w(1)n - W(T)N \\ & > f(\Lambda_1(0, T; n, N), \Lambda_2(0, T; n, N)) - w(0)n - W(T)N \end{aligned} \quad (5a)$$

for any  $T$ ,  $0 \leq T \leq 1$ . In words, for any given time allocation  $T$  of the type-2 workers, it is more profitable for the type-1 workers to devote themselves fully to task 1 than to devote themselves fully to task 2. Similarly, the comparative advantage type-2 workers implies:

$$\begin{aligned} & f(\Lambda_1(\mathbf{t}, 1; n, N), \Lambda_2(\mathbf{t}, 1; n, N)) - w(\mathbf{t})n - W(1)N \\ & > f(\Lambda_1(\mathbf{t}, 1; n, N), \Lambda_2(\mathbf{t}, 1; n, N)) - w(\mathbf{t})n - W(1)N \end{aligned} \quad (5b)$$

Observe that the type-1 and type-2 workers are in analogous positions with regard to the organization of work, i.e. they occupy analogous positions in the firm's production function and generate analogous costs. Thus, in the analysis that follows, it will be sufficient to focus on the type-1 worker alone.<sup>15</sup>

The firm's aim is to maximize its profit with respect to the number of employees ( $n$  and  $N$ ) and the organization of work ( $\mathbf{t}$  and  $T$ ). We now proceed to examine the determinants of the Tayloristic versus holistic organization of work.

### 3. The Tayloristic versus Holistic Organization of Work

Under the Tayloristic organization of work, type-1 workers specialize in task 1, so that  $\mathbf{t}=1$ ; whereas under the holistic work organization, the worker performs both tasks, so that  $0 < \mathbf{t} < 1$ .

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<sup>15</sup> Unless the two types of workers enter the profit function symmetrically, in the analysis below, the profit-maximizing organization of work for the type-1 workers need not be the same as the profit-maximizing organization of work for the type-2 workers.

The following proposition shows how the profit-maximizing firm chooses its organization of work:

**Proposition 1:** *Given the profit function  $\mathbf{p} = \mathbf{p}(\mathbf{t}, T, n, N)$ , the necessary conditions<sup>16</sup> for a profit-maximizing organization of work are:*

There exists a  $\mathbf{t}^*$  in the interval  $0 < \mathbf{t}^* < 1$ , such that

$$\left. \frac{\mathbb{J}\mathbf{p}}{\mathbb{J}\mathbf{t}} \right|_{\mathbf{t}=\mathbf{t}^*} = 0 \quad \text{and} \quad \left. \frac{\mathbb{J}^2\mathbf{p}}{\mathbb{J}\mathbf{t}^2} \right|_{\mathbf{t}=\mathbf{t}^*} < 0.$$

*The profit-maximizing organization of work is Tayloristic whenever this condition is violated, and thus  $\mathbf{t}^* = 1$ .*<sup>17</sup>

Intuitively, since workers specialize by task in a Tayloristic organization, the profit-maximizing allocation of time across tasks must lie at a corner point. But since workers in a holistic organization do not specialize in this way, the profit-maximizing allocation of time must lie in the interior of the feasible set.

We now proceed to examine various driving factors influencing a firm's choice of organizational form. The marginal profit from a change in the organization of work is

$$\frac{\mathbb{J}\mathbf{p}}{\mathbb{J}\mathbf{t}} = MR - MC^o - MC^w \quad (6)$$

where  $MR = f_1 \cdot \frac{\mathbb{J}\Lambda_1}{\mathbb{J}\mathbf{t}}$ ,  $MC^o = -f_2 \cdot \frac{\mathbb{J}\Lambda_2}{\mathbb{J}\mathbf{t}}$ ,  $MC^w = \frac{dw}{d\mathbf{t}} n$

$MR$  is the marginal revenue with respect to  $\mathbf{t}$ : an increase in the fraction of time at task 1 changes the firm's revenue by changing the labor services devoted to task 1.  $MC^o$  is the marginal opportunity cost of task 1 in terms of task 2: an increase in the fraction of time at task 1 changes the firm's revenue by changing the labor services devoted to task 2. And

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<sup>16</sup> The conditions of this proposition ensure that there exists a local profit maximum characterized by a holistic work organization. If there are multiple local maxima, we assume that the firm – knowing its entire profit function – is able to identify the global optimum. Then the organization of work is holistic if the conditions above are satisfied at the global maximum, and the organization is Tayloristic otherwise.

