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The Division of Labor Within Firms

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Abstract: The paper examines the determinants of the division of labor within firms. It provides an explanation of the pervasive change in work organization away from the traditional functional departments and towards multi-tasking and job rotation. Whereas the existing literature on the division of labor within firms emphasizes the returns from specialization and the need for coordination of the work of different workers, the present analysis focuses on the returns from multi-tasking, which is shown to arise from informational and technological complementarities among tasks as well as from the exploitation of the versatility of human capital.

1. Introduction

Since the time of Adam Smith, the ongoing division of labor has been viewed as a central feature of economic progress. This phenomenon has two aspects: (i) the division of labor within firms and (ii) the division of labor between firms. The former is concerned with the range of tasks performed by workers within any particular firm, while the latter deals with the range of products that any particular firm produces.

However, the past decade has witnessed widespread changes in the organization of firms that calls part of this conventional wisdom into question. These changes are documented in a large body of case studies in the management and business administration literatures.[1] On the one hand, the progressive specialization between firms continues, as large numbers of businesses in both the manufacturing and the service sectors divest themselves of marginal product lines and concentrate more heavily on their "core competencies". On the other hand, there is evidence of a progressive breakdown of occupational barriers within firms, as corporate hierarchies are restructured and delayered, and workers are given wider ranges of responsibilities across tasks. Consequently it may be said that, over the past decade, an increased division of labor *between* firms is often accompanied by a reduced division of labor *within* firms.

This paper focuses on the division of labor *within* firms, examining the change in work organization away from the traditional functional departments (e.g. production, administration, finance, design, and marketing departments) and towards multi-tasking and job rotation within relatively small customer-oriented teams. We provide an analysis that identifies some major determinants of this change and highlights some important channels whereby these determinants work.

Section 2 presents a simple model of work organization. Section 3 derives its implications for the division of labor within firms. Section 4 concludes, relating our analysis to the existing literature.

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[1] See, for example, Hammer and Champy (1993), Pfeiffer (1994), Wikström and Norman (1994).

2. A Simple Model of Work Organization

For simplicity, consider a firm that employs two workers at two tasks (1 and 2) to produce a homogeneous output q. The first worker devotes the proportion τ of his available time to task 1 (and thus the proportion (1-τ) to task 2), while the second worker devotes the proportion T to task 2 (and thus the proportion (1-T) to task 1). Let e_1 and e_2 be the first worker's labor endowment (labor input in efficiency units) at tasks 1 and 2, respectively; and let E_1 and E_2 be the second worker's labor endowment at these two tasks. Then the production function is

$$q = f\left(\tau e_1 + (1-\mathrm{T})E_1, (1-\tau)e_2 + \mathrm{T}E_2\right) \qquad (1)$$

where the marginal products are positive (f_1, $f_2 > 0$) and diminishing (f_{11}, $f_{22} < 0$). We assume that the first worker has a comparative advantage at task 1, relative to the second worker: $(e_1/e_2) > (E_1/E_2)$. Furthermore, for simplicity, the workers' labor is assumed to enter the production function symmetrically, so that we can restrict our attention to the first worker.

To get a straightforward handle on the worker's return from specialization versus multi-tasking, we assume that the worker's labor endowment e_i (i = 1,2) at each task i depends on two factors that we call

(i) the *return to specialization*: the more time a worker devotes to a task, the more productive he becomes, due to learning by doing, and

(ii) the *informational task complementarity*: the more time a worker devotes to one task, the more productive he becomes at another task, since the worker is able to use the information acquired at the former task to improve his performance at the latter.

Let the returns to specialization, for the first worker above, be represented by

$$s_1 = s_1(\tau) \text{ and } s_2 = s_2(1-\tau), \quad s_1', s_2' > 0 \qquad (2)$$

and let the corresponding informational task complementarities be given by

$$c_1 = c_1(1-\tau) \text{ and } c_2 = c_2(\tau), \quad c_1', c_2' > 0 \qquad (3)$$

We assume that the worker's labor endowment at task i depends positively on these two returns:

$$e_i = \xi_i(s_i, c_i) = s_i \cdot c_i, \; i = 1,2 \qquad (4)$$

where $\left(\partial\xi_j / \partial s_i\right), \left(\partial\xi_j / \partial c_i\right) > 0$ for i, j=1,2.

