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HUMAN CAPITAL ACCUMULATION AND THE TRANSITION FROM SPECIALIZATION TO MULTITASKING

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This paper provides theoretical foundations to the contemporaneous increase in computer usage, human capital, and multitasking observed in many OECD countries during the 1990s. The links among work organization, technology, and human capital is modelled by establishing the conditions under which firms allocate the workers' time among several productive tasks. Organizational change is then analyzed in a dynamic perspective as the transition from specialization toward multitasking emphasizing its technological and educational determinants. We show that large enough "organizational shocks" can trigger a transition from specialization to multitasking, and this transition obviously should be accompanied by gradual increases in human capital.

Keywords: Information Technologies, Organizational Change, Human Capital, Specialization, Multitasking, Dynamics

1. INTRODUCTION

One of the most striking economic facts of the last decade is certainly the long lived expansion experienced by the U.S. economy (around 4% of annual growth in productivity on average during the 1990s). Most industrial countries have benefited

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from the same conditions, albeit at a lower extent. An important aspect of this expansion episode concerns the role of information and communication technologies (ICT). There is an unanimous view according to which ICT have been indeed the driving force behind the 1990s boom [Gordon (2000); Jorgenson and Stiroh (1999); Oliner and Sichel (2000)]. Indeed, productivity growth has been so impressive in the ICT sectors and the weight of such sectors in the economy has increased so markedly in the 1990s that there cannot be any doubt about the leading role of ICT in the boom.

Nonetheless, an intense debate on the precise role of ICT as a long-term growth engine is still taking place. Is the ICT-induced growth in productivity just the result of a pure capital deepening mechanism, of massive purchases of ICT equipment, following the dramatic fall in the price of ICT tools? Or are there any **ICT usage effects** on total factor productivity in the non-ICT sectors? For Gordon, once the cyclical effects removed, there is no evidence on the existence of spillovers from the ICT sector (mainly hardware) to the rest of the economy. This view is challenged by Oliner and Sichel, for example.

For Askenazy and Gianella (2000), the absence of a compelling evidence on the existence of such spillovers on aggregate data reflect the role of organizational change. In the industries where new organizational practices (toward more flexibility) have accompanied the (rising) investment in ICT tools, the resulting productivity gains are significant. In others, such an adaptation effort in work organization has not been undertaken, and the increasing investment in ICT equipment has not proven productivity enhancing. In a few words, it seems that ICT investment and organizational change are complementary, spillovers only take place when some adequate changes in work organization are performed. Early empirical corroborations of such a complementarity property are due to Black and Lynch (2000), and Bresnahan et al. (2002).

As reported by Osterman (1994, 2000), there is an increasing use of flexible organization forms in United States. In the early 1990s, almost two-thirds of American firms use flexible forms of workplace organization, at least partially. Typical flexible organizations include work teams, job rotation, total quality control, and quality circles. Caroli and Van Reenen (2001) document the same kind of trends in British and French firms. In British establishments, in particular, the proportion of workers involved in organizational changes (having more responsiblity, a wider range of tasks performed, more interesting or more skilled jobs) increased on average from 25% in 1984 to 44% in 1990. The REPONSE survey conducted in French establishments also show that the proportion of firms for which the majority of its employees rotate among tasks amounted to 25.2% in 1998. Regarding German firms, Carstensen (2002) observes the existence of two polar forms of organizations in Germany: "tayloristic" organizations, based on labor specialization, and "holistic" organizations, based on multitasking. She reports that, between 1993 and 1997, 57% of German firms have adopted new organizational forms based on job enrichment, job enlargement, and overtime variability in task assignments. Holistic firms are also more productive, experience positive

TABLE 1. Computer use and multitasking by education level in French manufacturing, 1991 and 1998 (mean percentage)

	Computer use		Multitasking	
	1991	1998	1991	1998
Education level				
Primary	2.49	6.82	14.23	12.06
Lower secondary	2.56	4.72	4.06	4.11
Upper secondary, vocational/technical	4.61	16.73	14.72	18.28
Upper secondary	3.91	12.60	6.96	7.98
Tertiary	2.50	11.87	4.66	7.06
Post-tertiary, university	2.08	12.73	4.04	5.84
Total	18.14	65.47	48.67	55.33
Number of workers	20028	10369	20257	21374

Source: INSEE and DARES, Survey on Working Condition and Employment 1991, 1998.

marginal returns from reorganization toward multitasking, and rely on human capital accumulation strategies.

The adoption of more flexible organizational forms and the spread of multitasking practices is tightly liked to computerization. By making information cheaper and more abundant, the diffusion of information and communication technologies increases informational task complementarities, which in turn favors the adoption of multitasking.[1] This correlation between computerization and the diffusion of multitasking is clearly reflected in Table 1 constructed from a French survey on Working Conditions and Employment, 1991–1998.

Table 1 also reflects another important connected feature: Multitasking also raises the skills requirements, so that a natural trend would be an increasing average level of workers' qualifications as long as multitasking practices continue to be adopted. Indeed, the increasing employment share of skilled workers is a clearly observed fact both in the U.S. economy and in major OECD countries during the 1990s along with the dissemination of ICT, as clearly shown in Table 2.

Summing up, one can identify three main trends in major OECD countries during the past two decades:

- An increase in the employment shares of skilled workers
- An important adoption of new technologies, especially microcomputers
- The adoption of organizational forms favoring job rotation, teamwork, quality, with emphasis on multitasking

This paper is aimed at providing a *dynamic framework* allowing to capture the three trends outlined earlier: more computers in the workplace, more skilled people, and increasing multitasking. The literature of this field is overwhelmingly static so far. The dynamic flavor of our model comes from a standard human capital accumulation engine. We ultimately show that an (exogenous) improvement in the productivity of education and/or an ICT shock do induce a transition from

TABLE 2. High-skilled (HS) ICT workers in the European Union and the United States, Average annual employment growth (1995–2001) (* = in 2001)

	HS workers	HS ICT-related workers	Share of HS ICT workers in total occupations*
Greece	1.29	3.19	0.56
United States	2.79	5.29	2.63
France	1.67	7.11	2.05
Italy	5.99	8.58	1.30
Belgium	2.13	8.91	2.01
Germany	1.66	9.41	1.90
Denmark	3.08	9.49	2.58
EU	2.79	10.11	2.01
Netherlands	4.14	10.31	3.54
Sweden (1997–2001)	3.47	12.29	3.85
United Kingdom	1.37	12.63	2.60
Luxembourg	4.06	14.28	2.22
Spain	7.46	15.92	1.38
Finland (1997–2001)	5.22	16.89	2.34

Source: OECD (July 2004), based on the Eurostat Labour Force Survey and the U.S. Current Population Survey, May 2003.

specialization to multitasking. ICT shocks are modeled is such a way that they reflect an increase in informational task complementarities, thus rising the return to multitasking.

A previous important contribution to the literature of organizational choice is Lindbeck and Snower (2000). However, these authors study the problem of organizational choices in a static framework with exogenous skills. In their framework, work organization is modeled through by the time allocation of workers among several tasks. Specialization arises when workers perform only one task, whereas multitasking does when workers allocate their working time between the multiple activities. In deciding whether workers should specialize or perform multiple tasks, firms hence face a trade-off between two sets of returns: "Returns from specialization" or "intra-task learning," whereby the more time a worker spends on a task, the higher his productivity from this task, and "returns from multitasking" or "intertask learning" whereby a worker can use the information and skills acquired at one task to increase his productivity at another task.

We borrow this elementary allocation problem from Lindbeck and Snower. However, in our dynamic model, returns to specialization and multitasking are influenced by (exogenous) technological change and specially by endogenous human capital accumulation, and we are able to address the issue of transition from specialization to multitasking. Indeed, the role of human capital in organizational change is out of question as we have argued earlier. Even for fixed technology, the level of human capital has been shown to be crucial in the determination of workplace organization. For example, Autor, Levy, and Murnane (2002) neatly show how the same technology results in more specialization for low skilled employees and less specialization—and thus more multitasking—for high skilled.

