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Raouf Boucekkine
Patricia Crifo

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LABORATOIRE D'ECONOMETRIE
1rue Descartes F-75005 Paris
(33) 1 55558215
http://ceco.polytechnique.fr/
mailto:labecox@poly.polytechnique.fr

# Human Capital Accumulation and the Transition from Specialization to Multi-tasking

Raouf Boucekkine[1]
Patricia Crifo[2]

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**Résumé:** Cet article fournit des fondements théoriques à l'augmentation simultanée de la polyvalence, le capital humain et l'usage de l'informatique dans de nombreux pays de l'OCDE dans les années 1990. les liens entre organisation du travail, technologie et capital humain sont modélisés en établissant les conditions sous lesquelles les firmes allouent le temps de travail des travailleurs entre plusieurs tâches productives. Le changement organisationnel est ensuite analysé dans une perspective dynamique comme la transition de la spécialisation à la polyvalence en mettant l'accent sur ses déterminants technologiques et éducatifs.

**Abstract:** This paper provides theoretical foundations to the contemporaneous increase in computer usage, human capital and multi-tasking observed in many OECD countries during the 1990s. The links between 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 analysed in a dynamic perspective as the transition from specialization towards multi-tasking emphasizing its technological and educational determinants

***Mots clés :*** Technologies de l'Information, Changement organisationnel, Capital humain, Spécialisation, Polyvalence, Dynamique

***Key Words :*** Information technologies, Organizational change, Human capital, Specialization, Multi-tasking, Dynamics

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[1] CORE, Département d'Economie, Université Catholique de Louvain.
[2] Laboratoire d'Econométrie, CNRS et Ecole polytechnique.

# Human Capital Accumulation and the Transition from Specialization to Multi-tasking *

Raouf Boucekkine † Patricia Crifo ‡

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## 1 Introduction

One of the most striking economic facts of the last decade is certainly the long lived expansion experienced by the US economy (around 4% of annual growth in productivity on average during the 1990s). Most industrial countries have benefited from the same conditions though 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, 2000, and 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.

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†IRES and CORE, Catholic University of Louvain. boucekkine@ires.ucl.ac.be.

‡Corresponding author. CNRS-Laboratoire d'Econometrie, Ecole Polytechnique and IRES, Catholic University of Louvain. patricia.crifo@shs.polytechnique.fr.

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 (towards 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), there is an increasing use of flexible organization forms in the US. In the early 1990s, almost the 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. In particular, the ability of a worker to perform different tasks is becoming a key requirement. Obviously, multi-tasking also raises the skills requirements, so that a natural trend would be an increasing average level of workers' qualifications as long as multi-tasking practices continue to be adopted. Indeed, as documented more precisely in appendix 6.1 (tables I to III), the increasing employment share of skilled workers is a clearly observed fact both in the US economy and in major OECD countries during the 1990s.

The adoption of more flexible organizational forms and the spread of multi-tasking 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 multi-tasking. This is the main argument we put forward along this paper to connect ICT adoption with the rise of multi-tasking. 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 computer capital appears to substitute for a limited and well-defined set of human activities, those involving routine (repetitive) cognitive and manual tasks; and complements activities involving non-routine problem solving and interactive tasks. Provided these tasks are imperfect substitutes, their model implies measurable changes in the task content of employment, which they explore using representative data on job task requirements. Computerization is associated with declining relative industry demand for routine manual and cognitive tasks and increased relative demand for non-routine cognitive tasks. Notable changes in working conditions have indeed been observed in Europe during the 1990s. As documented precisely in appendix 6.1 these changes occured both at an aggregate level and at a more micro level. At an aggregate level, changes in working conditions involve new paces and methods of work (see Table IV), while at the firm level, they imply more intense job rotation and multi-tasking.

