LABOUR DEMAND AND WORKING TIME:

An analysis of the effectiveness of working time.

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Abstract: *This article is an analysis of the relation between worked hours and labour demand. We propose three different specifications of the optimization program of a firm behaviour by introducing the concept of effectiveness of labour according to the working time. These models are estimated on French data covering the period [1975-1990]. The first one uses a static optimization. State variables are hours and workers. The second presents a dynamic demand model with partial adjustment mechanisms. The last specification uses the Euler equation deduced from the intertemporal maximization of the firm profit with symmetric and asymmetric adjustment cost functions. We show that imperfect substitutability between numbers employed and hours per workers constitutes a constraint on the effectiveness of working time restriction as a means of reducing unemployment*

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1. Introduction

Since the beginning of the century working time has decreased in western economies by over one percent a year. The last two decades have seen our economies faced with a problem of massive unemployment. One of the solutions proposed to solve this problem is to accelerate the reduction of working time. The substitutability of hours and employees is the centre of numerous arguments between economists. The hypothesis of perfect substitutability seems unrealistic. But it is also unlikely that a decrease in the number of working hours will have no effect on the number of workers.

This imperfect substitutability between men and the hours encourages us to introduce the working hours into models of labour demand. It is not very likely that a reduction of 10% of the working time increases the number of worker by 10% (see *Hamermesh* [1993] and *Cahuc and Zylberberg* [1996]). Besides the quantitative variables usually considered in the production function, we must take into account the qualitative nature of some of them. Human behaviour is influenced by psychological and physiological considerations, it appears necessary to consider the quality of the work done during a given period. At the beginning of the working period productivity increases while with tiredness or weariness of the worker, productivity falls. Consequently, the concept of effectiveness of worker in relation to hours worked can be one of the explanations of imperfect substitutability. For this reason, we introduce a specific nonlinear function into the production function to measure the effectiveness of workers.

To explore these complex relations between labour demand and working time, we propose to estimate three different models introducing a specific function of effectiveness for the workers. If we take into account this function, we do not suppose an perfect substitutability between men and hours.

The first model assumes static optimization of profits by the firms. We propose three different hypotheses. The first one suppose a complete wage compensation, *i.e.* that wage is always the same whatever the working time. The second model takes into account the reduction of wages when the hours worked decrease. The last specification introduces a degree of wage rigidity.

The second model is dynamic. By introducing partial adjustment processes for labour and hours we estimate the dynamic factor demands (see *Nickell* [1986]). Adjustment processes imply the presence of adjustment costs which are not specified.

In the last model, we choose a representative firm which maximizes its profits in an infinite horizon with adjustment costs. Euler equations coming from resolution of such a program show us the complex relations existing between workers, their working time and the production. We test four adjustment costs specifications. There are three usual specifications (*Eisner and Strotz* [1963], *Summers* [1981] and *Pfann and Palm* [1993]). We also present a new specification. It introduces the relative effects into the asymmetric part.

In order to illustrate these relations between hours and men, and to estimate these three particular specifications we use the generalized method of moments (GMM) on French macroeconomic data covering the period 1975-1990. Since the crisis of 1973, one of the main discussions in French policy to reduce unemployment has been to decrease of working time in order to share employment. The French government decided on legal of working time. In 1981, the legal time of work has decreased from 40 hours to 39 hours a week. In 1997, the government constraints firms to carry out consultations about reduction from 39 hours to 35 hours before 2001. With dynamic labor demand, we want to show what is the impact of the reduction of hours of work on the employment level in the French case.

The aim of this paper is to study the links between men and hours. In section 2, we present a new production function to measure effective labour and its properties. In section 3, we specify the static and dynamic models and adjustment cost functions. In the last section, we estimate all these models. The dynamic model with new adjustment cost function and effectiveness function shows that imperfect substitutability between employment and hours per workers constitutes a constraint on the effectiveness of working time restriction as a means of reducing unemployment.

2. Theoretical relations between number of workers and working time

2.1 Labour and Hours worked in Production function

The concept of effectiveness of factors of production has interested economists for a long time. Indeed, *Robinson* [1938] introduced the concept of effectiveness of work. Labour is measured in effective units. This measure of the effectiveness considers that the labour force changes with time:

$$\begin{aligned} Y &\approxeq F(K, L, t) \quad (1) \\ &\approxeq F(K, \alpha(t) L) \approxeq F\left(K, \overline{L}\right). \end{aligned}$$

The two factors of production used are respectively labour (L) and the stock of capital (K). The function $\alpha(t)$ represents the technical progress, which increases the effective quantity of labour.

Nevertheless, the productivity of worker may also evolve during a given period of time without any change of the technological constraint. So, the effectiveness can be related to other criteria than technological ones. In the paper, we will try to focus model this second notion of the productive effectiveness.

Taking into account the current controversies about the degree of input utilization, the introduction of the degree of capital utilization and the number of the hours worked supplied by the employees become significant variables in the analysis of the production. Production function proposed by *Brechling* [1965] defines one elasticity for each factor multiplied by their degree of utilization:

$$Y = F(K, duc, L, h) = cst * (duc * K)^{\alpha} * (h * L)^{\beta}. \quad (2)$$

The production function depends of the effective capital $\left(\widetilde{K} = K * duc\right)$ and of the effective work $\left(\widetilde{L} = L * h\right)$ where h measures the number of working hours and duc, the degree of capital utilization. This function assumes perfect substitution between men and hours. Indeed, assuming constant production and fixed capital, a 10% reduction of working time is implied by a 10% increase in the number of employees.

By building on the preceding function (2), it is possible to consider different elasticities of the production with respect to all inputs:

$$Y \approxeq F(K, duc, L, h) \approxeq cst * K^{\alpha_k} * duc^{\alpha_d} * L^{\beta_l} * h^{\beta_h}. \tag{3}$$

If β_l is different from β_h, perfect substitution between men and hours does not exist. Consequently, two men working one hour will not have the same production as one man working two hours. The trade-off between men and working hours appears to be a consequence of production process.

To look further into this concept of trade-off, it is necessary to introduce the concept of effectiveness of working time. Effective labour thus depends on the effort supplied by the employees. On the basis of the canonical model of *Solow*, *Wadhani and Wall* [1991] and *Levine* [1992] showed that there is a positive connection between a variation of the rate of unemployment and/or alternative wages and firm's productivity. These two authors introduce an efficiency function into the production function.

In our study, we focus on the relation between labour and the number of working hours. It is easy to conceive that the effectiveness provided by the employees depends on the number of work hours. If we define the effectiveness of labour by the function $e(h)$, the function of production is thus written:

$$Y \approxeq F(K, duc, L, h) \approxeq cst * (ducK)^{\alpha} (e(h) L)^{\beta}. \tag{4}$$

Only two elasticities remain for the two effective factors. The function of effectiveness and the number of employees determine the quantity of labour $(e(h) L)$.

2.2 Function of effectiveness

The concept of effectiveness according to the working time can be compared to the efficiency functions used within the framework of the theory of efficiency wages[1]. But worker efficiency is not a function of the relative wages but of the number of hours carried out during one period. The concept of effectiveness is not linear. Indeed, it appears realistic that the productivity of an agent varies according to the working time.

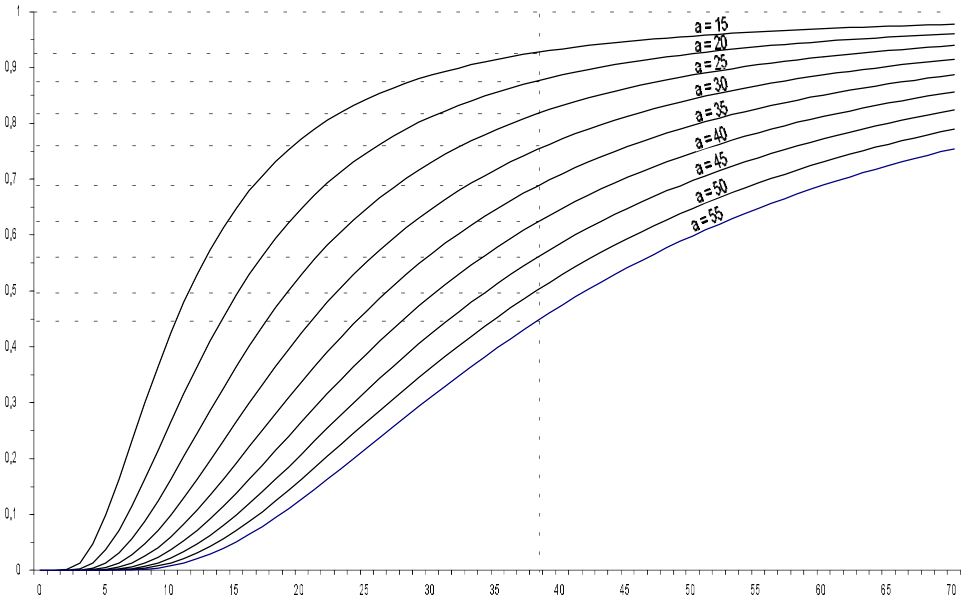
Thus, to describe this effectiveness, we use the following function[2]:

$$e(h) = 2\left(\cosh\left(\frac{a}{h}\right)\right)^{-1} = \frac{2}{e^{\left(\frac{a}{h}\right)} + e^{\left(-\frac{a}{h}\right)}}, \qquad with \qquad h > 0. \tag{5}$$

[1] *Layard, Nickell et Jackman* [1991] and *Crettez, Granier et Michel* [1997] use such function without defining a mathematical function.