Now define the elasticity of the return to specialization with respect to the fraction of time the worker devotes to the two tasks as[2]

$$\eta_1^s = \frac{s_1'}{s_1}\tau > 0, \quad \eta_2^s = \frac{s_2'}{s_2}(1-\tau) > 0 \tag{5a}$$

and define the elasticity of informational task complementarities with respect to the fraction of time the worker devotes to the two tasks as[3]

$$\eta_1^c = -\frac{c_1'}{c_1}\tau < 0, \quad \eta_2^c = -\frac{c_2'}{c_2}(1-\tau) < 0 \tag{5b}$$

To provide a simple model of how the return to specialization and the informational task complementarity affects the organization of work, it will be convenient to assume that these elasticities are constants.

Another aspect of the firm's production technology that plays an important role in the analysis below is the degree of *technological complementarity* among the two tasks, as represented by the cross-partial derivatives of the production function (1). This feature may be called the "technological task complementarity." Denoting the labor services at the two tasks by $\lambda_1 = \tau e_1 + (1-\mathrm{T})E_1$ and $\lambda_2 = (1-\tau)e_2 + \mathrm{T}E_2$, we measure this complementarity in terms of $\varepsilon_{ij} = \frac{\partial f_i}{\partial \lambda_j}\frac{\lambda_j}{f_i} = \frac{f_{ij}}{f_i} e_j \upsilon$, which is the elasticity of the marginal product of one task with respect to the other task, where *i, j* = 1,2, $i \neq j$, and $\upsilon = \tau, 1-\tau$ when *j* = 1,2.

Let the firm's profit be $\pi = q - \kappa$, where κ is the labor cost which, for simplicity, is assumed independent of the workers' time allocation among tasks.[4] The firm is assumed to determine this time allocation. The profitability of a marginal reallocation of the workers' time across tasks is

$$\frac{\partial \pi}{\partial \tau} = f_1 \cdot \left(1 + \eta_1^s + \eta_1^c\right) \cdot \left(s_1 \cdot c_1 \cdot n\right) - f_2 \cdot \left(1 + \eta_2^s + \eta_2^c\right) \cdot \left(s_2 \cdot c_2 \cdot n\right) \tag{6a}$$

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[2] As the worker devotes a greater proportion τ of time to task 1, his returns to specialization at that task rise, so that the elasticity η_1^s is positive. Similarly for task 2.

[3] As the worker devotes a greater proportion τ of time to task 1, his informational task complementarity from task 2 falls, so that the elasticity η_1^c is negative.

[4] This assumption is easily relaxed. If, for example, workers are not indifferent to their time allocation and if the labor cost reflects these preferences, then the preferences would enter as another determinant of the restructuring process below.

and the rate of increasing or decreasing returns to the marginal time reallocation is

$$\begin{aligned}\frac{\partial^2\pi}{\partial\tau^2} = &\left(1+\eta_1^s+\eta_1^c\right)\cdot\left(s_1\cdot c_1\cdot n\right)\cdot\left[\frac{f_1}{\tau}\left[\varepsilon_{11}\left(1+\eta_1^s+\eta_1^c\right)+\left(\eta_1^s+\eta_1^c\right)\right]-\varepsilon_{12}\frac{f_1}{1-\tau}\left(1+\eta_2^s+\eta_2^c\right)\right] \\ &+\left(1+\eta_2^s+\eta_2^c\right)\cdot\left(s_2\cdot c_2\cdot n\right)\cdot\left[\frac{f_2}{1-\tau}\left[\varepsilon_{22}\left(1+\eta_2^s+\eta_2^c\right)+\left(\eta_2^s+\eta_2^c\right)\right]-\varepsilon_{21}\frac{f_2}{\tau}\left(1+\eta_1^s+\eta_1^c\right)\right]\end{aligned} \quad (6b)$$

by the profit function, the production function (1), and the labor endowments specified in (2)-(5b).

Then the firm's profit-maximizing organization of work is given by the following condition:[5]

Condition C1*: If* $\left(\partial\pi/\partial\tau\right)=0$ *for* $0<\tau<1$, *and* $\left(\partial^2\pi/\partial\tau^2\right)<0$ *in the neighborhood of* $\left(\partial\pi/\partial\tau\right)=0$, *then the worker will be engaged in multi-tasking; otherwise the worker will specialize by task.*

We now proceed to examine determinants of work organization and the role of these determinants in the restructuring process.