<sup>17</sup> Under Tayloristic organization, the type-1 worker specializes in task 1 and the type-2 worker specializes in task 2 on account of the comparative advantage conditions (5a) and (5b).

$MC^w$  is the marginal cost due to changes in the wage rate that result from changes in the time allocation  $\mathbf{t}$ . These marginal revenue and cost terms are illustrated in Figures 1.

The change in the marginal profit is

$$\frac{\mathcal{J}^2 \mathbf{p}}{\mathcal{J} \mathbf{t}^2} = \frac{\partial MR}{\partial \mathbf{t}} - \frac{\partial MC^o}{\partial \mathbf{t}} - \frac{\partial MC^w}{\partial \mathbf{t}} \quad (7)$$

where

$$\begin{aligned} \frac{\partial MR}{\partial \mathbf{t}} &= \left[ \left( f_{11} \frac{\mathcal{J} \Lambda_1}{\mathcal{J} \mathbf{t}} + f_{12} \frac{\mathcal{J} \Lambda_2}{\mathcal{J} \mathbf{t}} \right) \frac{\mathcal{J} \Lambda_1}{\mathcal{J} \mathbf{t}} + f_1 \frac{\mathcal{J}^2 \Lambda_1}{\mathcal{J} \mathbf{t}^2} \right], \\ \frac{\partial MC^o}{\partial \mathbf{t}} &= - \left[ \left( f_{12} \frac{\partial \Lambda_1}{\partial \mathbf{t}} + f_{22} \frac{\partial \Lambda_2}{\partial \mathbf{t}} \right) \frac{\partial \Lambda_2}{\partial \mathbf{t}} + f_2 \frac{\partial^2 \Lambda_2}{\partial \mathbf{t}^2} \right], \\ \frac{\partial MC^w}{\partial \mathbf{t}} &= \frac{d^2 w}{d \mathbf{t}^2} n \end{aligned}$$

To fix ideas, we assume that the tasks are technological complements:

$$f_{12} = f_{21} > 0.$$

Moreover, if  $(\mathcal{J} \Lambda_1 / \mathcal{J} \mathbf{t}) > 0$ ,  $(\mathcal{J} \Lambda_2 / \mathcal{J} \mathbf{t}) < 0$ , and  $f_{11} < 0$ , then the first term of  $(\mathcal{J} MR / \mathcal{J} \mathbf{t})$  is negative. Consequently the sign of  $(\mathcal{J} MR / \mathcal{J} \mathbf{t})$  depends critically on  $f_1 (\mathcal{J}^2 \Lambda_1 / \mathcal{J} \mathbf{t}^2)$ , where  $f_1 > 0$  and  $(\mathcal{J}^2 \Lambda_1 / \mathcal{J} \mathbf{t}^2)$  measures the diminishing (or increasing) returns to the time allocation  $\mathbf{t}$ .

The term  $(\mathcal{J}^2 \Lambda_1 / \mathcal{J} \mathbf{t}^2)$  depends on the returns to specialization relative to the returns to informational task complementarities. In particular, recall that raising  $\mathbf{t}$  increases the opportunity to reap the returns from specialization at task 1 but reduces the opportunity to reap the return from using information gained at task 1 to enhance his productivity at task 2. Thus, the more rapidly the return from specialization falls relative to the task-1 return from the informational task complementarity (productivity at task 1 gained from information at task 2), the more rapidly will the type-1 labor service decline as  $\mathbf{t}$  rises. Thus, the lower is  $f_1 (\mathcal{J}^2 \Lambda_1 / \mathcal{J} \mathbf{t}^2)$  and the more rapidly the marginal revenue declines (or the more slowly it rises) with respect to  $\mathbf{t}$  (i.e. the lower is  $(\mathcal{J} MR / \mathcal{J} \mathbf{t})$ ). As Figures 1a and 1b imply, the more rapidly the marginal revenue declines (or the more slowly it rises), the more attractive it eventually becomes for the firm to adopt a holistic organization of work.