Our model is consistent with these findings. In order to get a clear picture of the role of human capital in the story, we depart from Lindbeck and Snower in other respects. In particular, we propose an analytical case with homogenous workers and asymmetric tasks [while two categories of workers are considered in Lindbeck and Snower (2000, 2001)]. In such a framework, we are able to derive the global dynamics analytically, and to point at the mechanisms at work in the transition from specialization to multitasking. The results are quite intuitive. Accounting for heterogeneity and/or considering any task configuration would disable such a transparent study because of the huge algebraic complexity involved. The constructed model has many useful implications. In particular, it predicts that there exists a threshold for human capital above which the transition from specialization to multitasking occurs. Consistently with Autor, Levy, and Murname (2003), it also stresses the predominant role of the task content of employment. In contrast to the traditional skill-biased technical change literature that views computerization and ICT as a source of a demand shift favoring better-educated labor and increasing wage inequality, the changing nature of jobs is key in our setting: Technological change and education systems improve the ability of workers to perform a variety of new tasks, that is to become more versatile, and this is the way multitasking originates.

This paper is organized as follows. Section 2 develops the model, and Section 3 analyzes the stationary equilibria. Section 4 studies the dynamics and transition from specialization to multitasking. Section 5 concludes.

2. THE MODEL

2.1. General Set-Up

To formalize organizational choices, work organization is modeled as an allocation of workers' individual time between several tasks or activities. We consider that production of a homogeneous good requires the realization of K tasks. The price of this good is normalized to one. For now, and to simplify notations, we abstract from time indexes (we will reintroduce them later on). The firm is composed of I types of workers and the production level of a worker $i \in I$ depends on the number of tasks she realizes. We envision a worker's production activity as having a principal stage or activity and potentially several additional ones once the principal task has been accomplished. Hence, each worker is assigned a principal task and may perform more tasks, but only provided that the principal activity has been realized. The tasks need not be radically distinct in nature. Our model bears all possible interpretations. It entails the configuration outlined by Autor, Levy, and Murnane (2003), mentioned in the introduction, with a first manual task and a second non-repetitive task.[2] Working time is normalized to one. If individual i performs several tasks, her overall productivity q_i is the sum of her productivity on each task q_{ki}, defined as the product of the time allocated to this task τ_{ki} and the productivity of each hour ε_{ki}:

$$q_i = \sum_{k\in K} q_{ki} \quad \text{with} \quad q_{ki} = \tau_{ki} \times \varepsilon_{ki} \quad \text{and} \quad \sum_{k\in K} \tau_{ki} = 1\ \forall i \in I. \tag{1}$$

If we denote by n_i the number of employees of type $i \in I$, aggregate output realized by employees of type i is defined by $L_i = q_i \cdot n_i$ and labor input L writes $L = (L_1, \ldots, L_i, \ldots, L_I)$.

Considering that labor is the sole input, the production function writes

$$F\left(\sum_{k\in K} \varepsilon_{k1} \cdot \tau_{k1} \cdot n_1 \quad , \ldots, \quad \sum\nolimits_{k\in K} \varepsilon_{ki} \cdot \tau_{ki} \cdot n_i, \quad \ldots\right),$$
$$F_i > 0, \quad \sum_{k\in K} \tau_{ki} = 1\ \forall i \in I,$$

where function F is homogeneous of degree 1 and F_i denotes the partial derivative of F with respect to its ith argument. Profits are then given by[3]

$$\Pi = F\left(\sum_{k\in K} \varepsilon_{k1} \cdot \tau_{k1} \cdot n_1 \quad , \ldots, \quad \sum_{k\in K} \varepsilon_{ki} \cdot \tau_{ki} \cdot n_i, \quad \ldots\right)$$
$$- \sum_{i\in I} w_i \cdot n_i, \quad \sum_{k\in K} \tau_{ki} = 1\ \forall i \in I,$$

where w_i is the wage rate of an individual of type i.

2.1.1. Application to a 2×2 *framework.* We restrict our attention to the case where production requires two tasks $K = \{1, 2\}$ and two types of labor $I = \{1, 2\}$. Each individual has a principal task to realize, she may perform both tasks but only after the principal activity has been accomplished. In other words, task 1 is necessary and must be realized before task 2. By convention of notation, task 1 denotes the worker's principal activity and task 2 the secondary activity. If we denote by τ_i the time spent by individual i on her principal activity, we have $\tau_{1i} \equiv \tau_i$, and since working time is normalized to one, the time constraint $\sum_{k\in K} \tau_{ki} = 1 \forall i \in I$ transforms into: $\tau_{11} \equiv \tau_1$, $\tau_{21} \equiv 1 - \tau_1$ and $\tau_{12} \equiv \tau_2$, $\tau_{22} \equiv 1 - \tau_2$. The profit function then writes

$$\Pi = F(L_1, L_2) - w_1 n_1 - w_2 n_2$$
$$L_1 = [\varepsilon_{11}\tau_1 + \varepsilon_{21}(1 - \tau_1)]n_1, \quad L_2 = [\varepsilon_{12}\tau_2 + \varepsilon_{22}(1 - \tau_2)]n_2.$$

The productivity of worker i at each task depends on her human capital, h_i, and her exposure (how much time is spent) at the principal task:

$$\varepsilon_{ki} = \varepsilon_{ki}(\tau_i, h_i), \quad k \in K \quad i \in I. \tag{2}$$

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Labor inputs then write[4]

$$L_1 = [\varepsilon_{11}(\tau_1, h_1)\tau_1 + \varepsilon_{21}(\tau_1, h_1)(1-\tau_1)]n_1$$
$$L_2 = [\varepsilon_{12}(\tau_2, h_2)\tau_2 + \varepsilon_{22}(\tau_2, h_2)(1-\tau_2)]n_2.$$

The firm then chooses its organization of work by maximizing profits according to the following program.[5]

$$\max_{\tau_1, n_1 \tau_2, n_2} \Pi = F\{[\varepsilon_{11}(\tau_1, h_1)\tau_1 + \varepsilon_{21}(\tau_1, h_1)(1-\tau_1)]n_1, \\ [\varepsilon_{12}(\tau_2, h_2)\tau_2 + \varepsilon_{22}(\tau_2, h_2)(1-\tau_2)]n_2\} - \sum_{i=1,2} w_i \cdot n_i. \tag{3}$$

The first-order conditions of this program are given by

$$F_i \cdot n_i \cdot \left\{ \left[\frac{\partial \varepsilon_{1i}(\tau_i, h_i)}{\partial \tau_i} \tau_i + \varepsilon_{1i}(\tau_i, h_i) \right] \right. \\ \left. + \left[\frac{\partial \varepsilon_{2i}(\tau_i, h_i)}{\partial \tau_i} (1-\tau_i) - \varepsilon_{2i}(\tau_i, , h_i) \right] \right\} \geq 0, \; i = 1, 2. \tag{4}$$

Together with the zero-profit condition: $F(., .) - \sum_{i=1,2} w_i \cdot n_i = 0$.

We are now going to define specialization and multitasking to analyze the optimal work organization derived from the firm's maximization program.

DEFINITION 1. *The optimal work organization consists in an allocation of working time based on:*

- *specialization* (*single-task organization*) *when both types of workers realize only one activity* (*their principal task*), *that is when* (4) *admits a corner solution* $\tau_i = 1\ \forall i = 1, 2$.
- *multitasking when at least one worker accomplishes both tasks*, *that is when* (4) *admits an interior solution* $\tau_i \in]0, 1[$ *for at least one type-*i *worker*, $i = 1, 2$. *When* $\tau_i \in]0, 1[\ \forall i = 1, 2$, *multitasking is full*, *and when* $\tau_i \in]0, 1[$ *and* $\tau_j = 1$ *for* $j \neq i$, $i, j = 1, 2$, *multitasking is partial.*

Organizational change will be defined later on in the dynamic framework as the transition from specialization to multitasking.