3. Determinants of the Organization of Work

Within this framework, the role of task complementarities and returns to specialization in determining the organization of work can be highlighted by examining two polar extremes of a worker's human capital across the two tasks: "complete one-sidedness" and "complete versatility:"

Case I: We call a worker *completely one-sided* when he is productive only at the task in which he has a comparative advantage: $s_1(\tau)>0$ for $\tau>0$, and $s_2(1-\tau)=0$ for all τ. In this case equation (6a) becomes

$$\frac{\partial\pi}{\partial\tau} = f_1\cdot\left(1+\eta_1^s+\eta_1^c\right)\cdot\left(s_1\cdot c_1\cdot n\right)>0 \quad (6a')$$

Since an interior optimum in the allocation of time across tasks is impossible in this case, the organization of work will invariably be specialized by task.

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[5] Since the labor of both types of workers enters the production function symmetrically, conditions analogous to C1 and C2 determine whether the second worker specializes or engages in multi-tasking. If there is specialization, the first worker specializes at task 1 while the second specializes at task 2, since the first worker has a comparative advantage at task 1, relative to the second worker.

Case II: We call a worker *completely versatile*, when he is equally productive at both tasks: $s_1(x) = s_2(x) = s(x)$ and $c_1(y) = c_2(y) = c(y)$ for any positive x and y, $0 \le x, y \le 1$. If both workers are completely versatile, then, by our assumption of symmetry, $f_1 = f_2 = f'$, $\varepsilon_{11} = \varepsilon_{22} = \varepsilon_{ii}$, $\eta_1^s = \eta_2^s = \eta^s$, $\eta_1^c = \eta_2^c = \eta^c$ and $\varepsilon_{12} = \varepsilon_{21} = \varepsilon_{ij}$ for $i \neq j$. Then equation (6b) reduces to

$$\frac{\partial^2 \pi}{\partial \tau^2} = 4\left(1+\eta^s+\eta^c\right)\cdot\left(s\cdot c\cdot n\right)\cdot\left[f'\cdot\left[\varepsilon_{ii}\left(1+\eta^s+\eta^c\right)+\left(\eta^s+\eta^c\right)\right]-\varepsilon_{ij}\cdot f'\left(1+\eta^s+\eta^c\right)\right] \quad \text{(6b')}$$

Equation (6b') together with Condition C1 imply that the organization of work depends on (a) the elasticity of the return to specialization (η^s) relative to the elasticity of the informational task complementarity (η^s) and (b) the technological task complementarity (ε_{ij}, $i \neq j$) relative to diminishing returns to labor (ε_{ii}). To see this simply and clearly, consider the following two special cases.

Case IIa: When there are *constant returns to labor* (so that $f_{ij} = \varepsilon_{ij} = 0$, for $i,j = 1,2$), it can be shown that the organization of work depends entirely on the returns to specialization relative to the informational task complementarities. When an increase in the time spent at a task raises the productivity of labor at that task by more than it raises the productivity of labor at the other task, then work will be specialized by task. In other words, there will be complete specialization when an increase in experience at a task raises the proportional returns to specialization at that task by more than it raises the associated informational task complementarities, i.e. when $\eta^s + \eta^c > 0$. Conversely, there will be multi-tasking when an increase in experience at a task raises the informational task complementarities by more than the returns to specialization, i.e. when $\eta^s + \eta^c < 0$. In sum:

Proposition 1*: If the marginal products of labor are constant ($\varepsilon_{ij} = 0$ for i, j = 1,2), then the organization of work depends on the returns to specialization relative to the informational task complementarity. In particular, when $\eta^s + \eta^c < 0$ there is multi-tasking, and when $\eta^s + \eta^c > 0$ there is complete specialization.*

To see this, it is convenient to visualize the firm's profit maximization problem in terms of an opportunity locus and an isoquant in $\lambda_1 - \lambda_2$ space. In particular, the opportunity locus is given by $\lambda_1 = \tau e_1 + (1-\mathrm{T})E_1$ and $\lambda_2 = (1-\tau)e_2 + \mathrm{T}E_2$, and the isoquant is given by $f(\lambda_1, \lambda_2) = \bar{q}$ (a constant). The firm's problem is to choose the time allocation τ so as to reach the highest isoquant achievable along its opportunity locus.