[2] See *Bresson, Debrand et Patrat* [1999].

figure 1: Function of effectiveness with respect to hours worked



The values taken by the function of effectiveness lie between 0 and 1 (see *Johnson and Kotz* [1970]). The larger the parameter a is, the smaller the effectiveness supplied by the employees is. With constant quantity of employment, the larger a is, the less important the number of workers must be (see figure (1)).

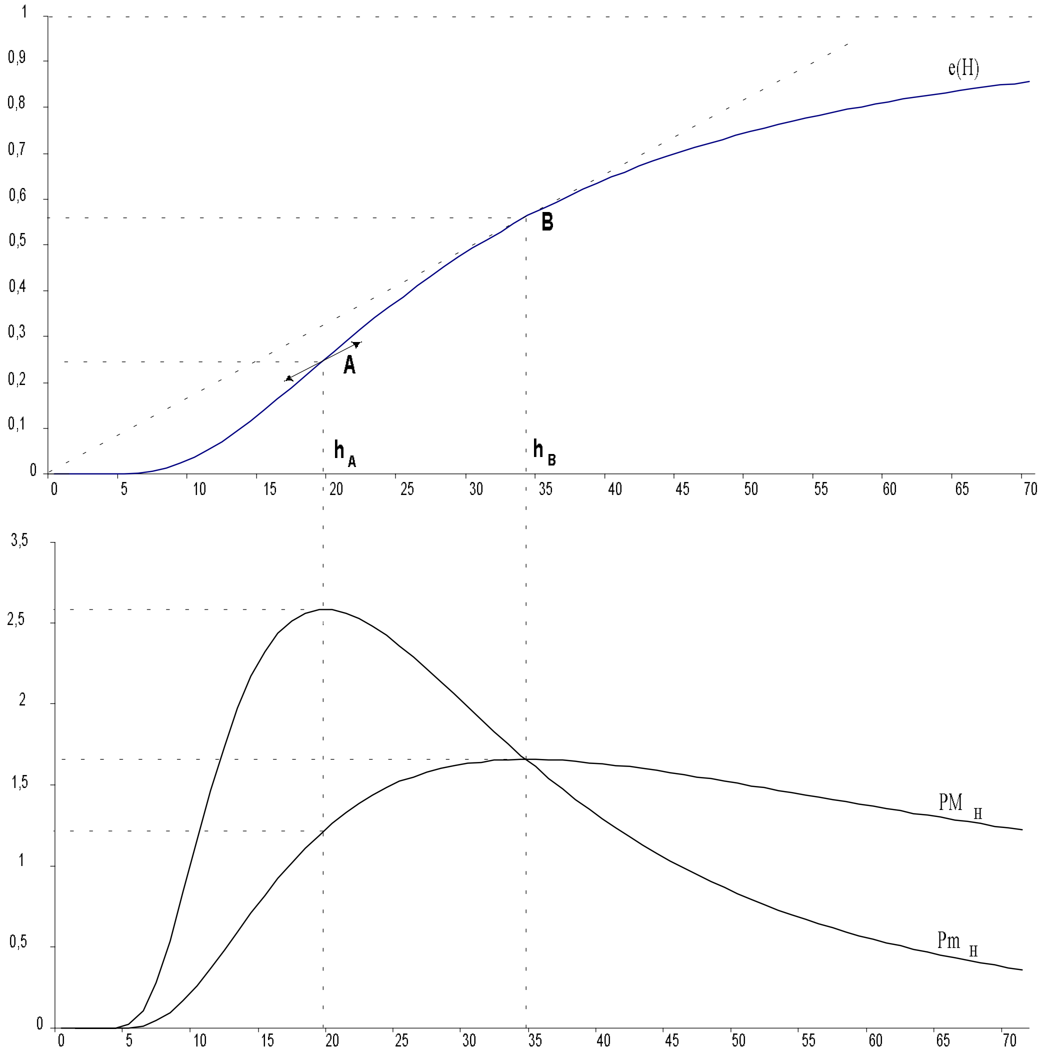
The elasticity of effectiveness with respect to hours worked is thus written:

$$\eta_h^e = \frac{e'(h) * h}{e(h)} = \frac{a}{h} \tanh\left(\frac{a}{h}\right) = \frac{a}{h} \frac{\left(e^{\left(\frac{a}{h}\right)} - e^{\left(-\frac{a}{h}\right)}\right)}{\left(e^{\left(\frac{a}{h}\right)} + e^{\left(-\frac{a}{h}\right)}\right)} > 0 \qquad (6)$$

The function of effectiveness and its elasticity change with the coefficient a. If a rises, for a given number of hours, then the effectiveness of the worker $(e(h))$ decreases and its elasticity (η_h^e) increases. And conversely, if a decreases.

In the short run, we suppose that only working time can be adjusted. All the other inputs are considered fixed. Consequently, the function of effectiveness of working time has a direct impact on the marginal and average productivity (see figure(2)). The form of the function of effectiveness induces the form of the production function.

It is possible to define three areas (see *Filer, Hamermesh and Rees* [1996]). The first one corresponds to the part of the function of effectiveness between O and A. The marginal productivity of one hour of work is increasing and is higher than the average productivity of one working hour. Between (AB), the marginal productivity is decreasing but it remains higher than the average productivity. We deduce the following figure 2: Impact of function of effectiveness on production



inequality from it (see figure(2)):

$$\frac{\partial\left(\eta_{h}^{e}\right)}{\partial h}<0 \qquad for \qquad h>h_{A}. \tag{7}$$

To the right of point B [3], the marginal productivity remains decreasing but it is lower than the average productivity. Using one supplementary working time decreases the average productivity of the employees.

3. Determination of the static and dynamic factors demands

In order to understand the complex phenomena intervening in the determinations of the factor demands, the static analysis will be differentiated from the dynamic analysis. Statics correspond to a stationary state of the economy. Henceforth we will consider that the factors are flexible, or "quasi-fixed" (see *Oi* [1962]). On the other hand, dynamics taking into account adjustment processes and the adjustment costs, seek to analyze the phases of transition of an economy facing exogenous shocks. However, labour cost and user cost of capital are not modified by adjustment costs in the long run. There is no effect of hysteresis due to the presence of these adjustment costs. These costs modify the speed of adjustment (see *Pfann and Palm* [1993] and *Bresson and Debrand* [1998]) but do not disturb the equilibrium level in the long run.

3.1 Static and dynamic analysis of the factors demand

Labour demand in static analysis results from the resolution of a program of optimization. Indeed, the behaviour of the representative firm is described by the maximization of its profits. Our aggregate production function requires the use of only one category of workers and capital.

In the most general framework (see *Symons and Layard* [1984] and *Cahuc and Zylberberg* [1996]), the optimization problem of the firm is:

$$\left\{\begin{array}{l} Max \quad p_{(Q)}Q-w(h)\widetilde{L}+cuk\left(h\right)\widetilde{K} \\ \qquad with \qquad Q=F\left(\widetilde{K},\widetilde{L}\right) \quad , \quad \widetilde{L}=Le\left(h\right) \quad and \quad \widetilde{K}=Kd\left(h\right). \end{array}\right.$$

The levels of wages and user cost of capital depend on the duration of the working time. This problem supposes the existence of a function of compensation of employees according to hours worked, of a function of the user cost of capital according to the duration of its use and two functions determining effective labour $e\left(h\right)$ and effective capital $d\left(h\right)$. Moreover, prices of the production $\left(p_{(Q)}\right)$ depend on the level of production and thus of the quantities of effective work and effective capital. The solution of such a program is relatively complex. It is necessary to define four functional forms that depend on h.

3 Point (h_B) is determined by:

$$\frac{\partial\left(e\left(h_{B}\right)\right)}{\partial\left(h_{B}\right)}-\frac{e\left(h_{B}\right)}{h_{B}}=0$$

We will introduce simplifying assumptions about costs and effectiveness of capital function to focus on the relationship between labour demand and working hours. Effective capital is thus the product of the capital with the degree of capacity utilization. This function uses four inputs: stock of capital, degree of capital utilization, number of workers and duration of working time.