In our expression for the change in the marginal opportunity cost of task 1 in terms of task 2,  $\frac{\partial MC^o}{\partial t} = - \left[ \left( f_{21} \frac{\mathcal{J}\Lambda_1}{\mathcal{J}t} + f_{22} \frac{\mathcal{J}\Lambda_2}{\mathcal{J}t} \right) \frac{\mathcal{J}\Lambda_2}{\mathcal{J}t} + f_2 \frac{\mathcal{J}^2\Lambda_2}{\mathcal{J}t^2} \right]$ , the first term of  $(\mathcal{J}MC^o / \mathcal{J}t)$  is positive, provided that  $(\mathcal{J}\Lambda_1 / \mathcal{J}t) > 0$ ,  $(\mathcal{J}\Lambda_2 / \mathcal{J}t) < 0$ ,  $f_{22} < 0$ , and  $f_{21} > 0$ . Then the sign of  $(\mathcal{J}MC^o / \mathcal{J}t)$  depends critically on  $f_2 (\mathcal{J}^2\Lambda_2 / \mathcal{J}t^2)$ , where  $f_2 > 0$  and  $(\mathcal{J}^2\Lambda_2 / \mathcal{J}t^2)$  indicates the diminishing (or increasing) returns to the time allocation  $t$ . In particular,  $(\mathcal{J}^2\Lambda_2 / \mathcal{J}t^2)$  will be lower the faster the rate at which the task-2 return to specialization falls relative to the task-2 return to the informational task complementarity (productivity at task 2 gained from information at task 1). Thus the faster will the marginal cost  $MC^o$  rise (or the more slowly it will fall) with respect to  $t$ . Then, as Figures 1 imply, the firm's eventually gains an incentive to adopt a holistic work organization.

Finally, the change in the marginal cost in terms of the wage  $(\mathcal{J}MC^w / \mathcal{J}t)$  depends on the worker's preferences regarding work versatility. The more the worker prefers versatile work over task specialization, the greater is  $\frac{d^2w}{dt^2}$ , and thus the faster will the marginal cost  $MC^w$  rise (or the more slowly will it fall) with respect to  $t$ . Consequently, as indicated in Figures 1, the more worthwhile it eventually is for the firm to adopt a holistic organizational form.

In Figure 1a we assume that (i) the returns to specialization (at each task) increase sufficiently fast relative to the returns from informational task complementarities and (ii) the type-1 workers have a sufficiently strong preference for specialized work, so that the marginal revenue rises with  $t$  ( $(\mathcal{J}MR / \mathcal{J}t) > 0$ ) and the total marginal cost declines with  $t$  ( $(\mathcal{J}MC / \mathcal{J}t) < 0$ ). Here work is organized along Tayloristic lines.<sup>18</sup>

In Figure 1b, by contrast, we assume that (i) the returns from the informational task complementarity (at each task) increases sufficiently fast relative to the associated returns to specialization and (ii) the type-1 workers have a sufficiently strong preference for versatile work, so that the marginal revenue falls with  $t$  and the total marginal cost rises with

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<sup>18</sup>Note that under a Tayloristic work organization  $t$  must be equal to unity, rather than zero, since type-1 workers have a comparative advantage in task 1.

$t$ . Since the intersection of the marginal revenue and marginal cost curves occurs at  $t^* < 1$  in the figure, the organization of work is holistic.