But if the development of multi-tasking relies on the returns to task complementarities, it also creates complex interactions among the different activities performed. When production requires the realization of a series of tasks, mistakes in any of them can widely reduce the product's value. In the extreme case of O-ring technologies[1] (Kremer, 1993), interactions among tasks are multiplicative so that the entire value of output can be destroyed if only one task is incorrectly performed. The workers' productivity, which can be assimilated to the probability of correctly performing a task in Kremer's model, then interact in such a way that the quantity of labor is not perfectly substitutable to labor quality. An increase in the productivity of skilled workers can in turn makes it more profitable for skilled workers to work by themselves in separate reorganized firms to avoid that unskilled workers put downward pressure on the productivity of skilled workers (Kremer and Maskin, 1996 and Acemoglu, 1999).

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 micro computers
- The adoption of organizational forms favoring job rotation, team work, quality, with emphasis on multi-tasking

This paper is aimed at providing a **dynamic framework** allowing to capture the three trends outlined above: more computers in the workplace, more skilled people, and increasing multi-tasking. 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

[1] O-rings were one of the components of the space shuttle Challenger. This shuttle exploded because the launching temperature caused these components to malfunction.

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

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 modelled through by the time allocation of workers among several tasks. Specialization arises when workers perform only one task, while multi-tasking 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 multi-tasking" or "inter-task 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 multi-tasking 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 already argued above. 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 multi-tasking- for high skilled. Our model is consistent with these findings. In particular, it predicts that there exists a threshold for human capital above which the transition from specialization to multi-tasking occurs.

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 multi-tasking. Section 5 concludes.

# 2 The model

## 2.1 Workers′ production function

Firms produce a homogenous good using labor as only input. Production relies on the realization of $k = 1, ...n$ tasks. For the sake of simplicity, we restrict our attention to the case of two productive tasks: $n = 2$. Firms have to decide the range and proportion of tasks that will be performed. Both aspects are embedded into the allocation of the workers' time between both tasks. When workers are assigned to one task only, work organization is based on specialization, when workers perform both tasks work organization is based on multi-tasking.

As in Lindbeck and Snower (2000), the efficiency units of labor supplied by workers have two determinants: returns to specialization and returns to multi-tasking. Returns to specialization imply that a worker's productivity at one task increases with his exposure to that task. Returns to multi-tasking rely on the idea that a worker can also use the information and skills acquired at one task to improve his performance at another task. This kind of returns can be considered as "informational task complementarities". There are many examples of informational complementarities in real life: working on various parts of an automobile (rather than specializing on the motor part for example), working on an entire banking transaction for one client...etc...

The tasks need not be radically distinct in nature. Our model bears all possible interpretations. It entails the configuration outlined by Autor, Murnane and Levy (2001), mentioned in the introduction, with a first manual task and a second non-repetitive task. But given the specifications of the returns to specialization Vs multi-tasking given just below, mainly involving time spent at each task and workers' human capital, the two tasks need not be so radically differentiated.[2]

We normalize workers' available time to one and denote by $\tau_t$ the time devoted to task 1 and $(1 - \tau_t)$ the time devoted to task 2. We consider that returns to specialization simply capture the fact that the greater the fraction of the worker's working time devoted to a particular task, the more productive he becomes at that task. However, we consider that human capital complements the time devoted to task 1. Returns to specialization are therefore given by:

$$s(\tau_t, h_t) = A_t \cdot \tau_t \cdot h_t^{\alpha} \tag{1}$$

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

where $0 < \alpha < 1$, $h_t$ is the worker's human capital, and $A_t > 0$ is a productivity parameter.[3]

Returns to multi-tasking exhibit more complex interactions. We consider that when a worker's attention is allocated to several tasks, there exist multiplicative interactions among them. [4] Returns to multi-tasking are therefore the product of two components: informational task complementarities and the quality of work performed (*i.e.* the worker's human capital). For informational task complementarities to exist, the worker must spend time both on task 1 and on task 2. Informational task complementarities are hence given by $\tau_t \cdot (1 - \tau_t)$. In addition, human capital complement informational task complementarities in the determination of returns to multi-tasking. Returns to multi-tasking are hence defined by:

$$m(\tau_t, h_t) = B_t \cdot \tau_t \cdot (1 - \tau_t) \cdot h_t^{\beta} \tag{2}$$

where $B_t$ is a productivity parameter, $0 < \beta < 1$ and $0 < \alpha < 1$. The output of a worker with human capital $h_t$ is then given by:

$$y_t = A_t \cdot \tau_t \cdot h_t^{\alpha} + B_t \cdot \tau_t \cdot (1 - \tau_t) \cdot h_t^{\beta} \tag{3}$$