Given that $F_i > 0$, the necessary condition for a multitask work organization to be optimal is that there exists for at least one type-i worker a $\tau_i^* \in]0, 1[$ such that

$$\left(\left. \frac{\partial \varepsilon_{1i}(\tau_i, h_i)}{\partial \tau_i} \right|_{\tau_i = \tau_i^*} \cdot \tau_i^* + \varepsilon_{1i}(\tau_i^*, h_i) \right) \\ + \left(\left. \frac{\partial \varepsilon_{2i}(\tau_i, h_i)}{\partial \tau_i} \right|_{\tau_i = \tau_i^*} \cdot (1-\tau_i^*) - \varepsilon_{2i}(\tau_i^*, h_i) \right) = 0.$$

After simplifying notations, this condition writes

$$1+\frac{\varepsilon_{1i}^{'}(\tau_i^*,h_i)}{\varepsilon_{1i}(\tau_i^*,h_i)}\cdot\tau_i^*+\left(\frac{\varepsilon_{2i}^{'}(\tau_i^*,h_i)}{\varepsilon_{1i}(\tau_i^*,h_i)}\cdot(1-\tau_i^*)-\frac{\varepsilon_{2i}(\tau_i^*,h_i)}{\varepsilon_{1i}(\tau_i^*,h_i)}\right)=0. \qquad \mathbf{(5)}$$

Let us denote by $\Delta_{i,s}$ the time elasticity of specialization productivity, that is the elasticity of labor productivity at the principal task with respect to the time spent on this task, and by $\Delta_{i,m}$ the time elasticity of multitasking productivity, that is the elasticity of labor productivity at the second task with respect to the time spent on this activity:

$$\begin{aligned}\Delta_{i,s}&=\frac{\partial\varepsilon_{1i}(\tau_i,h_i)}{\partial\tau_i}\times\frac{\tau_i}{\varepsilon_{1i}(\tau_i,h_i)}=\frac{\varepsilon_{1i}^{'}(\tau_i,h_i)}{\varepsilon_{1i}(\tau_i,h_i)}\times\tau_i\\ \Delta_{i,m}&=\frac{\partial\varepsilon_{2i}(\tau_i,h_i)}{\partial(1-\tau_i)}\times\frac{(1-\tau_i)}{\varepsilon_{2i}(\tau_i,h_i)}=-\frac{\varepsilon_{2i}^{'}(\tau_i,h_i)}{\varepsilon_{2i}(\tau_i,h_i)}\times(1-\tau_i).\end{aligned} \qquad \mathbf{(6)}$$

Condition (5) then may be written as

$$1+\Delta_{i,s}=\left(1+\Delta_{i,m}\right)\cdot\frac{\varepsilon_{2i}(\tau_i^*,h_i)}{\varepsilon_{1i}(\tau_i^*,h_i)}\Leftrightarrow\frac{1+\Delta_{i,s}}{1+\Delta_{i,m}}=\frac{\varepsilon_{2i}(\tau_i^*,h_i)}{\varepsilon_{1i}(\tau_i^*,h_i)}. \qquad \mathbf{(7)}$$

The left-hand side of equation (7) is the ratio of the time elasticity of specialization productivity relative to the time elasticity of multitasking productivity. The right-hand side of equation (7) is the ratio of the productivity of multitasking relative to the productivity of specialization in efficiency units that is adjusted by human capital.

In sum, (7) establishes that *the optimal work organization is based on partial (full) multitasking if there exists for at least one type-i (both types of) worker(s) a* $\tau_i^*\in]0,1[$ *such that the relative time elasticity of specialization is equal to the adjusted relative productivity of multitasking*.

2.2. An Analytical Case: Homogenous Workers and Task Asymmetry

We reintroduce now time indexes to take into account production and work organization in a dynamic framework. Moreover, we make additional assumptions regarding labor productivity and the composition of the workforce.

2.2.1. Labor productivity: introducing human capital and task asymmetry. To go further in the analysis of the interplay between human capital and work organization we have to specify more precisely how human capital affects labor productivity in the single-task and in the multitask organization. As emphasized by Lindbeck and Snower (2000), returns from multitasking may be divided into two forms of task complementarities: technological and informational task complementarities. Technological task complementarities appear in the cross-partial derivatives between the labor inputs in the production function $F_{ij},\ i\neq j$. These complementarities hence simply capture the relative substitution possibility between inputs in the production technology. Informational task complementarities result from the learning process by which a worker's human capital at one task depends on his activity at other tasks. This learning process may be decomposed into two dimensions: intratask and intertask learning.

Intratask learning is captured in definition (1) by the fact that the worker's overall productivity $q_{ki}(t)$ increases with her exposure (time devoted) to each task:

$$q_{1i}(t) = \varepsilon_{1i}[\tau_i(t), h_i(t)] \times \tau_i(t)$$
$$q_{2i}(t) = \varepsilon_{2i}[\tau_i(t), h_i(t)] \times [1 - \tau_i(t)]. \tag{8}$$

Intertask learning represents the worker's ability to increase his productivity at one task through time spent on the other task. We shall introduce the *task asymmetry* at this point. More precisely, the latter ability is determined by human capital h_i and a task-specific productivity parameter according to

$$\varepsilon_{1i}[\tau_i(t), h_i(t)] = A_i(t) \times \varepsilon_1[h_i(t)]$$
$$\varepsilon_{2i}[\tau_i(t), h_i(t)] = B_i[\tau_i(t)] \times \varepsilon_2[h_i(t)],\ B_i^{'}[\tau_i(t)] > 0. \tag{9}$$

The asymmetry introduced is now clear: $B_i(.)$ increases with $\tau_i(t)$ while $A_i(.)$ does not depend on $1 - \tau_i(t)$ because the principal task is necessary and must be realized before the second task. Hence, productivity at the second task depends on how much time is spent on the first (principal) task but the time spent on task 2 does not affect labor productivity at the first task. There are numerous examples of this configuration. Consider, for instance, a researcher who types her own paper: By spending time on the first activity—producing new ideas—the productivity of typing articles is improved, but spending time on typing does not improves efficiency at developing new ideas. Similarly, consider a worker on an assembly line who is asked to correct machine breakdowns: the time spent on the machine gives information useful for knowing how it works and therefore how to repair the breakdown, but knowing how to repair does not *per se* increase productivity at the repetitive assembly line task.

Thus, this asymmetry in the nature of both tasks allows capturing the idea that the transition from specialization to multitasking may not mean a complete redesign of all activities performed by a worker but, rather, an broadening of her competencies, that is a requirement to perform one (or more) task(s) in addition to the main activity of the job.

We further parameterize $B_i[\tau_i(t)]$ as follows:

$$B_i[\tau_i(t)] = B_i(t) \times \tau_i(t), \tag{10}$$

where $B_i(t)$, just like $A_i(t)$, is an exogenous productivity parameter, independent of the time allocation decisions. Notice that by construction the ratio $B_i(t)/A_i(t)$

measures the (exogenous) relative returns to multitasking. We shall exploit it later in this paper.

2.2.2. Composition of the workforce: The implications of homogeneity in the Lindbeck-Snower setup. Despite the fact that workers enter the profit function symmetrically, they are heterogeneous in their human capital level and therefore the optimal organization of work for the type-i worker need not be the same as the optimal organization of work for the type-j worker, $j \neq i$. Hence, as stated in definition 1, two different cases of multitasking exist depending on whether condition (7) holds for either one type of worker (partial multitasking) or for both types of worker (full multitasking). When the workforce is homogeneous, that is all workers take the same characteristics (at least from the firm viewpoint), work organization will be based on either full specialization or full multitasking. We shall study this simpler case in order to highlight at the lowest algebraic case the mechanisms behind the transition from specialization to multitasking.

Indeed, when the population is homogeneous, the index i can be removed, and given that function F is homogeneous of degree 1, and $L_1 = L_2 = L$ by homogeneity, the production function could be written as $f(u) \equiv u\ F(1, 1)$. We shall normalize $F(1, 1)$ to 1. Notice that the homogeneity of the workforce implies a linear production function *a posteriori*. By doing so, we certainly take out one source of multitasking, which arises from technological task complementarities (nonzero cross-partial derivatives between the labor inputs in the production function $F_{ij},\ i \neq j$), but the informational task complementarities source, resulting from the learning process by which a worker's human capital at one task depends on his activity at other tasks, is still active. And, as we shall see, it is enough to make the point at a very low algebraic cost.