Static labour demand and working time

We suppose initially that the compensation of employees does not depend explicitly on working time, but on fixed wages per period, *i.e.* the duration of the working time does not intervene directly in the cost function. The relation between working hours and the number of workers is given by the production function. The optimization program becomes:

$$\begin{cases} Max \quad Q - wL + cukK \\ \quad with \qquad Q = F(K, d, L, h) = cstK^{\alpha_K} d^{\alpha_s} L^{\beta_l} e(h)^{\beta_h} e^{\gamma t}. \end{cases} \tag{8}$$

We determine the static labour demand with function of effectiveness $\left(L_{ef}^{*}\right)$:

$$L_{ef}^{*} = \left(\frac{\beta_l}{\alpha_k}\right)^{\frac{\alpha_k}{\alpha_k+\beta_l}} \left(\frac{cuk}{w}\right)^{\frac{\alpha_k}{\alpha_k+\beta_l}} Q^{\frac{1}{\alpha_k+\beta_l}} cst^{-\frac{1}{\alpha_k+\beta_l}} d^{-\frac{\alpha_d}{\alpha_k+\beta_l}} e(h)^{-\frac{\beta_h}{\alpha_k+\beta_l}} e^{-\frac{\gamma}{\alpha_k+\beta_l} t}. \tag{9}$$

Thus, the relationship between labour demand and hours worked depends on the form of the function of effectiveness. We will study two cases: the traditional way is to consider a linear function of effectiveness $(e(h) = h)$. The contribution of the workers to the production remains constant during the entire work period. A more realistic representation supposes the use of the function of effectiveness previously studied $\left(e(h) = 2\cosh^{-1}(\frac{a}{h})\right)$. At the beginning of the working period, there are increasing returns afterwards, with tiredness or weariness of the worker, the returns become decreasing.

Firstly, we suppose that the function of effectiveness is linear. Labour demand[4] (L^*) is:

$$L^{*} = \left(\frac{cuk}{w}\right)^{\frac{\alpha_k}{\alpha_k+\beta_l}} \left(\frac{\beta_l}{\alpha_k}\right)^{\frac{\alpha_k}{\alpha_k+\beta_l}} Q^{\frac{1}{\alpha_k+\beta_l}} cst^{-\frac{1}{\alpha_k+\beta_l}} d^{-\frac{\alpha_d}{\alpha_k+\beta_l}} h^{-\frac{\beta_h}{\alpha_k+\beta_l}} e^{-\frac{\gamma}{\alpha_k+\beta_l} t}. \tag{10}$$

The linearity assumption greatly simplifies the expression for working time elasticities. Consequently they are :

- Elasticity of labour with respect to hours worked: $\varepsilon_{L/h} = -\frac{\beta_h}{\alpha_k+\beta_l}$
- Elasticity of labour with respect to production: $\varepsilon_{L/Q} = \frac{1}{\alpha_k+\beta_l}$
- Elasticity of production with respect to hours worked: $\varepsilon_{Q/h} = \beta_h$.

Secondly, we consider the impact of a reduction of the working time on labour demand with function of effectiveness. The consideration of this specific function changes the values of elasticities.

[4] without new function of effectiveness.

The introduction of a non-linear form to describe the effectiveness prevents us from obtaining an explicit and linear formulation of dynamic labour demand. But it is possible to determine simple expressions of elasticities. Indeed, they are function of a variation of the effectiveness provided by the employees. Thus to study a variation of employment when working time is modified, it is necessary to analyze the variation of the effectiveness with respect to the hours worked. This variation induces a variation of a number of employee $\left(\Delta h = \xi \quad \rightarrow \quad \Delta e\left(\xi\right) = \xi' \quad \rightarrow \quad \Delta L\left(\xi'\right) = \xi''\right)$. The increasing monotonic function $e\left(h\right)$ is lying between $]0;1[$, the value (ξ) of the variation of h is always higher than the value $\left(\xi'\right)$ of the variation $e\left(h\right)$.

The elasticities of labour and production thus have more complex forms:

- Elasticity of labour with respect to hours worked[5]: $\varepsilon_{L_{ef}/h} = \eta_h^e * \varepsilon_{L/h}$
- Elasticity of labour with respect to production: $\varepsilon_{Lef/Q} = \varepsilon_{L/Q}$
- Elasticity of production with respect to hours worked: $\varepsilon_{Qef/h} = \eta_h^e * \varepsilon_{Q/h}$.

The elasticity of labour with respect to production is equal to the elasticity of production with respect to effective work multiplied by the elasticity of the effectiveness function.

The preceding expressions suppose complete wage compensation, *i.e.* the wages of an employee are always the same whatever the number of hours worked. Using this assumption[6], we can establish a simple expression for the elasticity of labour with respect to working hours:

$$\begin{aligned}\varepsilon_{L_{ef}/h}^{comp} &= -\frac{\alpha_k}{\alpha_k+\beta_l} - \frac{\beta_h}{\alpha_k+\beta_l} * \varepsilon_{L/h} = -\frac{\alpha_k}{\alpha_k+\beta_l} + \eta_h^e * \varepsilon_{L/h} \\ &= \varepsilon_{L_{ef}/h} - \frac{\alpha_k}{\alpha_k+\beta_l}. \end{aligned} \tag{11}$$

If the reduction of working time is accompanied by a reduction of wages, then the elasticity of labour demand decreases $\left(\frac{\alpha_k}{\alpha_k+\beta_l} > 0\right)$. Consequently a reduction in working time would be accompanied by a greater growth in employment. These two situations represent two extreme cases. It is extremely likely that reality is between theses extremes. It is easy to introduce into the basic model (8), downwardly rigid on the reduction wages when working time decreases. It is sufficient to incorporate the parameter of rs in the labour cost of workers. The wage cost becomes $\left(w^h h^{rs} L \quad with \quad 0 \leq rs \leq 1\right)$[7].

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[5] Where $\eta_h^e \left(= \frac{a}{h}\frac{\left(e^{\frac{a}{h}} - e^{-\frac{a}{h}}\right)}{\left(e^{\frac{a}{h}} + e^{-\frac{a}{h}}\right)}\right)$ given by equation (6) and $\varepsilon_{L/h} = -\frac{\beta_h}{\alpha_k+\beta_l}$.

[6] Labour demand becomes:

$$L_{ef}^* = \left(\frac{\beta_l}{\alpha_k}\right)^{\frac{\alpha_k}{\alpha_k+\beta_l}} \left(\frac{cuk}{w^h h}\right)^{\frac{\alpha_k}{\alpha_k+\beta_l}} Q^{\frac{1}{\alpha_k+\beta_l}} cst^{-\frac{1}{\alpha_k+\beta_l}} d^{-\frac{\alpha_d}{\alpha_k+\beta_l}} e\left(h\right)^{-\frac{\beta_h}{\alpha_k+\beta_l}} e^{-\frac{\gamma}{\alpha_k+\beta_l}t},$$

where w^h is the hourly wage.

[7] We suppose that the elasticity of employment with respect to working time is between the elasticity with and without wage compensation. Consequently, rs cannot take all the values between 0 and 1. If $rs = 0$, then the wage of the employee is equal to the hourly wage. It is reasonable to suppose that for a reduction from 39 to 35 hours rs belongs to the interval $\left[0.897\left(=\frac{35}{39}\right), 1\right]$. We will see later, this restriction is not necessary.

The elasticity of labour demand with respect to hours worked becomes:

$$\varepsilon^{rs}_{L_{ef}/h} = \varepsilon_{L_{ef}/h} - rs\left(\frac{\alpha_k}{\alpha_k + \beta_l}\right).$$

Thus if rs is equal to zero, we have complete wage compensation, i.e. the wages of the employees do not change with duration of the working time. If rs is equal to unity, then we are in the second situation. Reduction of the wages also changes the elasticity of production with respect to the working hours :

$$\varepsilon^{comp}_{Q_{ef}/h} = \varepsilon_{Q_{ef}/h} + \alpha_k \qquad and \qquad \varepsilon^{rs}_{Q_{ef}/h} = \varepsilon_{Q_{ef}/h} + rs\left(\alpha_k\right).$$

These different elasticities can be ordered. The elasticity of labour with respect to hours worked without effectiveness function is smaller than the same elasticity with effectiveness function. Elasticities without wage compensation are between these two previous elasticities. Thus, the order of elasticities is $\varepsilon_{L/h} < \varepsilon^{comp}_{L_{ef}/h} < \varepsilon^{rs}_{L_{ef}/h} < \varepsilon_{L_{ef}/h}$.

These expressions describe the determination of labor demand in the framework of a static model. Now, we analyze dynamic of labor demand by introducing a partial adjustment mechanism.