In contrast to Lindbeck and Snower (2000, 2001), we do not assume a fixed allocation of the workforce between two categories of workers. In our set-up, endogenous human capital accumulation is allowed, ultimately leading to a dynamic model of organizational change. As claimed in the introduction, our story is consistent with the findings of Autor, Levy and Murnane (2001), who claim that organizational change is the result of the interaction between available technologies and available skills. In particular, the level of human capital is decisive for a given technology to induce a push towards multi-tasking and other more flexible forms of organization in the workplace. Precisely in our model, the returns to multi-tasking and the returns to specialization depend on the level of human capital. In particular, on the one hand, the marginal return of time spent on task 1 depends on a technological parameter and human capital, but not on the time spent on this task. On the other hand, the marginal return of time spent on task 2 not only depends on technology and human capital, but it also depends on informational task complementarity, that is on the time spent on task 1.

[3] We thus assume that firms hire only one sort of worker, i.e. one type of human capital. As pointed out by an anonymous referee, this is not an innocuous assumption: a strong heterogeneity of human capital in the work place may be a barrier to the spread multi-tasking, for example consistently with Kremer's O-ring theory (1993).

[4] This specification is again consistent with the "O-ring technologies", see Kremer (1993).

## 2.2 Optimal work organization

What we call work organization in this model is the optimal time allocation mode. When $\tau_t = 1$, work organization is specialized, whereas when $\tau_t < 1$ work organization is based on multi-tasking.

Firms determine the optimal share of workers' time devoted to task 1 ($\tau_t$) and task 2 ($1-\tau_t$) and the optimal quantity of labor input that maximize profits [5]. The profits of a production unit employing $N_t$ individuals with human capital level $h_t$ are given by:

$$\pi_t = [y_t - w_t] \cdot N_t \tag{4}$$

where $w_t \equiv w(h_t)$ is the wage rate of a worker with human capital $h_t$.

The optimal work organization and quantity of labor input are the solutions of the following program:

$$\begin{aligned} \max_{\tau_t\ ,\ N_t} \pi_t &= [y_t - w_t] \cdot N_t \\ s.c. \quad y_t &= A_t \tau_t h_t^{\alpha} + B_t \tau_t (1-\tau_t) h_t^{\beta} \end{aligned}$$

- The first order condition on $\tau_t$ writes[6]:

$$A_t h_t^{\alpha} + B_t h_t^{\beta}(1-2\tau_t) \geq 0$$

The optimal time allocation is therefore given by:

$$\begin{cases} \tau_t = 1 \quad \text{if} \quad h_t \leq \overline{h}_t \equiv \left(\frac{A_t}{B_t}\right)^{\frac{1}{\beta-\alpha}} \\ \tau_t = \frac{1}{2}\left[1 + \frac{A_t}{B_t} h_t^{\alpha-\beta}\right] \quad \text{if} \quad h_t > \overline{h}_t \equiv \left(\frac{A_t}{B_t}\right)^{\frac{1}{\beta-\alpha}} \end{cases} \tag{5}$$

[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 upon 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: $-2B_t h_t^{\beta} < 0$.

- Given the linearity of the problem with respect to $N_t$, we can extract the traditional zero-profit condition:

$$w_t = y_t \tag{6}$$

Given the optimal work organization (5), we get:

$$\begin{cases} w_t = A_t h_t^{\alpha} & \text{if} \quad h_t \leq \overline{h}_t \\ w_t = \frac{h_t^{-\beta}}{4B_t}\left[A_t h_t^{\alpha} + B_t h_t^{\beta}\right]^2 & \text{if} \quad h_t > \overline{h}_t \end{cases} \tag{7}$$

## 2.3 The workers′ behavior

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 (7).