Just like Autor, Levy, and Murname (2003), our modeling emphasizes the predominant role of the task content of employment. Although the traditional skill-biased technical change literature puts forward computerization and ICT as a source of a demand shift favoring better-educated labor and increasing wage inequality, we focus on the changing nature of jobs as technological change and education systems improve the ability of workers to perform a variety of new tasks, that is to become more versatile.

2.2.3. Explicit productivity functions. Finally, we will adopt the following functional forms for ε_1 and ε_2:

$$\begin{aligned} \varepsilon_1[h_i(t)] &= h_i^{\alpha}(t),\ 0 < \alpha < 1, \\ \varepsilon_2[h_i(t)] &= h_i^{\beta}(t),\ 0 < \beta < 1. \end{aligned} \tag{11}$$

With constant technological progress, $A_i(t) \equiv A_t,\ B_i(t) \equiv B_t$, condition (7) becomes $\frac{\tau_t^*}{2\tau_t^*-1} = \frac{B_t \times \tau_t^*}{A_t} h_t^{\beta-\alpha} \Leftrightarrow \tau_t^* = \frac{1}{2}(1 + \frac{A_t}{B_t} h_t^{\alpha-\beta})$ and the optimal time

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allocation is given by[6]

$$\begin{cases} \tau_t = 1 \quad \text{if} \quad h_t \leq \overline{h}_t \equiv \left(\dfrac{A_t}{B_t}\right)^{\frac{1}{\beta-\alpha}} \\ \tau_t = \dfrac{1}{2}\left[1 + \dfrac{A_t}{B_t} h_t^{\alpha-\beta}\right] \quad \text{if} \quad h_t > \overline{h}_t \equiv \left(\dfrac{A_t}{B_t}\right)^{\frac{1}{\beta-\alpha}}. \end{cases} \tag{12}$$

And, given the optimal work organization (12), we get

$$\begin{cases} w_t = A_t h_t^{\alpha} \quad \text{if} \quad h_t \leq \overline{h}_t \\ w_t = \dfrac{h_t^{-\beta}}{4B_t}\left[A_t h_t^{\alpha} + B_t h_t^{\beta}\right]^2 \quad \text{if} \quad h_t > \overline{h}_t. \end{cases} \tag{13}$$

We shall interpret in detail the outcomes just above later in the text. Notice at the minute that the firm's problem already connects human capital with multitasking and technological progress. Equation (12) allow identifying a threshold level for human capital above which multitasking is optimal. This threshold level depends on the productivity parameters, and in particular on the ratio $B_i(t)/A_i(t)$, which captures the relative returns to multitasking. Human capital accumulation and technological progress are thus crucial in the evolution of job content. We shall get a more accurate picture of this triple connection once human capital accumulation is endogenized. This task is undertaken in the next section.

2.3. Endogenous Human Capital Accumulation

The economy is populated by overlapping generations of individuals who live for two periods. They decide to invest in human capital in the first period and they work in the second period. To simplify, individuals do not consume during the first period. We denote by $t+1$ the generation born in t. The utility function of a member of this generation is given by[7]

$$u_{t+1} = \ln(1 - e_t) + \ln c_{t+1},$$

where e_t denotes time spent on education in the first period. Total time being normalized to 1, $(1 - e_t)$ represents leisure time. c_{t+1} denotes second period's consumption. Given that individuals do not consume in the first period, the budget constraint writes $c_{t+1} \leq w_{t+1}$ where the wage rate is defined by equation (13).

The level of human capital of a member of generation $t+1$, h_{t+1}, depends on two elements: The time spent acquiring education in the first period, e_t, and human capital of the previous generation h_t: $h_{t+1} = h(e_t, h_t)$, where $h(.,.)$ is increasing in both arguments, differentiable and concave. To obtain analytical results, we rely on the specific functional form:

$$h_{t+1} = E_t \cdot (e_t)^a \cdot (h_t)^{1-a}, \tag{14}$$

where E_t is an efficiency parameter and $0 < a < 1$.

Hence, individual decisions are made according to the following program:

$$\max_{e_t} \ln(1-e_t) + \ln(w_{t+1})$$
$$s.c. \quad h_{t+1} = E_t \cdot (e_t)^a \cdot (h_t)^{1-a}.$$

This program leads to the following condition:

$$\frac{1}{1-e_t} = \frac{\partial(\ln w_{t+1})}{\partial h_{t+1}} \cdot \frac{\partial h_{t+1}}{\partial e_t}. \tag{15}$$

Given (13), we get

$$e_t = \frac{a\phi\,(h_{t+1})}{1+a\phi\,(h_{t+1})} \tag{16}$$

where $\phi(.)$ is such that

$$\begin{aligned} &\phi\,(h_{t+1}) = \alpha \quad if \quad h_{t+1} \leq \overline{h}_{t+1} \\ &\phi\,(h_{t+1}) = \frac{(2\alpha-\beta)\,A_{t+1}\,(h_{t+1})^{\alpha} + \beta B_{t+1}(h_{t+1})^{\beta}}{A_{t+1}\,(h_{t+1})^{\alpha} + B_{t+1}(h_{t+1})^{\beta}} \quad if \quad h_{t+1} > \overline{h}_{t+1}. \end{aligned} \tag{17}$$

Given equation (14), the dynamics of human capital is governed by the following equation:

$$h_{t+1} = E_t \cdot \left[\frac{a\phi\,(h_{t+1})}{1+a\phi\,(h_{t+1})}\right]^a \cdot (h_t)^{1-a}. \tag{18}$$

When $h_{t+1} > \overline{h}_{t+1}$, the relationship between h_t and h_{t+1} is still functional, that is, to each h_t corresponds a unique h_{t+1}. Equation (18) can indeed be rewritten as

$$h_{t+1} = h_t \cdot \left(E_t^{\frac{1}{a}} \cdot \frac{1}{h_{t+1}} \cdot \frac{a\phi(h_{t+1})}{1+a\phi(h_{t+1})}\right)^{\frac{a}{1-a}},$$

that is,

$$h_{t+1} = h_t \cdot [1 - G(h_{t+1})]^{\frac{a}{1-a}}, \quad G(h_{t+1}) = 1 - E_t^{\frac{1}{a}} \cdot \frac{1}{h_{t+1}} \cdot \frac{a\phi(h_{t+1})}{1+a\phi(h_{t+1})}.$$

We show in the Appendix that function $G(.)$ is strictly increasing. Using the implicit function theorem, h_{t+1} therefore is monotonic and strictly increasing in h_t. For each h_t corresponds a unique h_{t+1}.

3. STATIONARY EQUILIBRIA

We first study the existence of solutions under a stationary environment. In particular, we assume that A_t, B_t and E_t are constant, equal to A, E and B. The threshold human capital value is therefore constant equal to $\overline{h} = (A/B)^{\frac{1}{\beta-\alpha}}$. This stationary threshold value defines two possible steady-state regimes: Specialization below this value, and multitasking above. Let e_s (respectively e_m) and $h_s \leq \overline{h}$ (respectively $h_m > \overline{h}$) denote the steady-state values of education investments

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and human capital in the specialization regime (respectively in the multitasking regime). We shall study the existence and uniqueness of these equilibrium values.

To get an immediate idea about how the model works in this respect, notice that given equations (14), (16), and (18) we have

$$e_s = \frac{\alpha a}{1+\alpha a}, \quad h_s = E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a}. \tag{19}$$

However, this stationary value of human capital under specialization only makes sense if $h_s \leq \overline{h}$. This condition imposes the following restriction on the environment:

$$E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} \leq \left(\frac{A}{B}\right)^{\frac{1}{\beta-\alpha}}. \tag{C1}$$

Notice that condition (C1) holds with equality if and only if $h_s = \overline{h}$. Condition (C1) can be interpreted in two ways. For fixed "organizational parameters," A, B, α and β, the specialization equilibrium exists if and only if the education productivity variable E is small enough. In other words, specialization is an equilibrium organization of work when the productivity of the education technology is too low to allow reaching the threshold value of human capital above which firms would choose multitasking. Another interpretation is that for fixed education parameters, condition (C1) implies a lower bound for the ratio $\frac{A}{B}$, which implies that the specialization equilibrium exists if A is large enough with respect to B, which is a very natural outcome. Intuitively, specialization is an equilibrium organization of work when the relative technological productivity of labor services in such a case (A compared to B) is high enough. Does a multitasking equilibrium exist in such a case? Notice that if such an equilibrium exists, then the multitasking equilibrium effort and human capital are respectively:

$$e_m = \frac{a\phi(h_m)}{1+a\phi(h_m)}, \qquad h_m = E^{\frac{1}{a}} \cdot \frac{a\phi(h_m)}{1+a\phi(h_m)}, \tag{20}$$

where $\phi(h_m) = \frac{(2\alpha-\beta)A(h_m)^{\alpha}+\beta B(h_m)^{\beta}}{A(h_m)^{\alpha}+B(h_m)^{\beta}}$.