#### **4. The Restructuring Process**

In this context we are now able to analyze the determinants of the restructuring process whereby Tayloristic organizations turn into holistic ones. We conceive of this process as being driven by four major forces: (i) changes in physical capital, (ii) changes in information technology, (iii) changes in workers' preferences, and (iv) changes in human capital.<sup>19</sup>

Only certain types of *changes in physical capital* give firms an incentive to adopt holistic organizational forms. In the traditional literature on capital formation, the productivity of capital and the complementarity between capital and labor (or between capital and other factors of production) is often the center of attention. Our analysis focuses attention on a different characteristic of physical capital, namely, the associated technological task complementarities. In the model above, these complementarities are captured by the cross-partial  $f_{12} = f_{21}$  of the revenue function.

We argue that whereas the prominent changes in physical capital occurring in the first half of the twentieth century favored Tayloristic organizations, the more recent changes (occurring over the past decade or two) are strongly biased in favor of holistic organizations. The big breakthroughs in mass production and mass marketing that were the hallmark of technological progress in the first part of this century - such as assembly lines, specialized manufacturing equipment, hierarchical organizations within firms - accentuated returns to scale at specialized tasks. In terms of our analysis, they can be viewed as being associated with large returns to specialization and low technological task complementarities (i.e. low inter-task cross partials such as  $f_{12} = f_{21}$ ).

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<sup>19</sup>A fifth force, lying beyond the scope of our analysis, is a trend change in consumer preferences in favor of more highly differentiated products. This force favors holistic organizations over Tayloristic ones since holistic organizations usually permit closer interactions between their employees and the customers and enable the employees to use their detailed information about customer preferences to affect their performance of other tasks.

However, the salient recent advances in physical capital – such as the adoption of multi-purpose machine tools and programmable manufacturing equipment – have increased the versatility of machines across tasks and therefore facilitate the exploitation of inter-task complementarities. For instance, recent technical changes have enabled rapid retooling and reprogramming of machines in many sectors, to permit faster production responses to changes in customer demands, thereby making it easier to exploit complementarities between production and sales tasks. In short, as machines have become more versatile, so labor has been enabled to become more versatile as well. These advances may be expected to increase the technological task complementarities, i.e. raise the inter-task cross partials such as  $f_{12} = f_{21}$ .

By equation (7), an increase in the cross partial  $f_{12} = f_{21}$  makes the marginal revenue fall more rapidly with respect to the time allocation  $t$  (i.e. reduces  $(\partial MR / \partial t)$ ) and makes the marginal opportunity cost of task 1 in terms of task 2 rise more rapidly with respect to  $t$  (i.e. increases  $(\partial MC^o / \partial t)$ ). Through these channels, the above changes in physical capital reduce the value of  $(\partial^2 p / \partial t^2)$ .

To highlight the role of changes in physical capital that increase the value  $f_{12}$ , observe that equation (7) implies that

$$\frac{\partial^2 p}{\partial t^2} < 0 \Leftrightarrow$$

$$f_{12} > \frac{1}{\frac{\partial \Lambda_1}{\partial t} \frac{\partial \Lambda_2}{\partial t}} \left[ -f_{11} \left( \frac{\partial \Lambda_1}{\partial t} \right)^2 - f_1 \frac{\partial^2 \Lambda_1}{\partial t^2} - f_{22} \left( \frac{\partial \Lambda_2}{\partial t} \right)^2 - f_2 \frac{\partial^2 \Lambda_2}{\partial t^2} + \frac{\partial^2 w}{\partial t^2} n \right]$$

Thus a rise in  $f_{12}$  reduces the second derivative of the profit function. If this change is sufficiently large to ensure that the above inequality holds, the firm may choose a holistic organization of work.

Furthermore, we argue that recent *changes in information technologies* – such as the proliferation of information gathering processes and introduction of computerized production, design, and product development – also favor holistic organizations. The reason is that these advances provide rapid and cheap access to information; thereby they encourage the exercise of multiple skills over multiple tasks and provide scope for inter-task

learning. In this respect, they may be expected to augment informational task complementarities relative to the associated returns to specialization.