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

$$h_{t+1} = E_t \cdot (e_t)^a \cdot (h_t)^{1-a} \tag{8}$$

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

[7] Lindbeck and Snower assume that reservation wages express the preferences of workers for specialization or multi-tasking. This induces a non convexity in the disutility of effort. Our model is different since we model preferences in an intertemporal framework where there is a trade-off between education and consumption.

Individual decisions hence are made according to the following program:

$$\begin{array}{l} \max\limits_{e_t} \ln(1-e_t)+\ln(w_{t+1}) \\ s.c. \quad h_{t+1}=E_t\cdot(e_t)^a\cdot(h_t)^{1-a} \end{array}$$

This program leads to the following condition:

$$\frac{1}{1-e_t}=\frac{\partial(\ln w_{t+1})}{\partial h_{t+1}}\cdot\frac{\partial h_{t+1}}{\partial e_t} \tag{9}$$

Given (7), we get:

$$e_t=\frac{a\phi\left(h_{t+1}\right)}{1+a\phi\left(h_{t+1}\right)} \tag{10}$$

where $\phi(.)$ is such that:

$$\begin{array}{l} \phi\left(h_{t+1}\right)=\alpha \quad if \quad h_{t+1}\leq\overline{h}_{t+1} \\ \phi\left(h_{t+1}\right)=\frac{(2\alpha-\beta)A_{t+1}(h_{t+1})^{\alpha}+\beta B_{t+1}(h_{t+1})^{\beta}}{A_{t+1}(h_{t+1})^{\alpha}+B_{t+1}(h_{t+1})^{\beta}} \quad if \quad h_{t+1}>\overline{h}_{t+1} \end{array} \tag{11}$$

Given equation (8), the dynamics of human capital is governed by the following equation:

$$h_{t+1}=E_t\cdot\left(\frac{a\phi\left(h_{t+1}\right)}{1+a\phi\left(h_{t+1}\right)}\right)^a\cdot(h_t)^{1-a} \tag{12}$$

When $h_{t+1}>\overline{h}_{t+1}$, the relationship between $h_t$ and $h_{t+1}$ is still functional, *i.e.* to each $h_t$ corresponds a unique $h_{t+1}$. Equation (12) 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:

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

We show in Appendix (6.2) 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 $\overline{h} = \left(\frac{A}{B}\right)^{\frac{1}{\beta-\alpha}}$. This stationary threshold value defines two possible steady state regimes: specialization below this value, and multi-tasking 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 and human capital in the specialization regime (respectively in the multi-tasking 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 (8), (10), and (11) we have:

$$e_s = \frac{\alpha a}{1+\alpha a}, \quad h_s = E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} \tag{13}$$

However, this stationary value of human capital under specialization only makes sense if $h_s \leq \overline{h}$. This conditions 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", $A$, $B$, $\alpha$ and $\beta$, 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 multi-tasking. 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 multi-tasking equilibrium exist in such a case? Notice that if such an equilibrium exists, then the multi-tasking equilibrium effort and human capital are respectively:

$$e_m = \frac{a\phi\left(h_m\right)}{1+a\phi\left(h_m\right)}, \qquad h_m = E^{\frac{1}{a}} \cdot \frac{a\phi\left(h_m\right)}{1+a\phi\left(h_m\right)} \tag{14}$$

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

We assume that parameters $\alpha$ and $\beta$ are such that

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

Assumption (A1) is a sufficient condition for the multi-tasking 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 multi-tasking equilibrium as long as the contribution of human capital to the returns to labor services is higher in the multi-tasking 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 multi-tasking. 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 multi-tasking equilibrium does.*

Proof:

The existence and uniqueness of the steady-state with specialization is immediate from equation (13) under condition (C1). The existence of the multi-tasking 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: $\lim_{h\to 0}\phi\left(h\right) = \left(2\alpha - \beta\right)$, $\lim_{h\to+\infty}\phi\left(h\right) = \beta$ and therefore, under assumption A1:

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

We show in Appendix (6.2) that function $G(.)$ is strictly increasing on $\mathbb{R}_+$. Hence, there exists a multi-tasking equilibrium if and only if $G(\overline{h}) < 0$. Notice that this condition is exactly the opposite of (C1) since $\phi\left(\overline{h}\right) = \alpha$. So under (C1), we cannot have a multi-tasking equilibrium.