We assume that parameters α and β are such that

$$\alpha < \beta < 2\alpha. \tag{A1}$$

Assumption (A1) is a sufficient condition for the multitasking equilibrium, *when it exists*, to be unique.[8] The interpretation of this assumption is the following. The optimal work organization, combined to the stationary level of human capital accumulated by workers, leads to a unique multitasking equilibrium as long as the contribution of human capital to the returns to labor services is higher in the multitasking organization than in the specialization-based structure ($\beta > \alpha$), but it should not be not too high for a stationary level of human capital to exist ($\beta < 2\alpha$).

The analysis is much less trivial in the case of multitasking. The following proposition summarizes the findings regarding these issues.

PROPOSITION 1 (Steady States). *Under assumption* (A1)*, the model has a unique steady state. If condition* (C1) *is fulfilled, the specialization equilibrium prevails. If not, the multitasking equilibrium does.*

Proof. The existence and uniqueness of the steady state with specialization is immediate from equation (19) under condition (C1). The existence of the multitasking equilibrium amounts to solving the equation $G(h) = 0$ with $G(h) = 1 - E^{\frac{1}{a}} \cdot \frac{1}{h} \cdot \frac{a\phi(h)}{1+a\phi(h)}$.

We have $\lim_{h\to 0} \phi(h) = (2\alpha - \beta)$, $\lim_{h\to +\infty} \phi(h) = \beta$ and therefore, under assumption A1

$$\lim_{h\to 0} G(h) = -\infty, \quad \lim_{h\to +\infty} G(h) = 1.$$

We show in the Appendix that function $G(.)$ is strictly increasing on $\mathbb{R}_+$. Hence, there exists a multitasking equilibrium if and only if $G(\overline{h}) < 0$. Notice that this condition is exactly the opposite of (C1) since $\phi(\overline{h}) = \alpha$. So under (C1), we cannot have a multitasking equilibrium.

Assume now that (C1) does not hold. Then,

$$E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} > \left(\frac{A}{B}\right)^{\frac{1}{\beta-\alpha}}.$$

In such a case, the specialization equilibrium cannot exist. In contrast, since $G(\overline{h}) < 0$ if (C1) is violated, a multitasking equilibrium exists and is unique. ∎

It follows that the values of the exogenous variables A, B, and E are crucial in the nature of the long-term organizational regime. If the education effort is efficient enough and/or if the multitasking regime is profitable enough (relatively to specialization), the unique possible stationary equilibrium is multitasking, and vice versa. Of course, it remains to study if the obtained stationary equilibria are stable.

4. DYNAMICS AND TRANSITION FROM SPECIALIZATION TO MULTITASKING

We shall now study the global dynamics. As announced in the introduction section, we will also identify the cases where a transition from specialization to multitasking takes place.

4.1. Global Dynamics under Condition (C1)

Consider a situation in which the environment is stationary, that is, with constant A_t, B_t and E_t, and where condition (C1) holds. Hence, by Proposition 1, the specialization regime is the unique prevailing stationary equilibrium. Suppose that the initial value of human capital is bigger than h_s: $h_s < h_0$. The following proposition gives the exact dynamics in such a case when $h_s < \overline{h}$.

PROPOSITION 2 (Transition Dynamics When $h_s < \overline{h}$). *Under assumptions* (A1), *provided* (C1) *holds, if* $h_s < h_0$, *the equilibrium sequence* h_t, $t \geq 0$, *decreases to the specialization human capital stationary value* h_s. *If* $0 < h_0 < h_s$, *the equilibrium sequence* h_t, $t \geq 0$, *increases to the specialization human capital stationary value* h_s.

Proof. Let us start with the case $h_0 > h_s$. We will prove that the human capital sequence is decreasing and bounded from below by h_s; hence, it is converging necessarily to the fixed point h_s.

First, suppose $h_s < h_t < \overline{h}$. Then, either $h_{t+1} > \overline{h}$ or $h_{t+1} < \overline{h}$. In the latter case: $h_{t+1} = E\ (e_t)^a \cdot (h_t)^{1-a}$, and $e_t = \frac{\alpha a}{1+\alpha a}$.

Since $h_s < h_t$, we get: $h_{t+1} > E\ (e_t)^a \cdot (h_s)^{1-a}$, so that

$$\frac{h_{t+1}}{h_s} > E\ (e_t)^a \cdot (h_s)^{-a}.$$

Given that $e_s = e_t$ for every t when $h_t < \overline{h}$, and as $h_s = E^{\frac{1}{a}}\ e_s$, it follows that $h_{t+1}/h_s > 1$. The human capital sequence is bounded from below by the fixed point of the sequence h_s. Moreover, we have $h_{t+1}/h_t = E\ (e_t)^a \cdot (h_t)^{-a}$, and provided that $h_t > h_s$, it follows that $h_{t+1}/h_t < E\ (e_t)^a \cdot (h_s)^{-a}$.

Again, we use the relations $e_s = e_t$ and $h_s = E^{\frac{1}{a}}\ e_s$ since when $h_t < \overline{h}$, and we get immediately $h_{t+1}/h_t < 1$.

Hence, if $h_{t+1} < \overline{h}$, we have $h_s < h_{t+1} < h_t < \overline{h}$.

Suppose now that $0 < h_t < \overline{h}$ and $h_{t+1} > \overline{h}$. Then, $e_t = \frac{a\ \phi(h_{t+1})}{1+a\ \phi(h_{t+1})}$, and $h_{t+1} = E\ [\frac{a\ \phi(h_{t+1})}{1+a\ \phi(h_{t+1})}]^a \cdot (h_t)^{1-a}$.

We can rewrite the equation just above as

$$\frac{h_{t+1}}{h_t} = \left\{ \frac{E^{\frac{1}{a}}\ a\ \phi(h_{t+1})}{h_{t+1}\ [1 + a\ \phi(h_{t+1})]} \right\}^{\frac{a}{1-a}},$$

we then have $h_{t+1}/h_t = [1 - G(h_{t+1})]^{\frac{a}{1-a}}$.

Since condition (C1) is fulfilled, $0 < G(x) < 1$ for every $x \geq \overline{h}$. As $h_{t+1} > \overline{h}$, it follows that $h_{t+1}/h_t < 1$, which contradicts the assumption $h_t < \overline{h}$ and $h_{t+1} > \overline{h}$.

It follows that whence $h_t < \overline{h}$, h_{t+1} is necessarily below the threshold, and $h_s < h_{t+1} < h_t$. Convergence follows.

Consider now the case where $h_t > \overline{h}$. Then either h_{t+1} is below the threshold and we come back to the previous case, or h_{t+1} is above the threshold, and in such a case we have the relation $h_{t+1}/h_t = [1 - G(h_{t+1})]^{\frac{a}{1-a}}$, with $0 < G(x) < 1$ for every $x \geq \overline{h}$.

The sequence is in any case strictly decreasing. At some point in time, it should go below the threshold $\overline{h}$ value,[9] and then it converges to the unique fixed point under (C1), namely h_s.