In the context of our model, an increase in informational task complementarities may be represented by an increase in  $(\partial e_1 / \partial c_1)$  and  $(\partial e_2 / \partial c_2)$ , and possibly also by an increase in  $(\partial^2 e_1 / \partial c_1^2)$  and  $(\partial^2 e_2 / \partial c_2^2)$ . These changes have the following effects on the relation between the type-1 and type-2 labor services and the time allocation between tasks:

They reduce  $\frac{\partial \Lambda_1}{\partial t} = -\frac{\partial e_1}{\partial c_1} t n + e_1 n$  and  $\frac{\partial \Lambda_2}{\partial t} = -\frac{\partial e_2}{\partial c_2} (1-t) n - e_2 n$ , and they also reduce

$\frac{\partial^2 \Lambda_1}{\partial t^2} = -\frac{\partial^2 e_1}{\partial c_1^2} t n + 2 \frac{\partial e_1}{\partial c_1} n$  and  $\frac{\partial^2 \Lambda_2}{\partial t^2} = -\frac{\partial^2 e_2}{\partial c_2^2} (1-t) n$ . By (7), these changes make the

marginal revenue fall more rapidly with respect to the time allocation  $t$  and make the marginal opportunity cost of task 1 in terms of task 2 rise more rapidly with respect to  $t$ , thus reducing the value of  $(\mathcal{J}^2 p / \mathcal{J} t^2)$ . As noted, if this value becomes negative, the firm may choose a holistic work organization.

To clarify the influence of the above changes in information technologies on work organization, let us simply suppose that  $(\mathcal{J}^2 \Lambda_1 / \mathcal{J} t^2) = (\mathcal{J}^2 \Lambda_2 / \mathcal{J} t^2)$ . Then equation (7) implies that

$$\frac{\partial^2 p}{\partial t^2} < 0 \Leftrightarrow$$

$$\frac{\partial^2 I_i}{\partial t^2} < \frac{1}{f_1 + f_2} \left[ - \left( f_{11} \frac{\partial \Lambda_1}{\partial t} + f_{12} \frac{\partial \Lambda_2}{\partial t} \right) \frac{\partial \Lambda_1}{\partial t} - \left( f_{21} \frac{\partial \Lambda_1}{\partial t} + f_{22} \frac{\partial \Lambda_2}{\partial t} \right) \frac{\partial \Lambda_2}{\partial t} + \frac{\partial^2 w}{\partial t^2} n \right]$$

for  $i = 1, 2$ . Consequently, a change in information technology that reduces the value of  $(\mathcal{J}^2 \Lambda_i / \mathcal{J} t^2)$  will reduce the second derivative of the profit function. If this change is sufficiently large to ensure that the above inequality holds, a holistic organizational form will be chosen.

Along the same lines, *changes in worker preferences* in favor of versatile work increase the value of  $(\partial^2 w / \partial t^2)$ , and thereby increase the marginal cost  $(\mathcal{J} MC^w / \mathcal{J} t)$  and thereby also reduce  $(\mathcal{J}^2 p / \mathcal{J} t^2)$ . There is plentiful evidence in the sociology and business literatures (referenced above) that many workers have a growing need to be stimulated at work. Since holistic work tends to be more varied, creative, and challenging than the

narrowly defined Tayloristic jobs, these workers are likely to be progressively less inclined to work for Tayloristic organizations than for holistic ones. In the context of our analysis, by equation (7), it is clear that if  $(\partial^2 w / \partial t^2)$  is large enough so that

$$\frac{d^2 w}{dt^2} > \frac{1}{n} \left[ \left( f_{11} \frac{\mathcal{I}\Lambda_1}{\mathcal{I}t} + f_{12} \frac{\mathcal{I}\Lambda_2}{\mathcal{I}t} \right) \frac{\mathcal{I}\Lambda_1}{\mathcal{I}t} + f_1 \frac{\mathcal{I}^2 \Lambda_1}{\mathcal{I}t^2} \right] + \frac{1}{n} \left[ \left( f_{21} \frac{\mathcal{I}\Lambda_1}{\mathcal{I}t} + f_{22} \frac{\mathcal{I}\Lambda_2}{\mathcal{I}t} \right) \frac{\mathcal{I}\Lambda_2}{\mathcal{I}t} + f_2 \frac{\mathcal{I}^2 \Lambda_2}{\mathcal{I}t^2} \right]$$

then  $(\mathcal{I}^2 p / \mathcal{I}t^2) < 0$ , and the firm may prefer a holistic organizational form.