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

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

[8] Therefore, (A1) is a uniqueness condition, not an existence condition, and it is only needed to ensure the uniqueness of the multi-tasking equilibrium.

In such a case, the specialization equilibrium cannot exist. In contrast, since $G(\overline{h}) < 0$ if (C1) is violated, a multi-tasking 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 multi-tasking regime is profitable enough (relatively to specialization), the unique possible stationary equilibrium is multi-tasking, and *vice versa*. Of course, it remains to study if the obtained stationary equilibria are stable.

# 4 Dynamics and transition from specialization to multi-tasking

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 multi-tasking takes place.

## 4.1 Global dynamics under condition (C1)

Consider a situation where the environment is stationary, *i.e.* 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 $\frac{h_{t+1}}{h_s} > 1$. The human capital sequence is bounded from below by the fixed point of the sequence $h_s$. Moreover, we have: $\frac{h_{t+1}}{h_t} = E\ (e_t)^a \cdot (h_t)^{-a}$, and provided that $h_t > h_s$, it follows that: $\frac{h_{t+1}}{h_t} < E\ (e_t)^a \cdot (h_s)^{-a}$.

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 $\frac{h_{t+1}}{h_t} < 1$.

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

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

Since condition (C1) is fulfilled, $0 < G(x) < 1$ for every $x \geq \overline{h}$. As $h_{t+1} > \overline{h}$, it follows that $\frac{h_{t+1}}{h_t} < 1$, 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: $\frac{h_{t+1}}{h_t} = [1 - G(h_{t+1})]^{\frac{a}{1-a}}$, 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 $h_s$.

[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-though 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.

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

Figure 2 depicts the dynamical system when condition (C1) holds with $h_s < \overline{h}$. The trivial case $h_s = \overline{h}$ is studied in appendix 6.3. A final comment on wage equilibrium pattern when condition (C1) holds can be made. In this case, the returns to specialization and wages are equal: $w_t = A_t h_t^{\alpha}$ and $s(\tau = 1, h_t) = A_t h_t^{\alpha}$ if $h_t \leq \overline{h_t}$. Wage is an increasing function of human capital $(\partial w_t / \partial h_t = \alpha A_t h_t^{\alpha - 1} > 0)$. 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 multi-tasking 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 multi-tasking human capital stationary value $h_m$.*

Proof.

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

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

We have two possible sub-cases: either $h_{t+1} > h_m$ or $h_{t+1} < h_m$. The second sub-case 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 since 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:

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

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 multi-tasking 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 sub-cases are still possible: either $h_{t+1} > h_m$ or $h_{t+1} < h_m$. Again we use the law of motion, $\frac{h_{t+1}}{h_t} = [1 - G(h_{t+1})]^{\frac{a}{1-a}}$, to discriminate. Indeed, notice that since $1 > G(x) > 0$ when $x > h_m$, we have $\frac{h_{t+1}}{h_t} < 1$ 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 $\frac{h_{t+1}}{h_t} > 1$. 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 $h_m$. $\square$

Figure 3 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 multi-tasking.

[10] By the same argument as in Footnote 7.

When condition (C1) does not hold, the returns to multi-tasking and wages are also increasing functions of human capital[11]. This human capital effect is however higher in the multi-tasking than in the specialization regime. Indeed, in the former case, returns to human capital are the sum of returns to specialization and returns to multi-tasking, while in the latter case returns to human capital are uniquely composed of returns to specialization. Hence, in addition to the human capital effect, there is also a multi-tasking effect on wages. This property has been documented by Chaudhury (2002) who shows that the trend towards multi-tasking implies steeper individual age-wage profiles.