Dynamic factor demands with a partial adjustment mechanism

It seems obvious that the use and duration of the working time do not adjust instantly to their targets in the long run. We thus suppose the existence a partial adjustment mechanism (see *Nickell* [1984]):

$$\log L_t - \log L_{t-1} = \pi_L\left(\log L^*_t - \log L_{t-1}\right) \qquad with \qquad 0 < \pi_L < 1. \tag{12}$$

$$\log h_t - \log h_{t-1} = \pi_h\left(\log h^*_t - \log h_{t-1}\right) \qquad with \qquad 0 < \pi_h < 1. \tag{13}$$

By combining labour demand equation (10) and the partial adjustment mechanism (12), we can determine a dynamic specification of labour demand[8]:

$$\begin{aligned}\log L_t = {} & (1-\pi_L)\log L_{t-1} - \frac{\pi_L\alpha_k}{\alpha_k+\beta_l}\log\left(\frac{w}{cuk}\right)_t + \frac{\pi_L}{\alpha_k+\beta_l}\log\left(Q_t\right) \\ & - \frac{\pi_L\beta_h}{\alpha_k+\beta_l}\log\left(h_t\right) - \frac{\pi_L\alpha_d}{\alpha_k+\beta_l}\log\left(d_t\right) + \frac{\alpha_k}{\alpha_k+\beta_l}\log\left(\frac{\beta_l}{\alpha_k}\right) - \frac{\gamma}{\alpha_k+\beta_l}t.\end{aligned} \tag{14}$$

It is the same for the hours worked:

$$\begin{aligned}\log h_t = {} & (1-\pi_h)\log h_{t-1} - \frac{\pi_h\alpha_k}{\beta_h}\log\left(\frac{w}{cuk}\right)_t + \frac{\pi_h}{\beta_h}\log\left(Q_t\right) \\ & - \frac{\pi_h\left(\alpha_k+\beta_l\right)}{\beta_h}\log\left(L_t\right) - \frac{\pi_h\alpha_d}{\beta_h}\log\left(d_t\right) + \frac{\alpha_k}{\beta_h}\log\left(\frac{\beta_l}{\alpha_k}\right) - \frac{\gamma}{\beta_h}t.\end{aligned} \tag{15}$$

[8] Introduction of the function of effectiveness complicates the equations for factor demands. Simple and interpretable expression are no larger avialable.

From these expressions for the dynamics of the labour market, we can study the relationships between labour demand, working time and other inputs.

- Labour elasticities in the short run (sr) and long run (lr) with respect to the hours worked are[9]:

$$\overline{\varepsilon}_{L/h}^{sr} = -\frac{\pi_L \beta_h}{\alpha_k + \beta_l} \qquad and \qquad \overline{\varepsilon}_{L/h}^{lr} = -\frac{\beta_h}{\alpha_k + \beta_l}.$$

The elasticity in the long run corresponds to the elasticity of employment with respect to the hours worked determined using the static models. This confirms that adjustment costs do not affect long run behaviours.

- The Mean Adjustment Lags of labour[10] and hours worked are determined by the following relations:

$$\overline{MAL}_L = \frac{1-\pi_L}{\pi_L} \qquad and \qquad \overline{MAL}_h = \frac{1-\pi_h}{\pi_h}.$$

We can also establish elasticities in the short run and the long run of labour and hours worked with respect to all the endogenous variables for each equation. Thus for labour, we can calculate elasticities with respect to relative cost of the factors, production, work hours and degree of capital utilization. The same this can be done for hours worked.

Using static and dynamic relations, it is possible to obtain a complete picture of the influence of working hours on labour demand and thus to measure the sensitivity of employment to fluctuations of working hours. Moreover, with the mean adjustment lags it is possible to observe the speed of the reaction of employment and of hours with respect to the external shocks.

Nevertheless, both expressions take into account only partial dynamics of the various markets. The adjustment process implies the presence of adjustment costs on the factors which are not introduced in the representative firm program. In order to answer this criticism and to introduce function of effectiveness into the dynamic framework, we rewrite the program of the firm as dynamic optimization and study the Euler equations.

3.2 Dynamic factors demand analysis in the presence of costs of adjustment

The representative firm is assumed to be in a competitive market. It must adapt to external shocks. Behaviour

[9] Elasticities in the long term are obtained by dividing elasticities of short run by the speed of adjustment.

[10] We suppose a link between two variables x and y, such as: $(1-\varphi(L))\,y_t = \theta(L)\,x_t$. Mean adjustment lags are determined by the following relation: $\overline{MAL}_x = \frac{\theta'(1)}{\theta(1)} + \frac{\varphi'(1)}{1-\varphi(1)}$. With the equations (14) and (15), the coefficients of adjustment are $1-\pi$, the speed of adjustment is π and the means adjustment lag is defined by $\frac{1-\pi}{\pi}$.

is thus described by intertemporal optimization of the expected present value:

$$Max \underset{t}{E}\left[\sum_{\tau=0}^{\infty}\left(\frac{1}{1+r}\right)^{\tau}\left(\begin{array}{l} F\left(\overline{K}_{t+\tau},; L_{t+\tau}, e\left(h_{t+\tau}\right)\right) \\ -w_{t+\tau}^{h} h_{t+\tau} L_{t+\tau}-cuk_{t+\tau} \overline{K}_{t+\tau}-AC(\Delta L_{t+\tau}, \Delta h_{t+\tau}, \Delta \overline{K}_{t+\tau}) \end{array}\right) | \Omega_{t}\right] \tag{16}$$

where $\underset{t}{E}\left[X_{t+\tau} \mid \Omega_t\right]$ denotes the conditional expectation of X using information available at time t and r is the real discount rate. The three factors of production are workers $(L_{t+\tau})$, working time $(h_{t+\tau})$ and the effective capital stock $(\overline{K}_{t+\tau})$. Factor prices are worker wage costs for one hour $\left(w_{t+\tau}^{h}\right)$ and user cost of capital $(cuk_{t+\tau})$. $AC(\Delta L_{t+\tau}, \Delta h_{t+\tau}, \Delta \overline{K}_{t+\tau})$ is a function of the cost of adjustment at time $t+\tau$.

First order conditions for program (16) are given by the Euler equations. Considering that the three inputs in the function of production can vary at the optimum and for $\tau=0$, we obtain:

- for employment:

$$\underset{t}{E}\left[\left(\frac{\partial F(.)}{\partial L_t}+\frac{1}{1+r} \frac{\partial AC(.)}{\partial L_{t+1}}-\frac{\partial AC(.)}{\partial L_t}-w_t^h h_t\right) \mid \Omega_t\right]=0 \tag{17}$$

- for worked hours:

$$\underset{t}{E}\left[\left(\frac{\partial F(.)}{\partial h_t}+\frac{1}{1+r} \frac{\partial AC(.)}{\partial h_{t+1}}-\frac{\partial AC(.)}{\partial h_t}-w_t^h L_t\right) \mid \Omega_t\right]=0 \tag{18}$$

- for capital:

$$\underset{t}{E}\left[\left(\frac{\partial F(.)}{\partial \overline{K}_t}+\frac{1}{1+r} \frac{\partial AC(.)}{\partial \overline{K}_{t+1}}-\frac{\partial AC(.)}{\partial \overline{K}_t}-cuk_t\right) \mid \Omega_t\right]=0. \tag{19}$$

There are three controls variables: the number of workers, the stock of capital and the number of working hours per employee. The consideration of the equation (18) together with the more traditional equations (17) and (19), reflects the introduction of working time flexibility into the firm's behaviour.

3.3 functions of adjustment costs

Since pioneer work of *Oi* [1962], it has been recognized that labour does not adjusted automatically. Just like capital, the labour is regarded "as quasi-fixed factor". The concept of adjustment owes its existence to the imperfection of information and to physical barriers as well as legal barriers (see *Hamermesh and Pfann* [1996]). Many forms of adjustment cost exist. We are interested in this article in continuous forms.

The most traditional form of adjustment cost is quadratic (see *Eisner and Strotz* [1963]). Only the changes in the level of employment will influence the adjustment costs:

$$AC\left(\Delta X_t\right)=\frac{sym}{2}\left(\Delta X_t\right)^2 \qquad , \qquad sym \geq 0. \tag{20}$$

Meghir and alii [1994] determined the Euler equations resulting from the *Summers'* form [1981]. This symmetric form of costs is:

$$AC\left(\Delta X_t, X_{t-1}\right) = \frac{sym}{2}\left(\frac{\Delta X_t}{X_{t-1}}\right)^2 X_{t-1} \qquad , \qquad sym \geq 0. \tag{21}$$

The modeling of asymmetrical adjustment costs enables us to dissociate the growth and recession phases of the economy. The standard modeling of asymmetrical adjustment costs, for a variable X, is that defined by *Pfann and Verspagen* [1989] and by *Pfann and Palm* [1993]:

$$AC\left(\Delta X_t\right) = -asym\Delta X_t + \exp\left(asym\Delta X_t\right) - 1 + \frac{sym}{2}\left(\Delta X_t\right)^2 \qquad , \qquad sym \geq 0. \tag{22}$$

This formula adds a term representing asymmetry to the quadratic formulation of *Eisner and Strotz* [1963]. If $asym$ is positive, then the hiring costs are higher than the firing costs. Conversely, if $asym$ is negative, then the hiring costs are lower than the firing costs. And if $asym = 0$, then the adjustment costs are symmetrical.