Finally, we maintain that the steady *rise of human capital*, produced largely by education and training systems, has favored holistic organizations as well. In the traditional literature, the aspects of human capital growth that have been emphasized are those relating to the productivity of labor and the transferability of labor across firms (“general” versus “firm-specific” skills). Our analysis highlights a different aspect of human capital growth, namely, the increased ability to perform multiple tasks.

This development plays a different role in organizational change than the changes discussed above. As noted, the changes in physical capital, information technologies, and worker preferences analyzed above all serve to reduce the value of  $(\mathcal{I}^2 p / \mathcal{I}t^2)$ , ultimately making it negative. But, as Proposition 1 indicates, a negative value of  $(\mathcal{I}^2 p / \mathcal{I}t^2)$  is not sufficient to make a holistic organization more profitable than a Tayloristic one. What is required, in addition, is that  $(\mathcal{I}p / \mathcal{I}t) = 0$  for  $0 < t < 1$ . It is this latter aspect that is promoted by the “widening” of human capital.

Specifically, if  $(\mathcal{I}^2 p / \mathcal{I}t^2) < 0$ , then *changes in human capital* that enable workers to do more versatile work serve to move the profit maximizing time allocation  $t^*$  towards  $(1/2)$ , in the interior of the feasible region  $0 \leq t \leq 1$ . In other words, this development favors holistic work organization by increasing the rate at which the marginal opportunity cost of task 1 (in terms of task 2) rises with  $t$ .

The profit-maximizing responses in work organization to the above changes are summarized in the following proposition:

**Proposition 2:** *In response to sufficiently large*

- (i) *changes in production technologies that increase the technological task complementarities ( $f_{ij}$ ,  $i \neq j$ ),*
- (ii) *changes in information technologies that increase the informational task complementarities (reducing ( $\mathcal{J}^2 \Lambda_1 / \mathcal{J} \mathbf{t}^2$ )),*
- (iii) *changes in worker preferences in favor of versatile work (increasing ( $\partial^2 w / \partial \mathbf{t}^2$ )), and*
- (iv) *changes in human capital that increase worker versatility,*

*Tayloristic organizations gain the incentive to restructure into holistic organizations.*

These profit-maximizing responses follow directly from our framework of analysis, which we believe indicates the usefulness of this framework.

Our analysis also has implications for whether the restructuring process is continuous or discontinuous:

**Proposition 3:** *If the switch from a Tayloristic to a holistic organization of work is induced by changes in human capital that make workers more versatile, then the restructuring process will be smooth. If, on the other hand, the switch is induced by (i) increases in technological task complementarities, (ii) increases in informational task complementarities or (iii) greater preferences for versatile work, then the restructuring process may be discontinuous.*

To see this, observe that if it is the improvements in information and production technology that induce the switch, then it is the change in the sign of ( $\mathcal{J}^2 \mathbf{p} / \mathcal{J} \mathbf{t}^2$ ) that is responsible for the switch. Specifically, if ( $\mathcal{J}^2 \mathbf{p} / \mathcal{J} \mathbf{t}^2$ )  $> 0$  in the original equilibrium whereas ( $\mathcal{J}^2 \mathbf{p} / \mathcal{J} \mathbf{t}^2$ )  $< 0$  and ( $\mathcal{J} \mathbf{p} / \mathcal{J} \mathbf{t}$ ) = 0 at  $0 < \mathbf{t} < 1$  in the new equilibrium, then the profit maximizing number of hours changes discontinuously from complete specialization to multi-tasking. This phenomenon is illustrated in Figure 2a, where the initial profit function  $\mathbf{p}_1$  (for which ( $\mathcal{J}^2 \mathbf{p} / \mathcal{J} \mathbf{t}^2$ )  $> 0$ ) is maximized at the Tayloristic point  $E_1$  (where  $\mathbf{t}^* = 1$ ) and the new

profit function  $p_2$  (for which  $(\partial^2 p / \partial t^2) < 0$ ) is maximized at the holistic point  $E_2$  (where  $0 < t^* < 1$ ).