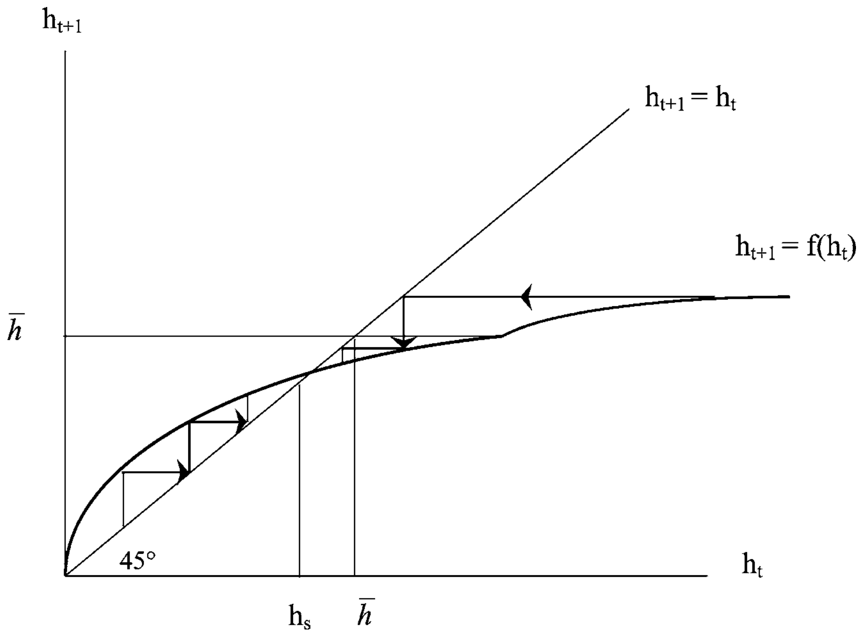

FIGURE 1. Dynamics of human capital when condition (C1) holds.

By similar arguments, we can prove that the same monotonic behavior arises when $0 < h_0 < h_s$. ■

Figure 1 depicts the dynamical system when condition (C1) holds with $h_s < \overline{h}$. The trivial case $h_s = \overline{h}$ is studied in the Appendix. A final comment on wage equilibrium pattern when condition (C1) holds can be made. In this case, wage is an increasing function of human capital (if $h_t \leq \overline{h_t}$ $w_t = A_t h_t^{\alpha}$ therefore $\partial w_t / \partial h_t = \alpha A_t h_t^{\alpha - 1} > 0$). Since wages are competitive, an increase in the efficiency units of labor supplied due to rising human capital, raises wages.

We now study the dynamics when condition (C1) is violated.

4.2. Global Dynamics When Condition (C1) Does Not Hold

If (C1) does not hold, the multitasking equilibrium is the unique steady state. Moreover, in such a case, $G(x) < 0$ for $\overline{h} < x < h_m$ and $G(x) > 0$ for $x > h_m$. This allows us to establish the following characterization of the global dynamics in such a case.

PROPOSITION 3 (Transition Dynamics When $h_0 > h_m$). *Under assumptions* (A1), *if condition* (C1) *does not hold, and* $h_0 > h_m$, *the equilibrium sequence* h_t, $t \geq 0$, *decreases to the multitasking human capital stationary value* h_m.

Proof. Suppose that $h_t > h_m$. Then, we have either $h_{t+1} > \overline{h}$ or $h_{t+1} < \overline{h}$.

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Consider first the case where $h_{t+1} > \overline{h}$ so that $h_{t+1}/h_t = [1 - G(h_{t+1})]^{\frac{a}{1-a}}$.

We have two possible subcases: either $h_{t+1} > h_m$ or $h_{t+1} < h_m$. The second subcase is impossible. Indeed, as $G(x) < 0$ for $x < h_m$, we have $\frac{h_{t+1}}{h_t} > 1$, which contradicts $h_t > h_m$ and $h_{t+1} < h_m$. In contrast, if $h_{t+1} > h_m$, we get no contradiction. Because $1 > G(x) > 0$ for $x > h_m$, it follows that: $h_m < h_{t+1} < h_t$.

This is indeed the unique possible case, as the alternative $h_{t+1} < \overline{h}$ is also impossible. Indeed, in such an alternative case, we have

$$h_{t+1} = E\left(\frac{\alpha a}{1+\alpha a}\right)^a \cdot (h_t)^{1-a},$$

and because $h_t > h_m > \overline{h}$ and $E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} > \overline{h}$ [condition (C1) violated], it follows that

$$h_{t+1} > (\overline{h})^a \cdot (\overline{h})^{1-a} = \overline{h}.$$

■

It remains to study the dynamics in the case where $h_0 < h_m$.

PROPOSITION 4 (Transition Dynamics When $h_0 < h_m$). *Under assumptions* A1, *if condition* (C1) *does not hold, and* $h_0 < h_m$, *the equilibrium sequence* h_t, $t \geq 0$, *increases to the multitasking human capital stationary value* h_m.

Proof. Let us first consider the case $\overline{h} < h_t < h_m$. We can prove exactly as in the end of the proof of Proposition 3, that $h_{t+1} \leq \overline{h}$ is impossible in such a case. Thus, $h_{t+1} > \overline{h}$.

A priori two subcases are still possible: either $h_{t+1} > h_m$ or $h_{t+1} < h_m$. Again, we use the law of motion, $h_{t+1}/h_t = [1 - G(h_{t+1})]^{\frac{a}{1-a}}$, to discriminate. Indeed, notice that since $1 > G(x) > 0$ when $x > h_m$, we have $h_{t+1}/h_t < 1$ if $h_{t+1} > h_m$, which contradicts $h_t < h_m$. Therefore: $h_{t+1} < h_m$. It follows that when the sequence starts below h_m (and above the threshold value), it converges monotonically to h_m.

We now end our analysis by solving the case of an initial condition below the threshold value, $h_t < \overline{h}$. We have either $h_{t+1} > \overline{h}$, and in such a case, it is trivial to show using the same argument just above that necessarily $h_{t+1} < h_m$, and we end up with the same story as before. Less trivially, the case $h_{t+1} < \overline{h}$, is solved by noticing that since the evolution of capital is given by

$$h_{t+1} = E\left(\frac{\alpha a}{1+\alpha a}\right)^a \cdot (h_t)^{1-a},$$

we have

$$\frac{h_{t+1}}{h_t} > E\left(\frac{\alpha a}{1+\alpha a}\right)^a \cdot (\overline{h})^{-a},$$

which implies since $E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} > \overline{h}$ [condition (C1) violated], that is $h_{t+1}/h_t > 1$. The sequence is increasing, and at some point in time, it should go above the threshold value, $\overline{h}$,[10] and converge to the unique fixed point under (C1), namely, h_m. ■

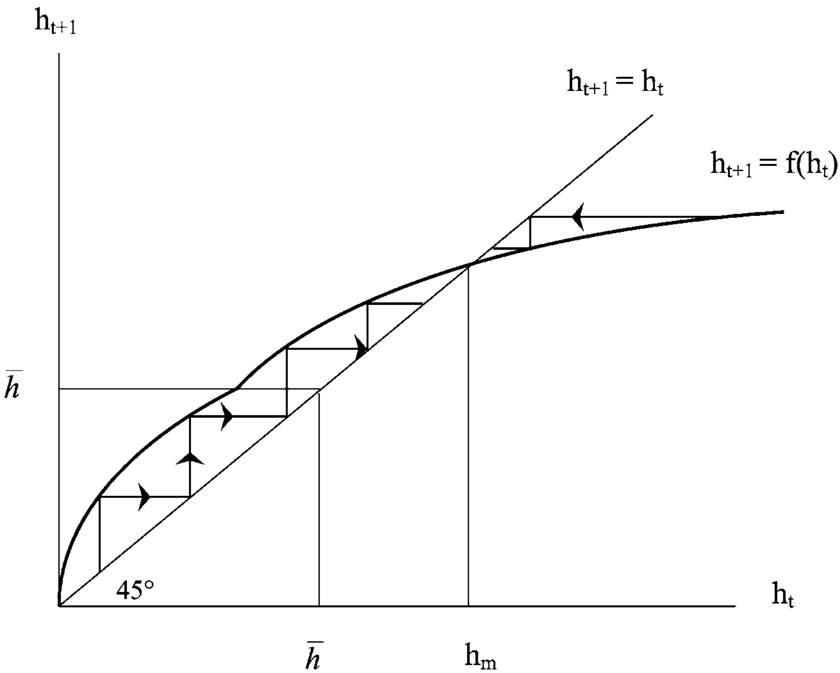

FIGURE 2. Dynamics of human capital when condition (C1) does not hold.

