**Technological Progress, Organizational Change and the ICT Revolution**

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## 1 Introduction

The recent Information and Communication Technologies (ICT) revolution has favoured the development of numerous innovative workplace practices in most OECD countries. Work organization inside firms evolved from specialization to multi-tasking, and flexible forms of workplace organization have largely diffused in most OECD economies.

Parallel to this trend, we can also observe an increasing employment share of skilled workers in major OECD countries during the 1990s along with the dissemination of ICT.

A definitely much less stressed aspect of organizational change, which is central in this paper, is the impact on human resources departments. In general, one would expect that the role of such department will be significantly altered in a situation where flexible forms of work organization are so massively adopted. Indeed, a quick look at the data confirms this intuition. In particular, the management ratio (managers as percentage of the workforce) increased in many OECD countries during the twentieth century, but started decreasing in the early 2000s. In France for instance, the percentage of workers employed in managerial and professional specialty occupations rose from 7.1% in 1982 to 11.1% in 2000 and decreased to 4.8% in 2004. Similarly, this ratio ranges from 10.5% in 1970 to 14.6% in 2000 and 13.9% in 2004 in the United States.

In the light of all these data, the evolution of skills, job content and work organization observed in many OECD countries over the past decades can be summarized in the following three main characteristics: 1) an increase in the proportion of workers employed in managerial occupations, together with a recent decrease since the ICT revolution; 2) the diffusion of innovative workplace practices based on multi-tasking and computer use; 3) an increase in skills requirements.

This paper studies the determination of the optimal number of tasks performed per worker in an economy where individuals devote time to production and human capital accumulation, and where multi-tasking both increases production and gives rise to coordination costs. In particular, we shall distinguish between horizontal coordination costs, which involve the costs of coordinating the tasks accomplished by each production worker, and vertical coordination costs, which reflect coordinating different workers and mainly concern workers employed in human resources services. We then examine how the economy reacts to permanent exogenous technological accelerations, and we find that the model is able to reproduce the three stylized facts outlined above.

# 2 The model

The model proposed in this paper considers an economy in discrete time (from 0 to $\infty$) with an active population of size $L$. The firm occupational structure is composed of two types of jobs: human resources jobs (in fraction $\rho$ of the workforce employed) and production jobs (in fraction $1-\rho$ of the workforce employed). Workers devote time to production (either in the human resources service or in the production service) and to human capital accumulation.

## 2.1 Technology and coordination costs

The economy is characterized by a representative firm that produces a homogeneous (numeraire) good according to the following technology:

$$y_t = A_t \cdot [(1-\rho_t) \cdot h_t \cdot T_t \cdot L_t]^{1-\alpha} n_t^{\alpha} \qquad 0 < \alpha < 1$$

where $A_t$ is a productivity parameter, $L_t$ is the volume of hours worked with human capital $h_t$, $T_t$ is worker's productive time, $n_t$ is the number of tasks performed per worker and $\rho_t$ is the fraction of the workforce in the personnel (human resources) service.

Producing the good implies two types of costs: production costs and coordination costs. Since production requires physical resources and knowledge about how to combine them, production costs correspond to traditional costs of transforming inputs into output (physical - productive - resources expenses) whereas coordination costs correspond to the costs of combining and managing interactions and dependencies between resources (tasks and/or workers). In our model, labour is the sole input, therefore production costs equal the total wage bill and coordination costs depend on the number of tasks realized per worker ($n$) and on the fraction of workers in the human resources service ($\rho$).

The firm's profits (given that output is the numeraire) then write:

$$\pi_t = A_t \cdot [(1-\rho_t) \cdot h_t \cdot T_t \cdot L_t]^{1-\alpha} n_t^{\alpha} - C(n,\rho) - w_t \cdot h_t \cdot T_t \cdot L_t$$

where $w_t$ is the wage rate per efficiency unit of labour and $C(n,\rho)$ represents coordination costs measured as pure output loss.

The coordination costs function depends on horizontal and vertical coordination costs as follows:

$$C(n,\rho) = \frac{h(n,\rho) \cdot v(\rho)}{d}$$

where $h(n,\rho)$ denotes horizontal coordination costs and $v(\rho)$ denotes vertical coordination costs, while $d$ reflects the extent of coordination costs (a higher $d$ reduces the importance or magnitude of coordination costs).