On the other hand, if  $(\partial^2 p / \partial t^2) < 0$  and the profit maximizing time allocation is initially at  $t^* = 1$ , then changes in human capital that make workers more versatile will move the profit maximizing time allocation gradually into the interior of the domain  $0 \leq t \leq 1$ . This change is continuous, as pictured in Figure 2b. Here the initial profit function, denoted by  $p_a$ , achieves a maximum at the Tayloristic point  $E_a$  (where  $t^* = 1$ ) and the new profit function  $p_b$  is maximized at the holistic point  $E_b$  (where  $0 < t^* < 1$ ).

## 5. Concluding remarks

This paper has analyzed the role of multi-tasking, intra-task learning, and inter-task learning in the contemporary reorganization of work. We have focused on four driving forces behind the reorganization process: advances in production technologies promoting technological task complementarities, advances in information technological promoting informational task complementarities, changes in worker preferences in favor of versatile work, and advances in human capital that make workers more versatile.

As mentioned in the introduction, the business and management literature indicates that a dramatic and broadly based process of organizational change – involving a move towards multi-tasking, job rotation, and inter-task learning – has been underway for some time, and is likely to continue. Furthermore, as noted, recent empirical studies suggest that reorganization of work is a quantitatively significant phenomenon. But while this reorganization has been much discussed in an informal, descriptive way, there has been little if any theoretical framework to analyze this process. The main ambition of this paper has been to develop such a framework. Once this has been done, the connections between the reorganization of work and its main determinants (recent changes in physical capital, information technologies, human capital, and preferences) look intuitively obvious.

Our analysis may also be viewed as a contribution to the contemporary debate on the sources of the increased dispersion of wages and job opportunities in the US and Europe. The dominant hypotheses thus far have been that these phenomena are the outcome of (i)

skill-biased international trade flows,<sup>20</sup> (ii) skill-biased technological change,<sup>21</sup> and (iii) deficient education and training relative to the demand for skilled labor.<sup>22</sup>

Our theory is complementary with the hypothesis resting on international trade, since the expansion of trade has enabled an increasing number of firms in the advanced industrialized countries to shift to products and production processes requiring holistic organization, while contracting out the routine, assembly line work to other countries. Our theory is also complementary to the hypotheses resting on technological change, education and training. But it goes further than these hypotheses in that it brings in organizational changes alongside changes in pure production technologies. In this way it helps explain wage and employment dispersion, since it specifies *how* changes in production and information technologies and *how* education and training may be expected to affect the dispersion of wages and employment opportunities in the context of the reorganization of work.

Finally, the three mainstream hypotheses above explain neither the widening inequality of wages *within* education, occupation, and job tenure groups in the US and the UK, nor the widening inequality of employment opportunities within these groups in various countries on the European continent. Our analysis offers an explanation for these phenomena: People within particular education, occupation, and job tenure groups are likely to vary considerably in terms of their social competence, judgment, and ability to perform multiple tasks. Thus, in countries such as the US and the UK, where real wages often respond flexibly to changes in labor demands and supplies, the move from Tayloristic to holistic organizations of work may lead to widening wage dispersion of wages within these groups. By contrast, in several European countries where real wages are more rigid, the reorganization of firms may give rise to a widening dispersion of employment opportunities among these groups, for a given distribution of abilities.

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<sup>20</sup> See, for example, Leamer (1996) and Sachs and Schatz (1994).