It can be shown that when $\eta^s + \eta^c > 0$, the opportunity locus is convex, as shown by the curve *OL* in Figure 1a. If $\varepsilon_{ij} = 0$ for *i*, *j* = 1,2, then the isoquant *IQ* is linear in $\lambda_1 - \lambda_2$ space. When workers are completely versatile, the opportunity locus is symmetric in $\lambda_1 - \lambda_2$ space, and by our symmetry assumption across tasks, the isoquant is symmetric in the same sense. Then highest isoquant is reached at the two end-points of the opportunity locus: $(0, \bar{\lambda}_2)$ and $(\bar{\lambda}_1, 0)$, which implies complete specialization.[6]

On the other hand, when $\eta^s + \eta^c < 0$, the opportunity locus is concave, as illustrated in Figure 1b. Then, clearly, the highest linear isoquant is attained in the interior of the opportunity locus, at $(\lambda_1^*, \lambda_2^*)$ in the figure. This implies multi-tasking, with τ^* = 1/2 in this special case.

Case IIb: When the returns to specialization and the associated informational task complementarities are equally responsive to changes in the fraction of available time devoted to the relevant task, then it can be shown that the organization of work depends on the technological task complementarity relative to diminishing returns to labor. In particular, if an increase in the fraction of time devoted to a task raises the returns to specialization at that task by the same proportional amount as the associated informational task complementarities ($\eta^s + \eta^c = 0$), the organization of work will involve complete specialization when the marginal product of labor service *i* (i=1,2) diminishes more rapidly with labor service *j* ($j \neq i$) than with labor service *i*: $\varepsilon_{ij} < \varepsilon_{ii}$. Conversely, there will be multi-tasking when $\varepsilon_{ij} > \varepsilon_{ii}$. In sum,

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[6]Needless to say, this solution is not one of multiple equilibria. Rather, when the workers are completely versatile, both types of workers are identical, and thus the firm finds it worthwhile to devote half its workforce to task 1 and the other half to task 2.

***Proposition 2**: If $\eta^s + \eta^c = 0$, then the organization of work depends on the technological task complementarity relative to diminishing returns to labor. In particular, when $\varepsilon_{ij} > \varepsilon_{ii}$, for $i \neq j$, there is multi-tasking; and when $\varepsilon_{ij} < \varepsilon_{ii}$, for $i \neq j$, there is complete specialization.*

If $\eta^s + \eta^c = 0$, the opportunity locus is linear; and if $\varepsilon_{ij} < \varepsilon_{ii}$, the isoquant is concave to the origin, as shown in Figure 1c. Thus, the highest isoquant is once again attained at the end-points of the opportunity, and workers will specialize by task. However, if $\varepsilon_{ij} > \varepsilon_{ii}$, the isoquant is convex to the origin, as illustrated in Figure 1d. Here the highest isoquant is reached in the interior of the linear opportunity locus, so that workers engage in multi-tasking.

The special cases above help shed light on three major determinants of the restructuring process, whereby the organization of work is changed from specialization by task to multi-tasking:

(i) *Changes in information technologies* that increase the informational task complementarities: For example, the introduction of computerized information systems often gives employees easy access to information within the firm and thereby encourages the exercise of multiple skills. In our model, the increase in informational task complementarities may be represented by an increase the absolute value of the elasticity η_i^c.

(ii) *Changes in production technologies* that increase the technological task complementarity: For example, the application of flexible machine tools and programmable equipment often makes different skills more complementary to one another. In our model, the increase in what may be called "technological task complementarities" may be represented by an increase in the elasticity ε_{ij} for $i \neq j$, since this technological change raises the amount by which the marginal product f_i of task i increases in response to additional labor services.

(iii) *Advances in human capital*, produced by the education system, enabling workers to become more versatile, i.e. more capable at performing multiple tasks: Recalling that the worker under consideration has a comparative advantage at task 1, this increase in versatility may be represented by an increase of $s_2(x)$ relative to $s_1(x)$, for any positive x, $0 \leq x \leq 1$.

Equations (6a) and (6b) provide a simple analytical context in which to analyze the above determinants of the restructuring process. The profit-maximizing responses of work organization to these determinants may be summarized by the following proposition:

Proposition 3*: Consider a firm in work is specialized by task (e.g., τ = 1). Then, in response to a sufficiently large*
(a) improvement in information technology that reduces η_i^c, for i = 1,2),
(b) improvement in production technology that raises ε_{ij}, for $i \neq j$, and
(c) improvement in the versatility of human capital that raises $s_2(x)$ relative to $s_1(x)$, for any positive x, $0 \leq x \leq 1$,
the firm has an incentive to change its work organization in favor of multi-tasking..