## 4.3 Transition from specialization to multi-tasking

We have shown that under a stationary environment, the steady-state regime is either the specialization regime (condition (C1) fulfilled) or the multi-tasking regime (condition (C1) violated). To analyze the conditions for a transition from the specialization regime to the multi-tasking 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 multi-tasking, $A$ and $B$. Given the structure of our model, the transition dynamics from one organizational form to another is endogenous.

Following Autor, Levy and Murname (2001), we may interpret time spent on task 1 as time spent on routine cognitive and manual task, and time spent on task 2 as activities requiring non-repetitive tasks.[12] Hence, our analysis of the transition from specialization to multi-tasking disentangles two kinds of shocks generating work reorganization. On the one hand, we consider technological advances embedded into information technologies that increase the relative returns of non-routine problem solving and interactive tasks, 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.

**Proposition 6. Transition from specialization to multi-tasking**

*A* ***large enough*** *increase in the efficiency of the education technology E or in the*

[11]When $w_t = \frac{h_t^{-\beta}}{4B_t}\left[A_t h_t^{\alpha} + B_t h_t^{\beta}\right]^2$ 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 mentioned in Section 2, this is just a plausible interpretation of the tasks, the second task need not be non-repetitive.

*relative returns to multi-tasking $B/A$ generates a transition from a specialization stationary regime to a multi-tasking 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: $E^{\frac{1}{a}} \cdot \frac{\alpha a}{1+\alpha a} < \left(\frac{A}{B}\right)^{\frac{1}{\beta-\alpha}}$. We have to show that after an increase in $E$ or in $B/A$, the multi-tasking 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 Appendix 6.2) 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 multi-tasking from $\frac{B}{A}$ to $\left(\frac{B^*}{A^*}\right)$, 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 above, 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 multi-tasking 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. First of all, the existence of such a threshold sounds as a crystal-clear regularity in the data as reported in Section 2. Second, though our model does not explicitly consider this aspect since 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 non-negligible size will push at least *some* workers (whose human capital is near the threshold) from specialization to multitasking. Of course, even with this interpretation in mind, a massive move towards multi-tasking 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 in the transition proposition. While an increase in E or B/A leads to the same transition from specialization to multi-tasking, 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 sub-optimal 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, since 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 which 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 multi-tasking. 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 multi-tasking. Intuitively, ICT usage provide workers with more information, both within firm and about customers, permitting employees to be more involved in multi-tasking. Autor, Levy and Murname (2001) indeed document that the adoption of ICT alters job content. Computer-based technologies substitute for routine tasks and complement non-routine activities, suggesting that workers using such technologies are required to become more versatile. An increase in the relative returns to multi-tasking due to ICT is in our model a second major force stimulating the transition from specialization to multi-tasking.

The novelty of our approach is to highlight, like Autor, Levy and Murname (2001), the predominant role of the task content of employment. While 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 multi-tasking during the twentieth 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 multi-tasking to specialization. Indeed, while ICT that have contributed to increase the returns to versatility, complementing non-routine activities and relying on higher human capital levels, the emergence of assembly lines in the first part of the twentieth century increased the returns to task specialization leading to wide-scale 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 multi-tasking 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 multi-tasking. The optimal time allocation mode involves multi-tasking when the workers' level of human capital is sufficiently high. The model has a unique steady state (specialization or multi-tasking) which is globally stable.

Organizational change taking the form of a the transition from specialization to multi-tasking occurs following two kinds of shocks: an increase in the productivity of the human capital technology or an increase in the relative returns of multi-tasking. 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 multi-tasking organizations, thereby explaining the contemporaneous increase in computer usage, human capital accumulation and multi-tasking observed in many OECD countries during the 1990s.