<sup>21</sup> See, for example, Berman, Bound and Grilliches (1994), Bound and Johnson (1992), Krueger (1993), Machin (1994), and Mincer (1993).

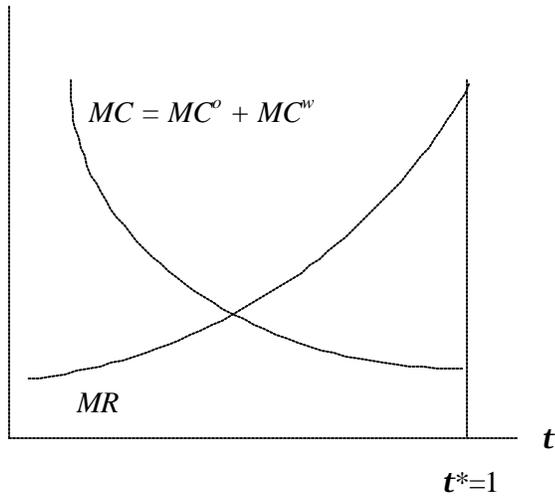
<sup>22</sup> See, for example, Mincer (1993), Levy and Murnane (1992), and Katz, Loveman, and Blanchflower (1995), among others.

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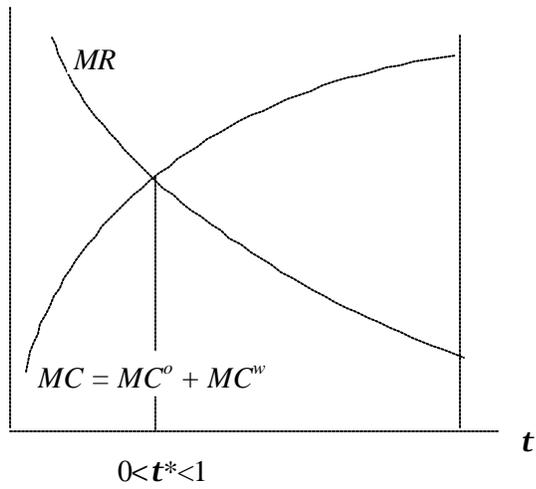
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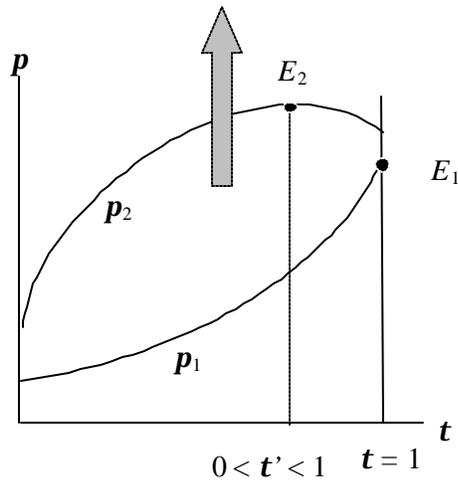


**Fig. 1a:**  
**Tayloristic Organization**

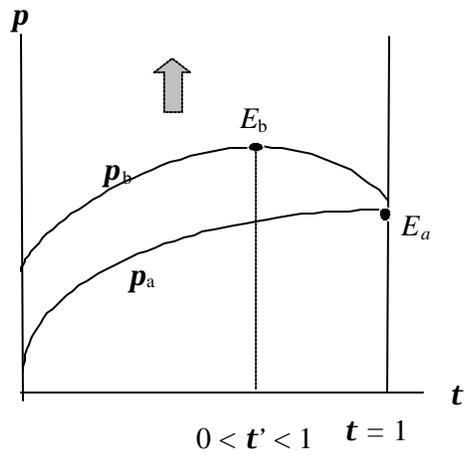


**Fig. 1b:**  
**Holistic Organization**

**Figures 1: The Organization of**



**Fig. 2a:**  
**The Discontinuous**  
**Process**



**Fig. 2b:**  
**The Continuous**  
**Process**

**Figures 2: The Restructuring Process**