Figure 2 depicts the dynamical system when condition (C1) does not hold. We now turn to the determinants of organizational change, that is the transition from specialization to multitasking.

When condition (C1) does not hold, the productivity of multitasking and wages are also increasing functions of human capital.[11] This human capital effect is however higher in the multitasking than in the specialization regime. Hence, in addition to the human capital effect, there is also a multitasking effect on wages. This property has been documented by Chaudhury (2002), who shows that the trend toward multitasking implies steeper individual age-wage profiles.

4.3. Transition from Specialization to Multitasking

We have shown that under a stationary environment, the steady-state regime is either the specialization regime [condition (C1) fulfilled] or the multitasking regime [condition (C1) violated]. To analyze the conditions for a transition from the specialization regime to the multitasking regime, we consider two different types of shock: A shock on the efficiency parameter of the education technology E, or a shock on the parameters of the returns to specialization and multitasking, A and B. On the one hand, we consider technological advances embedded into information technologies that increase the relative returns to multitasking, favored by computerization, which corresponds to an increase in the technological ratio B/A. On the other hand, we consider advances in the education system that improve the ability of individuals to learn how to perform various activities, that is how to become more versatile, which corresponds in the model to an increase in the efficiency of education E. Given the structure of our model, the transition dynamics from one organizational form to another is endogenous. The predictions of the model are summarized in the next proposition.

PROPOSITION 5 (Transition from Specialization to Multitasking). *A large enough increase in the efficiency of the education technology E or in the relative returns to multitasking B/A generates a transition from a specialization stationary regime to a multitasking regime.*

Proof. Let consider an initial situation in which condition (C1) is fulfilled and such that the specialization regime prevails. The stationary value of human capital under specialization is such that: $E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} < (\frac{A}{B})^{\frac{1}{\beta-\alpha}}$. We have to show that after an increase in E or in B/A, the multitasking regime prevails and is such that $h_m > E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a}$.

Consider first an increase in the efficiency parameter of the education technology from E to $\widetilde{E}$, large enough and such that

$$\widetilde{E}^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} > \overline{h} = \left(\frac{A}{B}\right)^{\frac{1}{\beta-\alpha}}.$$

Let $\widetilde{h} = \widetilde{E}^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a}$. Given that function $\phi(.)$ is strictly increasing (see the Appendix) and the fact that $\phi(\overline{h}) = \alpha$, we have

$$\begin{aligned}
\widetilde{h} &= \widetilde{E}^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} > \overline{h} \Leftrightarrow \frac{a\phi(\widetilde{h})}{1+a\phi(\widetilde{h})} > \frac{a\phi(\overline{h})}{1+a\phi(\overline{h})} \\
&\Leftrightarrow \frac{a\phi(\widetilde{h})}{1+a\phi(\widetilde{h})} > \frac{a\alpha}{1+a\alpha} \\
&\Leftrightarrow 1 - \frac{1+\alpha a}{\alpha a} \cdot \frac{a\phi(\widetilde{h})}{1+a\phi(\widetilde{h})} < 0.
\end{aligned}$$

Using the fact that $\frac{1+\alpha a}{\alpha a} = \frac{\widetilde{E}^{\frac{1}{a}}}{\widetilde{h}}$ we finally have

$$\widetilde{h} > \overline{h} \Leftrightarrow G(\widetilde{h}) = 1 - \frac{1}{\widetilde{h}} \cdot \widetilde{E}^{\frac{1}{a}} \cdot \frac{a\phi(\widetilde{h})}{1+a\phi(\widetilde{h})} < 0.$$

The stationary value of human capital is such that $G(h_m) = 0$, and given that function $G(.)$ is strictly increasing, we therefore have the following inequality:

$$\overline{h} < \widetilde{h} < h_m.$$

Consider now an increase in the relative returns to multitasking from B/A to (B^*/A^*), large enough and such that

$$E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} > \overline{h}^* = \left(\frac{A^*}{B^*}\right)^{\frac{1}{\beta-\alpha}}.$$

Using the same argument as earlier, we show that

$$\begin{aligned}
\widehat{h} = E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} > \overline{h}^* &\Leftrightarrow \frac{a\phi(\widehat{h})}{1+a\phi(\widehat{h})} > \frac{a\phi(\overline{h}^*)}{1+a\phi(\overline{h}^*)} \\
&\Leftrightarrow \frac{a\phi(\widehat{h})}{1+a\phi(\widehat{h})} > \frac{a\alpha}{1+a\alpha} \\
&\Leftrightarrow 1 - \frac{1+\alpha a}{\alpha a} \cdot \frac{a\phi(\widehat{h})}{1+a\phi(\widehat{h})} < 0 \\
&\Leftrightarrow G(\widehat{h}) = 1 - \frac{1}{\widehat{h}} \cdot E^{\frac{1}{a}} \cdot \frac{a\phi(\widehat{h})}{1+a\phi(\widehat{h})} < 0 \\
&\Leftrightarrow \overline{h}^* < \widehat{h} < h_m.
\end{aligned}$$

The transition dynamics from the initial specialization regime to multitasking follow from Proposition 4. ■

As one can guess, the education and technology shocks are required to be *large enough* because the organizational decisions rely on a threshold level for human capital. This should not be regarded as a weakness of the model. Although our model does not explicitly consider this aspect because we do not address the issue of the optimal skill composition in the workplace, one might reinterpret the firm problem considered, with a distribution of human capital in mind. Either an education or a technological shock of any nonnegligible size will push at least *some* workers (whose human capital is near the threshold) from specialization to multitasking.[12] Of course, even with this interpretation in mind, a massive move toward multitasking is only possible for large enough education and/or technological shocks, but this can be hardly considered as a weakness of the model, this is simply consistent with the data.

Let us now dig deeper into the transition proposition. While an increase in E or B/A leads to the same transition from specialization to multitasking, the mechanisms at work are slightly different. On the one hand, an increase in the efficiency of education E increases the incentives to acquire education. For a given level of technological parameters, as the efficiency of education rises, the specialization equilibrium becomes a suboptimal work organization. This mechanism captures an efficiency effect: An increase in the parameter E makes workers more able to perform a wider variety of tasks, as it increases the efficiency of education. Education systems improving cognitive abilities to become versatile, which translates in our model into a increase in the productivity of the education technology, hence appears to be one major source of organizational change. For Lindbeck and Snower (2000), an important determinant of organizational change indeed is the steady growth of human capital per worker generated by education systems that made workers improve their performance of particular skills and increase their ability to acquire a variety of skills. Such an evolution motivates firms to reorganize work in favor of multitasking. For Acemoglu (1999) as well, an increase in the productivity of education makes it more profitable for skilled workers to work in reorganized firms (separately from unskilled workers).

On the other hand, a shock on B/A reduces the threshold level above which firms choose to allocate workers to several tasks. Such a shift in the threshold level of human capital means that, for a given level of human capital, the ability of workers to perform various tasks is enhanced when B/A increases. This mechanism captures an allocation effect: An increase in B/A makes workers more easily allocated to multitasking. Intuitively, ICT usage provide workers with more information, both within firm and about customers, permitting employees to be more involved in multitasking.

As mentioned earlier, the novelty of our approach is to highlight, like Autor, Levy, and Murname (2003), the predominant role of the task content of employment. Although the traditional skill-biased technical change literature emphasizes computerization and ICT as a source of a demand shift favoring better-educated labor and increasing wage inequality, we focus on the changing nature of jobs as technological change and education systems improve the ability of workers to perform a variety of new tasks, that is to become more versatile.

Considering technological adoption in a historical perspective, there are several examples of innovations favoring successively specialization and multitasking during the 20th century. Automobile production is a good illustration for this [see Goldin and Katz (1998)]. It began in large artisanal shops where automobiles were assembled by highly skilled and versatile artisans. Technological advances associated with the emergence of assembly lines led to standardized and interchangeable parts that were assembled in factories by scores of less-skilled and specialized workers. Our model can account for such reverse transitions from multitasking to specialization. Indeed, although ICT that have contributed to increase the returns to versatility, complementing nonroutine activities and relying on higher human capital levels, the emergence of assembly lines in the first part of the 20th century increased the returns to task specialization leading to widescale division of labor. This would translate in our model into an increase in the ratio A/B, which leads, by symmetry with an increase in B/A, to a transition from multitasking to specialization.