We thus propose a new formula which takes into account the asymmetry of adjustment costs. It takes as a starting point the functions of *Summers* [1981] and of *Pfann and Palm* [1993]. It is presented in the following form:

$$AC\left(\frac{\Delta X_t}{X_t}, \Delta X_t\right) = -asym\Delta X_t + \exp\left(asym\frac{\Delta X_t}{X_t}\right) - 1 + \frac{sym}{2}\left(\left(\frac{\Delta X_t}{X_t}\right)\right)^2 \Delta X_t \qquad , \qquad sym \geq 0. \tag{23}$$

Contrary to the asymmetrical forms generally used to describe the evolution of labour the asymmetrical term also takes into account an effect of the growth rate. The coefficient $asym$ represents the asymmetrical character of the function of the adjustment costs, as in the function of *Pfann and Palm*. The dimension of the elements in the exponential operator is less than one. It is not the case with the preceding asymmetrical formulation which requires a precise choice of the units. The exponential operator not being linear, the choice of a very large unit decreases strongly the importance of the asymmetrical character and thus modifies the results of the estimates.

Economy behaviour is studied starting from the first order conditions, the term in difference in the asymmetrical part disappears. The only remainder then in the marginal adjustments costs are the parameters to estimate sym and $asym$ related to variables in growth rate.

Moreover, changes in a given factor demand influences the demands for the other factors. A change in a demand factor can disturb demands for other factors and thus produce an additional adjustment cost for the company. To model these mixed adjustment costs because of the interaction between the demands for factor X and for factor Y, the selected formulation is:

$$AC_c\left(\Delta X_t, \Delta Y_t\right) = sym_{XY}\left(\Delta X_t \Delta Y_t\right). \tag{24}$$

Adjustment costs are thus regarded as external costs to the productive process which are to the normal costs of the factors.

4. Estimating to relationship between hours worked, labour demand and adjustment costs

4.1 Data base and methods of estimation

We use a French macro-economic quarterly data base covering period [1975-1990], which was assembled under the direction of Guy Laroque at INSEE. Our variables are GDP (Y), the number of workers (L), gross salary (w), quarterly duration of the working time(ddt), Investment (I), capital (K), degree of capital utilization (duc) and the user cost of capital (cuk).

The estimation method used is the generalized method of moments (GMM). It enables us to take into account the problems of serially correlated and heteroscedastic errors (see *Gallant* [1987] and *Hamilton* [1996]).

We consider the linear or nonlinear model :

$$\varepsilon_t = q\left(y_t, x_t, \theta\right) \qquad with \qquad \begin{pmatrix} \varepsilon_{1,t} \\ \vdots \\ \varepsilon_{M,t} \end{pmatrix} = \begin{pmatrix} q_1\left(y_t, x_t, \theta_1\right) \\ \vdots \\ q_2\left(y_t, x_t, \theta_M\right) \end{pmatrix}_{(M,1)} .$$

x is a matrix of exogenous variables and y is a vector of endogenous variables. It is a system with M equations. GMM is a instrumental variables method. z_t is a K column vector of instruments:

$$z_t = Z\left(\overline{x}_t\right)_{(K,1)}$$

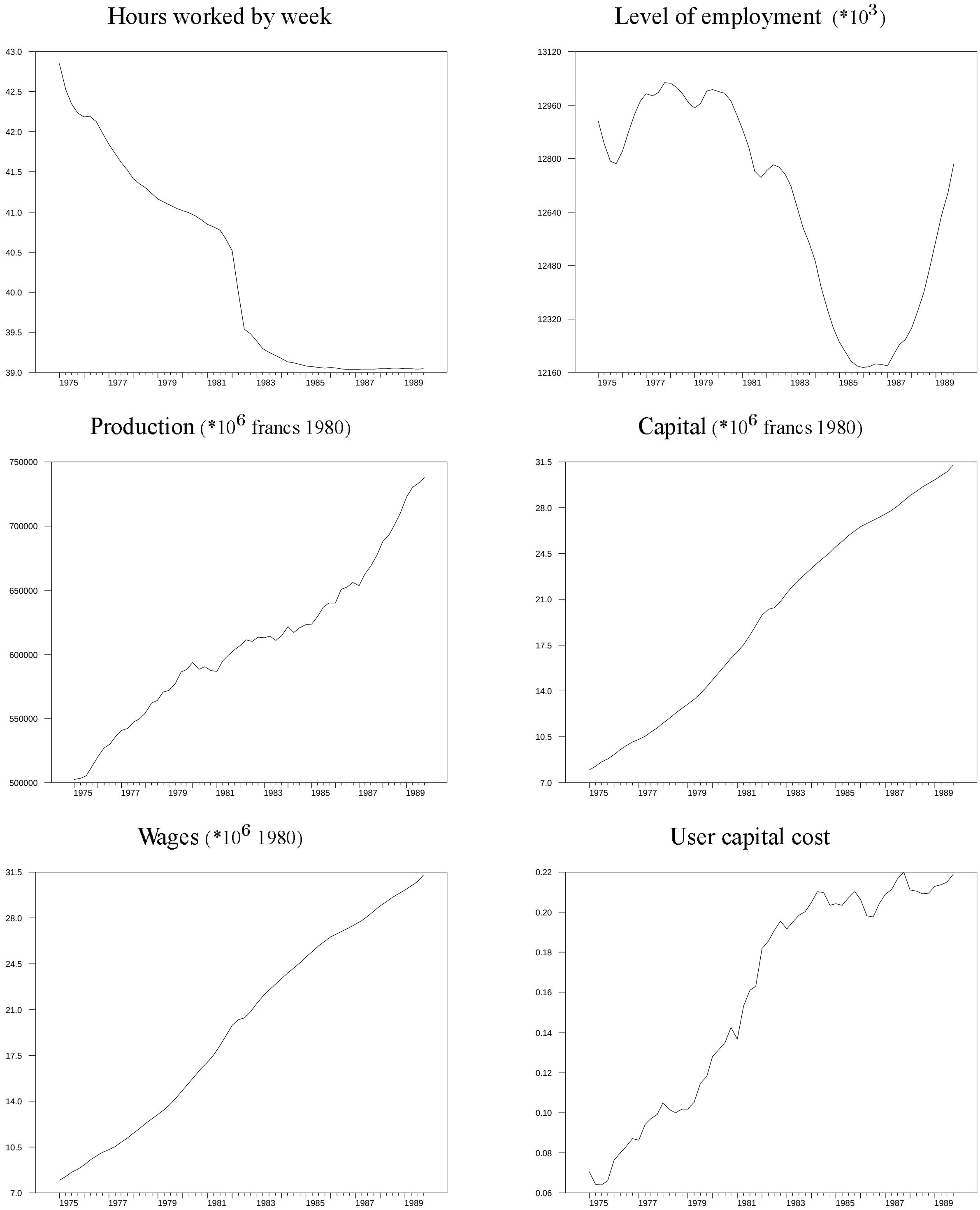
Thus, the orthogonality conditions are defined by:

$$E\left[\varepsilon_t \otimes z_t\right]_{(MK,1)} = 0.$$

We can write the first moment of the crossproducts:

$$\begin{aligned} m_n\left(\theta\right) &= \frac{1}{n}\sum_{t=1}^{n} m\left(y_t, x_t, \theta\right) \\ \Rightarrow &\qquad m\left(y_t, x_t, \theta\right) = q\left(y_t, x_t, \theta\right) \otimes z_t = \begin{pmatrix} q_1\left(y_t, x_t, \theta_1\right) z_t \\ \vdots \\ q_M\left(y_t, x_t, \theta_M\right) z_t \end{pmatrix}_{(MK,1)} . \end{aligned}$$

figure 3: The important variables



Estimate of the true parameter vector θ^o is given by the value of $\widehat{\theta}$ that minimizes:

$$S(\theta, V) = [m_n(\theta)]' V^{-1} [m_n(\theta)] \qquad \text{with} \qquad V = Cov([m_n(\theta^o)][m_n(\theta^o)]).$$

V is the matrix of the moment function that can be approximated by:

$$\begin{aligned} V &= E\left(\sum_{t=1}^{n} \varepsilon_t \otimes z_t\right)\left(\sum_{s=1}^{n} \varepsilon_s \otimes z_s\right)' \\ &= \sum_{t=1}^{n}\sum_{s=1}^{n} E\left[(\varepsilon_t \otimes z_t)(\varepsilon_s \otimes z_s)'\right] \\ &= \sum_{t=1}^{n}\sum_{s=1}^{n} \left[(q(y_t, x_t, \theta) \otimes z_t)(q(y_s, x_s, \theta) \otimes z_s)'\right] \end{aligned}$$

We must estimate the matrix of moment function while taking account of serially correlated and heteroscedastic disturbances (see *Gallant* [1987]). We must be sure that this matrix is positive definite. Usually, we use *White* [1980] approximation or, in the case of serially correlated disturbances, *Newey and West* [1987] approximation.