Proof: Suppose that initially $\left(\partial^2\pi / \partial\tau^2\right) > 0$. Then a sufficiently large reduction in η_i^c, for i = 1,2, and rise in ε_{ij}, for $i \neq j$ will lead to $\left(\partial^2\pi / \partial\tau^2\right) < 0$. But $\left(\partial^2\pi / \partial\tau^2\right) < 0$ is still compatible with a corner-point solution, provided that $(\partial\pi / \partial\tau)$ exceeds $(\partial\pi / \partial(1-\tau))$ over the entire range $0 \leq \tau \leq 1$. However, a sufficiently large rise in $s_2(x)$ relative to $s_1(x)$, for any positive x, $0 \leq x \leq 1$, will diminish $(\partial\pi / \partial\tau)$ relative to $(\partial\pi / \partial(1-\tau))$ and thus lead to an interior solution.

Figures 2 provide an intuitive understanding of Proposition 3. Fig. 2a pictures the firm's initial state, in which work is specialized. Here the firm's marginal profit with respect to the time allocation is $\frac{\partial\pi}{\partial\tau} = \frac{\partial f}{\partial\lambda_1}\frac{\partial\lambda_1}{\partial\tau} + \frac{\partial f}{\partial\lambda_2}\frac{\partial\lambda_2}{\partial\tau} > 0$ for the entire range $0 \leq \tau \leq 1$. Manipulating this condition, we obtain

$$-\frac{(\partial f / \partial\lambda_1)}{(\partial f / \partial\lambda_2)} < \frac{(\partial\lambda_2 / \partial\tau)}{(\partial\lambda_1 / \partial\tau)} \tag{7}$$

Observe that the left-hand term is the slope of the isoquant *IQ* and the right-hand term is the slope of the opportunity locus *OL* in Fig. 2a.

Then a sufficiently large increase in the informational task complementarities (i.e. a sufficiently large reduction in η_i^c, for i = 1,2) will turn the opportunity locus *OL* from a concave function (as in Fig. 2a) to a convex one (as in Figs. 2b and 2c). Moreover, a sufficiently large increase in the technological task complementarities (i.e. a sufficiently large rise in ε_{ij}, for $i \neq j$) will turn the isoquant *IQ* from a convex function (as in Fig. 2a) to a concave one (as in Figs. 2b and 2c). But as Fig. 2b shows, a convex opportunity locus and a convex isoquant are not sufficient to guarantee that multi-tasking will be more profitable than complete specialization, since it is possible for the opportunity locus to be sufficiently skewed to generate a corner-point solution. However, the increases in the versatility of human capital reduce the skewness of the opportunity locus and this, together with the increases in the informational and technological task complementarities, leads to an interior solution in which multi-tasking is the preferred organization of work.

4. Concluding Thoughts

Our analysis attempts to provide a new perspective on the organization of work. The recent literature on the division of labor within firms (e.g. Becker and Murphy (1992), Bolton and Dewatripont (1994), and Yang and Borland (1991)) focuses primarily on the returns to specialization relative to the costs of co-ordination *across workers*. It shows, among other things, that as the costs of communication among workers decline, the returns to specialization rise relative to the co-ordination costs and consequently the division of labor within firms increases. Another branch of the literature (e.g. Baumgardner (1988), Kim (1989), and Stigler (1951)) shows that as the size of the market increases (due to, say, economic growth or the expansion of international trade), the greater is the division of labor that it supports. Yet another branch (e.g. Holmstrom and Milgrom (1991)) shows how the division of labor within firms depends on the degree to which performance on particular tasks is measurable and the degree to which wages affect task performance. These contributions do not, however, explain how educational achievements and recent technological advances - particularly, the application of improved information technologies and the introduction of flexible machine tools and programmable, multi-purpose equipment - may lead to a *reduced* division of labor within firms. Our analysis has done so by examining changes in the division of labor from the perspective of the *intra-personal* returns from multi-tasking, rather than the *inter-personal* returns from co-ordination of worker activities or the incentive effects of wages.

In particular, our analysis has focused on how complementarities among tasks can be exploited when individual workers use their experience at one task to improve their performance at another task. In practice, this phenomenon - versatility across tasks, the ability to combine different tasks in meeting a customer's needs, the ability to apply the knowledge gained at one task to improve productivity at another task - can take on a wide variety of forms: the use of customer information gained from sales activities to improve product design, the use of technological information gained from production activities to improve financial accounting practices, the use of employee information gained from training activities to improve work practices, and so on. The literature on organizational restructuring (cited in Section 1) suggests that nowadays this phenomenon plays an increasingly important role in the restructuring of work. In this context the introduction of new computer technologies and versatile capital equipment can enhance inter-task complementarities and thereby lead to a decline in the division of labor within firms.

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