We then assume:

$$h(n,\rho) = n^{\xi} \cdot (1-\rho)^{\theta}$$

where $\xi, \theta > 0$, i.e. horizontal coordination costs increase with the number of tasks per capita $n$ and with the size of the production service $(1-\rho)$, given elasticities parameters $\xi$ and $\theta$, and also:

$$v(\rho) = \rho^{\eta}$$

where $\eta$ can be positive or negative, i.e. vertical coordination costs depend on the share of workers in the human resources service (when $\eta > 0$ they are an increasing function of this share, and this corresponds to a more bureaucratic situation, while when $\eta < 0$ they are a decreasing function of this share, and this corresponds to a less bureaucratic situation).

At this point in the decentralized economy the firm's optimization program is given by:

$$\max_{n_t, T_t^d, \rho_t} \pi_t = A_t \left[ (1-\rho_t) h_t T_t^d L_t \right]^{1-\alpha} n_t^{\alpha} - \frac{n_t^{\xi} (1-\rho_t)^{\theta} \rho_t^{\eta}}{d_t} - w_t h_t T_t^d L_t$$

where $d_t > 0$ and where $T_t^d$ denotes now the working time demanded by the firm.

## 2.2 Household and human capital accumulation

The household in the economy has a utility function given by:

$$u(c_t) = \ln c_t$$

and it is endowed with one unit of time supplied each period, that is spent on working (the fraction $T_t^s$) or on human capital accumulation (the fraction $1 - T_t^s$), and the accumulation of human capital is described by the following equation:

$$h_{t+1} = E_t \cdot h_t^{\delta} \cdot (1 - T_t^s)^{1-\delta} \qquad 0 < \delta < 1$$

where $E_t$ is an efficiency parameter.

The household's intertemporal optimization program in the decentralized economy is then given by:

$$\max_{\{c_t, T_t^s, a_{t+1}, h_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \ln c_t$$

$$s.t. \quad \begin{aligned} a_{t+1} &= (1 + r_t) a_t + w_t h_t T_t^s - c_t \\ h_{t+1} &= E_t h_t^{\delta} (1 - T_t^s)^{1-\delta} \end{aligned}$$

where $\beta$ is the discount factor (with $0 < \beta < 1$) and $a_t$ represents the assets held in $t$.

## 2.3 Market equilibrium conditions

Together with the solution of the problem of the firm and of the household, the stationary equilibrium of the decentralized economy is characterized also by the market equilibrium condition:

$$y_t = c_t + \frac{n_t^{\xi} (1-\rho_t)^{\theta} \rho_t^{\eta}}{d_t}$$

and by the labour market equilibrium condition:

$$T_t^d = T_t^s = T_t$$

It is now possible to derive the optimality and equilibrium conditions of the model, the steady-state values of the different variables and the associated comparative statics for the

decentralized economy. Finally, it is possible to consider some simulation exercises in order to examine how the economy reacts to permanent exogenous technological accelerations. The important aspect is that the model is able to reproduce the three stylized facts that emerge from the data. Indeed, it delivers a permanent trend towards multi-tasking and human capital accumulation following permanent technological accelerations, while the size of the human resources department (that is the fraction of workers devoted to reduce coordination costs) is also significantly raised and then reduced. In conclusion, the model behaves extremely well in replicating the organizational features of the ICT revolution.

# 3 Conclusion

This paper develops a model to analyze the intensity of multi-tasking under various exogenous technological accelerations. The model has two original characteristics: it includes endogenous coordination costs, and it introduces the size of the human resources department as a key variable for the firms to control their coordination costs. In our modelling, and building on recent economic and management literature, we distinguish between vertical and horizontal coordination costs, which proves crucial in the equilibrium properties of the model. The model also includes endogenous human capital accumulation, and therefore brings together enough ingredients to study some highly relevant stylized facts identified in OECD data. Although technological progress is exogenous in our set-up, and no technology adoption decision is to be taken, we believe that the model offers a useful shortcut to analyze the consequences of technological accelerations on workplace organization. The fact that all performed numerical simulations corroborate the ability of the model to replicate the observed stylized facts is a good indication of that.

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