The GMM requires the choice of instrumental variables. We thus should check the total exogeneity of the instruments. For that, we compare the value of statistics of Hansen-Sargan at $\chi^2 - statistic$ with n degrees of freedom[11].

4.2 Estimations of the static and dynamic relations without adjustment costs

In order to obtain a precise idea of the interactions between the four inputs: capital and employment and their degrees of utilization, several models were tested. The production function used is of the *Brechling* type. The three static models presented here cover the various possibilities suggested in the first part. The following table summaries the hypotheses of the three static models:

	Effectiveness	*Wage Rigidity*
$(1, f)$	No	No
$(2, f)$	Yes	No
$(3, f)$	Yes	Yes

All the estimated parameters are significantly different from zero. The estimate of the trend are very stable whatever the chosen formulation, lying between [0.0057 ; 0.0065]. This corresponds to technical progress of 2 or 3% per annum. The results of models $(1, f)$ to $(3, f)$ show that the returns to scale seem to

[11] The degrees of freedom are defined by the following relation: $Tk - p$, or T is the number of equations of the system, k the number of instrumental variables and p the number of parameters to estimate.

be slightly lower than unity.

Labour elasticity with respect to hours is negative whatever the selected model, meaning that reduction in the duration of working time would be accompanied by an increase in the number of workers. This result is due to the restrictive choice of the type of production function. However, these results are not aberrant (see *Hamermesh* [1993]). Therefore at first sight, a reduction of 10% of the working time (39 hours to 35 hours) would cause a positive shock employment of 6.1 to 8.6% *ceteris paribus*. These values are similar to those found by *Layard, Nickell and Jackman* [1987].

However, the observation of other elasticities moderates this increase. This 10% reduction generates a reduction in the production level. The elasticity of production with respect to the hours is positive ($[0.54; 0.73]$)[12]. There is also a positive link between production and employment[13] ($[1.13; 1.17]$). These two positive elasticities induce a moderation of the impact of the reduction of working time on labour demand.

There is a significant difference between the results with and without the function of effectiveness. The reduction of working time would have a lower effect on employment if the function of effectiveness were not included. The strong significant of the parameter (a) of this function shows the relevance of the use of such a function. Job creation following a reduction of working time of 10% would be 700 000 when considering the function of effectiveness (see estimation $(2, f)$).

The results of this simple static study are subject to various criticisms. Indeed, the consequences of the reduction of working time on the productivity of capital are not considered, neither is the amount of the wage adjustment decided by firms or imposed by the law.

The explanation of the consequences of the reduction of working time on employment and production by a simple static study is exposed to many criticisms. We do not take into account the economy as a whole. The consequences of the reduction of working time on the productivity of the capital, the role of the amount of the wage compensation or the legislative methods of this reduction are not taken into account.

However, considering reduction form 39 to 35 hours, these results are similar to those of the various overall macro-economic models. Hence, the Mosaique model of the OFCE and that of the Banque de France, predicts an increase of labour demand of approximately 700 000 employees in the medium run. The Métric model of the "direction de la prévision", using various scenarios for the reduction to 35 hours, estimates a positive impact of 200 000 to 500 000 jobs.

The significance of the estimated parameter (a) makes it possible to calculate the effectiveness of workers during working time. Thus for 39 hours working weekly:

- For the model $(2, f)$, $e(h) = 0.656$
- For the model $(3, f)$, $e(h) = 0.672$.

12 These values are identical to those found in the literature (see *Cahuc and Zylberberg* [1997]).
13 For all models: $\varepsilon_{L/Q} = \frac{1}{\alpha+\beta}$.

Table 1: Estimations of static models

	$(1,f)$	$(2,f)$	$(3,f)$
cst	0.8928 (3.22)	75.831 (3.12)	82.164 (2.97)
α_t	0.0065 (40.30)	0.0059 (32.51)	0.0057 (26.77)
α_{k*duc}	0.1169 (6.26)	0.1481 (6.85)	0.1522 (6.57)
α_{l*h}	0.7330 (71.46)	-	-
$\alpha_{e(h)l}$	-	0.7254 (71.42)	0.7081 (30.78)
a	-	460.62 (112.1)	445.85 (127.7)
rs	-	-	0.9381 (20.2)
$h-S$	31.79	32.66	30.81
ddl	22	21	20
$\chi^2_{5\%,ddl}$	33.92	32.67	31.41
$e\left(h\right)$	-	$[0.657; 0.675]$	$[0.666; 0.680]$
$Returns$	$[0.816; 0.897]$	$[0.838; 0.921]$	$[0.814; 0.918]$

$I.V.: Y/L_{t-2}, Y/L_{t-3}, Y/K_{t-2}, Y/K_{t-3}, K_{t-2}, h_{t-2}, L_{t-2}$
$DK_{t-2}, DK_{t-3}, Dh_{t-2}, Dh_{t-3}, DL_{t-2}, DL_{t-3}$.

Table 2: Elasticities of labour with respect to the hours worked

$\varepsilon_{L/h}$	$\varepsilon_{L_{ef}/h}$	$\varepsilon^{comp}_{L_{ef}/h}$	$\varepsilon^{rs}_{L_{ef}/h}$
-0.8624 (-44.92) $[-0.824; -0.899]$	-0.6171 (-40.33) $[-0.587; -0.647]$	-0.7865 (-145.65) $[-0.775; -0.797]$	-0.7469 (-143.63) $[-0.736; -0.757]$

Table 3: Elasticities of production with respect to the hours worked

$\varepsilon_{Q/h}$	$\varepsilon_{Q_{ef}/h}$	$\varepsilon^{comp}_{Q_{ef}/h}$	$\varepsilon^{rs}_{Q_{ef}/h}$
$+0.7329$ (71.85) $[+0.712; +0.753]$	$+0.5389$ (89.82) $[+0.527; +0.551]$	$+0.6869$ (32.09) $[+0.644; +0.728]$	$+0.6426$ (28.43) $[+0.598; +0.686]$

Table 4: Estimations of dynamic models

Labour demand	$Log\,(L_t)$	Hours demand	$Log\,(h_t)$
$Log\,(L_{t-1})$	0.8050 (35.83)	$Log\,(h_{t-1})$	0.7057 (35.91)
$Log\,(Q_t)$	0.1079 (7.99)	$Log\,(Q_t)$	0.0091 (1.63)
$Log\,(\frac{w}{cuk}{}_t)$	-0.0064 (-3.70)	$Log\,(\frac{w}{cuk}{}_t)$	-0.0075 (-11.94)
$Log\,(h_t)$	-0.1176 (-15.71)	$Log\,(L_t)$	0.0354 (2.95)
$Log\,(duc_t)$	-0.0164 (-1.90)	$Log\,(duc_t)$	0.0263 (6.25)
$H-S$	25.99	$\chi^2_{5\%,ddl}$	48.60
ddl	34	$P_{\left(\chi^2_{5\%,ddl}>\chi^2_c\right)}$	0.836

Table 5: Elasticities of labour

$MAL_{(L)}$	$\varepsilon^{ct}_{(L)/Q}$	$\varepsilon^{lt}_{(L)/Q}$	$\varepsilon^{ct}_{(L)/h}$	$\varepsilon^{lt}_{(L)/h}$	$\varepsilon^{ct}_{(L)/duc}$	$\varepsilon^{lt}_{(L)/duc}$	$\varepsilon^{ct}_{(L)/(\frac{w}{c})}$	$\varepsilon^{ht}_{(L)/(\frac{w}{c})}$
4.128 (6.98)	0.1079 (7.99)	0.5533 (3.47)	-0.1176 (-15.71)	-0.6031 (-19.65)	-0.016 (-1.90)	-0.084 (-1.91)	-0.0064 (-3.70)	-0.0328 (-7.31)

Table 6: Elasticities of hours worked

$MAL_{(h)}$	$\varepsilon^{ct}_{(h)/Q}$	$\varepsilon^{lt}_{(h)/Q}$	$\varepsilon^{ct}_{(h)/L}$	$\varepsilon^{lt}_{(h)/L}$	$\varepsilon^{ct}_{(h)/duc}$	$\varepsilon^{lt}_{(h)/duc}$	$\varepsilon^{ct}_{(h)/(\frac{w}{c})}$	$\varepsilon^{lt}_{(h)/(\frac{w}{c})}$
2.3978 (3.41)	0.0091 (1.63)	0.0308 (1.67)	0.0354 (2.95)	0.1204 (2.97)	0.0264 (6.25)	0.0895 (7.00)	-0.0075 (-11.94)	-0.0256 (-10.90)

The exact determination of the (a) parameter in the function of effectiveness is a very important in the construction of the macro-economic models. Those do not estimate a function of effectiveness but they take into account this specific behaviour of the workers. The value of this coefficient enables us to determine the form and both particular points of our function of effectiveness. Before the point A (see figure (2)), marginal productivity of hours is increasing . The duration of working time increases the average productivity by hours of employees. After this point, the marginal productivity of working time becomes decreasing and thus the average productivity by hours of employees decreases.