# 6 Appendix

## 6.1 Empirical evidence in OECD countries

We report here some evidence that there exists a threshold level for human capital above which workers receive better wages in the early 1990s, which corresponds to the threshold above which the transition from specialization to multi-tasking occurs in our model. Figure 1 draws the percentile distribution of gross earnings in major OECD countries over the 1970-2000 period[13]. The data highlights that for all countries except Japan, in the late 1980s-early 1990s, the mean wage starts being lower than the 60th percentile distribution of gross earnings. In other words, in the early 1990s, gross earnings at the top percentile distribution increase compared to the mean wage, while at the bottom of the distribution, gross earnings remain more or less flat. Hence, there seems to exist a threshold level for human capital above which workers receive better wages in the early 1990s, which corresponds to the threshold above which the transition from specialization to multi-tasking occurs in our model.

[Insert Figure 1]

If we consider now the employment share of high and low skilled workers, distinguishing in particular those using new information and communication technologies. Tables I to III clearly show two main trends in OECD countries: the diffusion of new information and communication technologies and the increase in the employment share of skilled workers using computers.

Table I: Share of high and low skills within the ICT-related occupations in the European Union and the United States, 2001

| | United States | EU-14 |
|---|---|---|
| Total computer-related occupations | 67 | 55 |
| Other high-skill ICT-related occupations | 11 | 8 |
| ICT low-skill occupations | 22 | 37 |

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

[13] We have chosen to report these data since gross earnings are independent of the tax system that prevails in each country, thereby reflecting labour productivity independently of institutional rules that affect the price of labour.

Table II: Computer workers in the European Union, share in total occupations

| | 1995 | 2001 |
|---|---|---|
| Greece | 0.22 | 0.36 |
| Italy | 0.71 | 1.09 |
| Spain | 0.53 | 1.13 |
| Germany | 0.98 | 1.68 |
| Belgium | 1.08 | 1.74 |
| EU | 1.00 | 1.76 |
| France | 1.31 | 1.84 |
| Luxembourg | 0.94 | 2.04 |
| Finland (1997-2001) | 1.29 | 2.15 |
| Denmark | 1.28 | 2.15 |
| United Kingdom | 1.02 | 2.33 |
| Netherlands | 1.99 | 3.18 |
| Sweden (1997-2001) | 2.23 | 3.42 |

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

Table III: High-skilled (HS) ICT workers in the European Union and the United States, Average annual employment growth (1995-01) (* = 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 US Current Population Survey, May 2003

Regarding organizational change, notable changes have been observed at an aggregate level in Europe during the 1990, in partiuclar in terms of paces and methods of work, as shown in Table IV.

Table IV: Working conditions in Europe, 1990-2001

Population-weighted averages for Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom

| | 1990-91 | 1995-96 | 2000-01 |
|---|---|---|---|
| Employees reporting working at very high speed | 46 | 54 | 56 |
| Employees reporting working to tight deadlines | 50 | 56 | 60 |
| Worker autonomy - order of tasks | | 64 | 64 |
| Worker autonomy - pace of work | 64 | 71 | 70 |
| Worker autonomy - methods of work | 60 | 71 | 70 |

Source: OECD Employment Outlook (2003), based on the European Survey on Working Conditions, waves 1 to 3 (1990/91, 1995/96 and 2000

At the firm level now, in addition to Autor, Levy and Murname (2001), Osterman (1994 and 2000) also reports that the proportion of American firms for which more than 50% of its employees are involved in job rotation rose from 26.6% in 1992 to 55.5% in 1997. 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 multi-tasking. She reports that between 1993 and 1997, 57 % of German firms have adopted new organizational forms based on job enrichment, job enlargement and over time variability in task assignments. Holistic firms are also more productive, experience positive marginal returns from reorganization towards multi-tasking and rely on human capital accumulation strategies.

## 6.2 Steady-state with multi-tasking

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 $G^{'}(h) > 0$.

### 6.3 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 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 $\frac{ht+1}{\overline{h}} < E(e_s)^a \, (\overline{h})^{-a} = 1$.

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.[14]

[14]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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