5. CONCLUSION

This paper provides theoretical foundations to the apparent complementarity between organizational change, ICT investment, and human capital. In deciding whether workers should specialize or perform multiple tasks, firms face a trade-off between the returns from specialization and the returns from multitasking. The optimal time allocation mode involves multitasking when the workers' level of human capital is sufficiently high. The model has a unique steady state (specialization or multitasking), which is globally stable.

Large enough "organizational shocks" can trigger a transition from specialization to multitasking and this transition should be obviously accompanied by gradual increases in human capital. The increase in the productivity of education, as well as the productivity effects of ICT in terms of informational and technological task complementarity favor the adoption of multitasking organizations, thereby explaining the contemporaneous increase in computer usage, human capital accumulation, and multitasking observed in many OECD countries during the 1990s.

NOTES

1. There are more arguments in the literature around the impact of computers on tasks content design. For example, Autor, Levy, and Murname (2001) study how computer technology alters job skill demands over 1960–1998 within American Firms. They show that computerization is associated with declining relative industry demand for routine manual and cognitive tasks and increased relative demand for nonroutine cognitive tasks.

2. As pointed out by an anonymous referee, the second task need not be nonrepetitive. There are many examples of repetitive second tasks—say, a professor who now types her own papers.

3. More generally, if we denote by X the other possible inputs, profits would write $\Pi = F(L, X) - C(L) - M(X)$, with $F(L, X)$ the production function, $C(L)$ the labor cost and $M(X)$ the cost of the other inputs.

4. At this stage, a particular case would be, as in Lindbeck and Snower (2000), to abstract from human capital h_i and consider that labour productivity at each task is the sum of returns to specialization, s_{ki} $(k = 1, 2)$, and returns to informational task complementarities, c_{ki} $(k = 1, 2)$, that is: $\varepsilon_{1i} = s_{1i}(\tau_i) + c_{1i}(1 - \tau_i)$, $\varepsilon_{2i} = s_{1i}(1 - \tau_i) + c_{1i}(\tau_i)$. By keeping parameters $\varepsilon_{ki}(\tau_i, h_i)$, we let the specification of labour productivity be as general as possible for now.

5. Lindbeck and Snower (2001) consider that employees have discretion over the proportions in which different tasks are performed (i.e., the task mix) and that, in the absence of centralized bargaining, the firm can offer a different wage to worker at each task. The employees' freedom to decide on the task mix, that is, the employees' autonomy, would indeed be adapted to organizations with pay plans based on individual performance measures (see, for instance, Holmström and Milgrom, 1991). This leads them naturally to focus on the relationship between centralized bargaining and reorganization. Our ambition is different and the issue of unionization and imperfectly competitive wage setting rules is beyond the scope of our paper. Indeed, relying on a competitive wage setting rule, we analyze on employees' education decisions in a dynamic context, given organizational choices at the employer level. This leads us to focus on the interactions between human capital accumulation and reorganization.

6. The second-order condition is always satisfied: $-2B_t h_t^{\beta} < 0$.

7. Lindbeck and Snower assume that reservation wages express the preferences of workers for specialization or multitasking. This induces a nonconvexity in the disutility of effort. Our model is different because we model preferences in an intertemporal framework where there is a trade-off between education and consumption.

8. Therefore, (A1) is a uniqueness condition, not an existence condition, and it is only needed to ensure the uniqueness of the multitasking equilibrium.

9. Notice that this should be the case because if the human capital sequence does not go below the threshold, this would mean that we have a strictly decreasing sequence bounded below by the threshold, thus converging. As the sequence is generated by a continuous—although not everywhere differentiable—map, it should converge to a fixed point of the map. There is no fixed point above the threshold when (C1) holds.

10. By the same argument as in Note 7.

11. When $w_t = \frac{h_t^{-\beta}}{4B_t}[A_t h_t^{\alpha} + B_t h_t^{\beta}]^2$ and under A1, $\partial w_t / \partial h_t = \frac{w_t}{h_t} \cdot \frac{(2\alpha - \beta) A_t h_t^{\alpha} + \beta B_t h_t^{\beta}}{A_t h_t^{\alpha} + B_t h_t^{\beta}} > 0$.

12. As pointed out by an anonymous referee, this would allow addressing the issue of a *gradual diffusion* of multitasking.

13. Indeed, in such a case, if h_{t+1} is still above $\overline{h}$, we can show as in the proof of Proposition 2 that the human capital sequence is then a strictly decreasing sequence, bounded from below by $\overline{h}$, which is precisely the fixed point of the map in the special case where (C1) is checked with equality; so convergence is ensured immediately.

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APPENDIX

A.1. STEADY-STATE WITH MULTITASKING

Deriving $G(.)$ implies

$$G'(h) = E^{\frac{1}{a}} \cdot \frac{1}{h} \cdot \frac{a\phi(h)}{1+a\phi(h)} \cdot \left\{ \frac{\phi(h)[1+a\phi(h)] - h\phi'(h)}{h\phi(h)[1+a\phi(h)]} \right\}.$$

In turn,

$$G'(h) > 0 \Leftrightarrow \phi(h)[1+a\phi(h)] - h\phi'(h) > 0.$$

Deriving $\phi(.)$ yields

$$\phi'(h) = \frac{2AB(\alpha-\beta)^2 h^{\alpha+\beta-1}}{[A(h)^\alpha + B(h)^\beta]^2} > 0.$$

Hence,

$$G'(h) > 0 \Leftrightarrow [1+a\phi(h)] \cdot \frac{1}{h\phi'(h)/\phi(h)} > 1.$$

We have

$$h\phi'(h)/\phi(h) = \frac{(2\alpha-\beta)\alpha A(h)^\alpha + \beta^2 B(h)^\beta}{(2\alpha-\beta)A(h)^\alpha + \beta B(h)^\beta} - \frac{\alpha A(h)^\alpha + \beta B(h)^\beta}{A(h)^\alpha + B(h)^\beta}.$$

Thus, after some calculations,

$$\begin{aligned} &h\phi'(h)/\phi(h) \lesseqgtr 1 \\ &\Leftrightarrow (2\alpha-\beta)[x(h)]^2 + \beta[y(h)]^2 + [\alpha(1-\alpha) + \beta(2\alpha-\beta)][x(h)y(h)] \gtreqless 0, \end{aligned}$$

where $x(h) \equiv A(h)^\alpha$ and $y(h) \equiv B(h)^\beta$.

Hence, under assumption A1, we have $2\alpha - \beta > 0$ and therefore $h\phi'(h)/\phi(h) < 1$.

In turn, since $1 + a\phi(h) > 1$ and $\frac{1}{h\phi'(h)/\phi(h)} > 1$, we have $G'(h) > 0$.

A.2. PARTICULAR CASE UNDER (C1): $h_s = \overline{h}$

This case is trivial and use the same arguments as before in a much simpler way. Suppose, for example, $h_t < \overline{h} = h_s$. Then, either $h_{t+1} < \overline{h}$ or $h_{t+1} > \overline{h}$. In the former case, we get

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immediately that the sequence h_t is increasing and bounded above by the fixed-point $\overline{h}$, thus it is converging to this point. Indeed, if $h_{t+1} < \overline{h}$, then $h_{t+1} = E(e_s)^a\ (h_t)^{1-a}$, and

$$\frac{h_{t+1}}{h_t} = E(e_s)^a\ (h_t)^{-a} > E(e_s)^a\ (\overline{h})^{-a} = 1.$$

Thus, the sequence is strictly increasing. It is also obviously bounded from above by the fixed-point because $h_{t+1} < E(e_s)^a\ (\overline{h})^{1-a}$, which implies $\frac{h_{t+1}}{\overline{h}} < E(e_s)^a\ (\overline{h})^{-a} = 1$.

If $h_t < \overline{h}$ but $h_{t+1} > \overline{h}$, we can use exactly the same argument in the proof of Proposition 2 for this case to get a contradiction and conclude that h_{t+1} cannot be bigger than $\overline{h}$. The remaining case $h_t > \overline{h}$ is also settled more easily than in the corresponding situation in Proposition 2.[13]