For (a) value included between 446 and 461, this point A is between 16.1 and 17.7 hours. Therefore a reduction of the working time would be accompanied by an increase in the average productivity of the workers. *Malinvaud* [1973] retains that increase in productivity corresponds to 50% of the reduction of the working time. The closer this point we are, lower the productivity increase is. Currently, the French macro-economists retain as an assumption that these profits are approximately of 33% of the reduction of the working time.

The second important point in the analysis of the effectiveness of the duration of the working time is between 31 and 32 hours by week(see figure (2) - point B). Beyond point B the contribution of a new hour worked decreases the average productivity of employees.

Estimation of dynamic labour demand with a partial adjustment process enables us to add to the analysis of the relationship between production factors. We estimate the two following equations describing the behaviours of labour and the number of working hours[14]:

$$\log L_t = \mu_1 \log L_{t-1} + \mu_2 \log Q_t + \mu_3 \log duc_t + \mu_4 \log h_t + \mu_5 \log \left(\frac{w}{cuk}\right)_t, \quad (25)$$

$$\log h_t = \overline{\mu}_1 \log h_{t-1} + \overline{\mu}_2 \log Q_t + \overline{\mu}_3 \log duc_t + \overline{\mu}_4 \log L_t + \overline{\mu}_5 \log \left(\frac{w}{cuk}\right)_t. \quad (26)$$

From these two equations, we determine the mean adjustment lags and the short and long run elasticities. The results presented in the table (4) show the reactions of the labour demand to production, relative factor costs and working time. The signs of the estimated coefficients for both equations conform to the patterns suggested by the economic theory.

Estimation of the elasticity of labour with respect to working time is -0.1176 in the short run and -0.6031 in the long run (see table (5)). This confirms the results found with our previous models (see table (1)). In the same way, we find a positive effect of the production on employment. The relative cost of the factors influences the labour demand negatively. If wages increase, without modification of the user cost of capital, that causes a reduction of the level of employment. However, the effects of the factor costs

[14] Instrumental variables are for two equations: $log\left(Y_{t-1}\right), log\left(Y_{t-2}\right), log\left(Y_{t-3}\right), duc_{t-1}, duc_{t-2}, w_{t-1}, w_{t-2}, cuk_{t-1}, cuk_{t-2}, log\left(w_{t-1}\right), log\left(w_{t-2}\right), log\left(cuk_{t-1}\right), log\left(cuk_{t-2}\right), h_{t-2}, h_{t-3}, log(L_{t-2}), log(L_{t-3}), L_{t-2}, L_{t-3}, log(h_{t-2}), log(h_{t-3})$.

are relatively weak. The degree of capital utilization affects employment[15] only weakly, but it positively influences duration of working time (see table (6)). The increase in the building occupation or in machine use results in an increase in the working time but not in the number of employees[16].

From equation (25) describing the dynamics of the labour demand, we can determine elasticities of the production function. The elasticities estimated from static and dynamic demands are not statistically different.

The mean adjustment lags (see table (5) and (6)) of employment corresponds to one year, whereas that of the hours corresponds to two or three quarters. These values are the same order of magnitude as those calculated by the the five principal French macro-economic models. Moreover, observation of the graph of hours-worked shows that the transition from 40 hours to 39 hours in 1982, occurred relatively quickly. The average of weekly working time passes from 40.52 hours to 39.54 hours in 2 quarters. This value corresponds exactly to our estimation.

The introduction of a partial adjustment mechanism, to describe the behaviour of our agent thus enables us to understand the dynamic interactions between the factors. However, to obtain a linear estimating equation, we were not able to introduce the function of effectiveness of the hours worked in the production function.

4.3 Estimations of the dynamic demands with adjustment costs

In order to study the dynamic interaction between the factors of production while taking into account the function of effectiveness, we will consider the estimation to the Euler equations resulting from the program of an intertemporal optimization of the expected present value of the cash flow. This dynamic program is thus derived with respect to employment but also with respect to working time. As previously we will be interested in dynamics on the labour market.

The Euler equation for labour is:

$$\underset{t}{E}\left[\left(\frac{\partial F(.)}{\partial L_t}+\frac{1}{1+r}\frac{\partial AC(.)}{\partial L_{t+1}}-\frac{\partial AC(.)}{\partial L_t}-w_t^h h_t\right)\mid\Omega_t\right]=0. \tag{27}$$

The Euler equation for hours is:

$$\underset{t}{E}\left[\left(\frac{\partial F(.)}{\partial h_t}+\frac{1}{1+r}\frac{\partial AC(.)}{\partial h_{t+1}}-\frac{\partial AC(.)}{\partial h_t}-w_t^h L_t\right)\mid\Omega_t\right]=0. \tag{28}$$

Our aim is to study the complex relations between the labour demand, the working hours and the adjustment costs. We will suppose that there are simultaneously adjustment costs on employment and hours. The function of adjustment is assumed to be separable:

$$AC(\Delta L_t,\Delta h_t)=AC(\Delta L_t)+AC(\Delta h_t)+AC_c(\Delta L_t,\Delta h_t).$$

15 This is not significant at a 5% level.

16 All elasticities of hours worked are rather weak

Table 7: Estimations of dynamic models with adjustment costs

	Euler equations with function of effectiveness			
	(e)	(s)	(pp)	(nf)
cst	81.107 (3.49)	81.159 (3.49)	36.686 (2.96)	77.588 (3.44)
α_t	0.0059 (34.72)	0.0059 (34.79)	0.0054 (24.20)	0.0059 (36.01)
α_{duck}	0.1424 (7.39)	0.1423 (7.40)	0.1956 (7.88)	0.1439 (7.96)
$\alpha_{e(h)l}$	0.7274 (125.2)	0.7273 (123.5)	0.7254 (47.59)	0.7296 (58.36)
a	461.70 (154.6)	461.72 (152.86)	445.97 (94.12)	461.36 (104.9)
sym_l	0.1498 (2.81)	1902.9 (2.85)	0.3031 (2.56)	3791.1 (3.56)
$asym_l$	-	-	-0.091 (-22.42)	-993.22 (-15.42)
sym_h	33.456 (1.56)	16825.6 (1.62)	52.954 (3.39)	24061.0 (2.39)
$asym_h$	-	-	32.847 (13.01)	12886.8 (7.09)
$crois_{lh}$	5.4456 (5.28)	5.4445 (2.39)	6.5399 (3.42)	6.1849 (4.52)
$h-S$	31.414	31.413	30.059	30.447
ddl	31	31	29	29
$\chi^2_{5\%,ddl}$	44.98	44.98	42.56	42.56
$e(h)$	0.655	0.655	0.672	0.655

$I.V.: (Y/L)_t\,, (Y/L)_{t-1}\,, (Y/K)_{t-1}\,, (Y/K)_{t-2}\,, L_{t-2}, h_{t-2}, K_{t-2},$
$\Delta L_{t-2}, \Delta L_{t-3}, \Delta K_{t-2}, \Delta K_{t-3}, \Delta h_{t-2}, \Delta h_{t-3}.$

Table 8: Functions of adjustment costs studied

		Functions of adjustment costs
Eisner et Strotz	(e)	$\frac{sym}{2}\left(\Delta X_t\right)^2$
Summers	(s)	$\frac{sym}{2}\left(\frac{\Delta X_t}{X_{t-1}}\right)^2 X_{t-1}$
Pfann et Palm	(pp)	$-asym\Delta X_t + \exp\left(asym\Delta X_t\right) - 1 + \frac{sym}{2}\left(\Delta X_t\right)^2$
New function	(nf)	$-asym\Delta X_t + \exp\left(asym\frac{\Delta X_t}{X_{t-1}}\right) - 1 + \frac{sym}{2}\left(\frac{\Delta X_t}{X_{t-1}}\right)^2 X_{t-1}$

We thus take into account the four forms of possible adjustment costs $(AC(.))$ discussed in section three (see table (8)). The variation of working hours intervenes in the labour demand[17]. The production function used is the same as in the static model $(2, f)$. By comparing these results (see table(3)) with those obtained in the table (7), we see that the values of the production elasticities with respect to inputs do not change. The returns to scale remain equal to unity. The estimations of the parameters of production function are very stable whatever the formulation of the adjustment costs. Finally, the coefficient of effectiveness (a) is always significantly different from zero. The value of the effectiveness of the employees is still between 65% and 67%.

The essential contribution of this modelling is to be able to take into account several forms of costs of adjustment and thus to study the asymmetry of the behaviours compared to the phases of growth or recession (see *Nickell* [1986] and *Pfann and Palm* [1993]).

One variable can be analyzed in the time domain but also in the frequency domain. The goal is to estimate how cycles of different frequency are in accounting for the behaviour of variables (voir *Hamilton* [1994] and *Bresson and Pirotte* [1996]). For example, the variable labour is described as a weighted sum of periodic functions of form $cos(\omega t)$ et $sin(\omega t)$, where ω is a particular frequency:

$$L_t = \mu + \int_0^{\pi} \alpha(\omega)\cos(\omega t)\,d\omega + \int_0^{\pi} \alpha(\omega)\sin(\omega t)\,d\omega,$$

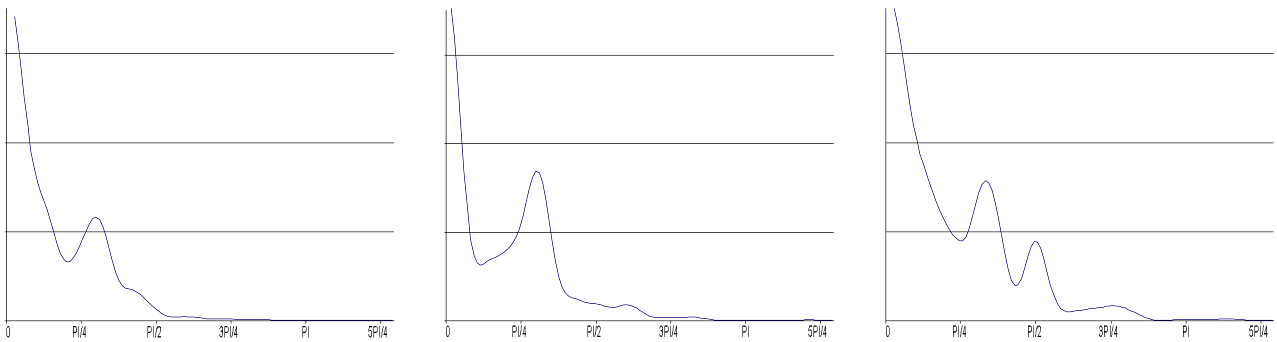
The spectral analysis study of the three series, hours, employment and production, reveals the same cycle periodicity. Indeed, the three spectra (see figure (4)) reveal peaks at frequencies for $\omega \in \left[\frac{\pi}{4}; \frac{\pi}{3}\right]$. By retaining the value $\omega = \frac{7\pi}{24}$, we thus find that there are cyclical processes of periodicity $T = 7$ periods $\left(T = \frac{2\pi}{\omega}\right)$. This cycle is slightly higher than the time necessary for the adjustment of men and hours previously determined: 4 quarters for the men and 2 quarters for the hours (see table (5) and (6)).

The presence of a cycle in employment and adjustment costs and partial adjustment mechanism suggests that the level of employment obtained in the dynamic specification is lower at the optimal level that the one determined static demand (see *Nickell* [1986]). Consequently, job creation following a decrease in the duration of working time is probably weaker than the one predicted by the static estimations. The adjustment costs can be interpreted as disturbing factors in the production function causing a decrease in production. They can also be seems as explicit costs increasing the usual factor costs. Anyway, both these adjustment costs have the same consequence, that is a reduction in labour demand. Therefore adjustment costs limit the effects of the cycles on factor demand but they tend also to reduce its level.

The coefficients of the adjustment costs are significantly different from zero (see table (7)). The graphics established for the new adjustment cost function (see equation (23)) clearly highlight asymmetries of the adjustment costs (see figure (5)). With regard to employment, the asymmetrical parameters $(asym)$ of both the *Pfann and Palm* and on new form are significantly negative. Thus, the hiring costs are lower than the

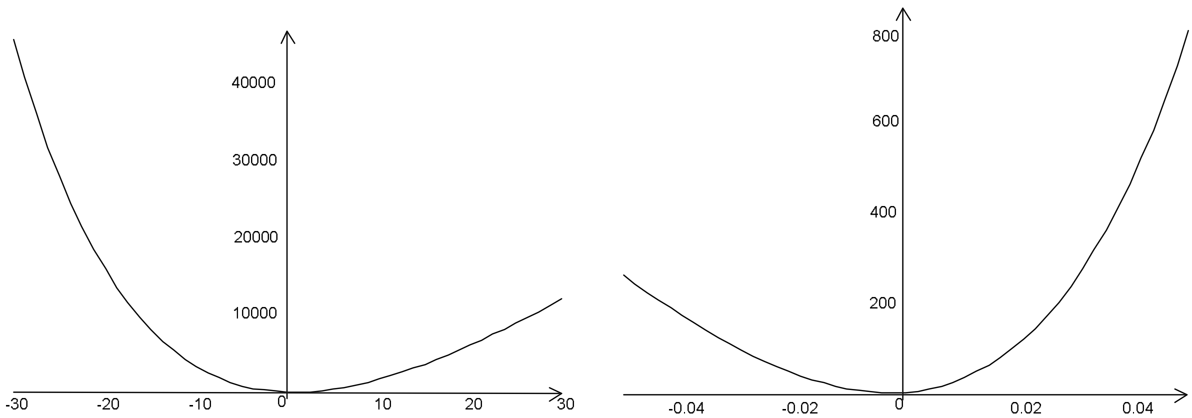
[17] $\frac{\partial AC(\Delta L_t, \Delta h_t)}{\partial L_t} = \frac{\partial AC(\Delta L_t)}{\partial L_t} + sym_{lh}\Delta h_t$.

figure 4: Spectral densities of labour, the hours worked and production



Labour spectral analysis Hours worked spectral analysis Production spectral analysis

figure 5: The Labour and Hours adjustment costs



The Labour adjustment costs The Hours adjustment costs firing costs. This result is in conformity with observations on data of French firms for the same period (see *Bresson and Debrand-Bonapetit* [1998]). For working hours, the asymmetrical coefficient of the adjustment costs is positive. That means that it is more expensive for a company to increase the working time than to reduce it.

These two asymmetries can be one of the explanations of the behaviour of demand during the business cycle (see *Hamermesh* [1993]). Indeed, there is a close link between speeds of adjustment and the adjustment costs. There are thus modifications in speeds of adjustment according to the economic situation. For employment, firing costs are higher than hiring costs. Consequently, the speed of adjustment will be slower in phases of recession than in phases of expansion (see *Nickell* [1986], *Pfann and Palm* [1993], *Bresson and Debrand* [1998]). For the number of hours, there is an opposite relation. The hours adjustment costs having a positive asymmetry, the costs caused by an increase in the duration of the work are higher than the costs generated by a reduction of working time. The speed of adjustment of hours worked in phases of expansion is lower than the speed of adjustment in phases of recession

Consequently, two different modes of behaviour of firms can be considered according to the phases of the cycle. In phases of recession, the firm would tend to limit the number of working hours before laying off. Whereas in the phases of expansion , the companies would increase their manpower, for example by temporary recruiting employees, rather than by increasing the duration of the work. The link between labour demand and working time changes at different phases of the business cycle.

5. Conclusion

This article analyzes the relationship between working hours and the static and dynamic labour demand. For that purpose, we proposed three different models describing the optimization program of firm's behaviour. These models were estimated on French data covering the period [1975-1990].

The first of these specifications corresponds to the estimate of a static labour demand. The production functions used require four inputs: capital, labour and the degree of utilization: degree of capital utilization and worked hours. For a duration of working time of 39 hours we can establish that the effectiveness is between 65.6% to 67.2% for workers. The effects of a reduction of the working time are difficult to perceive. By observing only the employment elasticity with respect to the working time, the reduction of the working time from 39 to 35 hours would create 700 000 jobs. However, the effect of this reduction is weakened by the impact of working time on production.

The second model studies the relationship between men and hours within a dynamic framework. Introducing partial adjustment processes for hours and men, we clarify the dynamic demand for these two factors. The estimation of the relations in the short run and the long run confirms the results established within the static framework. Moreover, we predict the mean adjustment lags, that correspond to six months for the hours and one year for men.

The consideration of the process of adjustment implies the presence of costs of adjustment which are not specified explicitly. In the final model, we estimated a program of intertemporal optimization with various forms of adjustment cost. The estimations of the Euler equations show a positive asymmetry for hours and a negative asymmetry for men. Moreover, this model enables us to find the value of the parameter of the function of effectiveness.

The estimates of these three models permit us to obtain a picture of the complex relations between men and hours. Imperfect substitutability between men and hours working suggest that effects for the reduction of unemployment by a important reduction of working time are limited. It is obvious that these simple models return only partially the set of interactions existing between the different aggregates. One solution would be to introduce a function of effectiveness in to the macroeconomic model.

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