Contributions

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How do firms adjust production factors to the cycle?

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Abstract: This paper studies the adjustment of production factors to the cycle taking into account factor utilization in multiple dimensions (labor working time, capital operating time and capital capacity utilization) and examines the impact of obstacles to increasing capital operating time on this adjustment path. Factor utilization adjusts the most rapidly, first through capital capacity utilization and capital operating time and then labor working time. The adjustment is slow for the number of employees and even slower for the capital stock. Obstacles to increasing capital operating time lead to a slower adjustment of capital operating time, offset by a stronger adjustment of capacity utilization.

Keywords: factor utilization; production function; rigidities.

JEL codes: D24; E22; O43.

1 Introduction

Firms continuously face demand or supply shocks that should lead them to adjust fluidly their production factors. This adjustment process is a key element of a well functioning economy: it allows firms to maintain their performances at their best through an optimal factor allocation at any time. Understanding this adjustment process, how capital, labor and their utilizations react to a shock, helps analysing cyclical fluctuations at the macroeconomic level and how the policy maker can reduce adjustment costs to improve the flexibility of the economy.

Indeed, it has been shown that firms adjust production factors, and especially capital, with delay (Caballero, Engel and Haltiwanger 1995; Doms and Dunne 1998, for capital; Caballero, Engel and Haltiwanger 1997, for employment). First, adjustment

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costs for capital and labor prevent a smooth change in the level of production factors (Hamermesh and Pfann 1996, for a literature review). These costs may be technical (hiring and training costs of employees, installation costs of new capital goods…) as well as regulatory (severance pay, regulation of depreciation in tax schedules…). They may be, at least partly, non-convex both for capital (Cooper and Haltiwanger 2006) and for labor (Caballero, Engel and Haltiwanger 1997). Second, capital expenditures tend to be irreversible as secondary markets for used capital are illiquid. In a context of uncertain long-run projects return, this leads to a lumpy behavior of investment, as waiting before making an investment decision provides managers with additional information (Bernanke 1983). Mumtaz and Zanetti (2012) have shown on US aggregated data that these costs are procyclical and amounts to 2% of output, in line with the estimates on disaggregated data by Bloom (2009).

These costs of adjustment and irreversibility of capital spending prevent factors level to adjust immediately to their long-term target levels. To satisfy demand, firms have to rely in the short run on factor utilization, which overreact at the occurrence of a shock compared to their long-run levels. Hence, the working time of capital and labor or the capital capacity utilization may differ temporarily from their long-term target in order to produce the desired level of output. Nadiri and Rosen (1969, 1973) have first emphasized empirically this role of factor utilization in short term adjustment dynamics, on macro data. They merged capital and labor functions and showed that capital and labor demands were interrelated. They provided an estimation of the factor adjustment path in case of, for example, a demand shock: immediately, factor utilization degrees overshoot their long-term targets to offset the lack of adjustment of the capital and labor stock levels; the number of employees is slowly adjusted to its target level (and slightly more to offset the capital gap) and the capital stock is even more slowly adjusted to its target level. During this adjustment process of labor and capital stocks, factor utilizations come progressively back to their initial optimal rates.

Regulation may alter the adjustment process. Eslava et al. (2010) have showed on Colombian macro data how deregulation of labor and financial markets in 1990 and 1991 has led to a quicker adjustment of production factors, and especially a faster downward adjustment of labor level, as it became cheaper to dismiss workers, and faster capital formation.

From this point of view, France is a particularly interesting case for studying the factor adjustment process. Working time regulation has been substantially modified at the turn of the 2000s, becoming more flexible with a substantial role given to collective bargaining: the threshold of overtime premium was decreased from 39 h to 35 h a week but in the same time, should a firm or branch agreement be reached, the workweek length could be measured on an annual basis, giving large leeway to adjust factor utilization throughout the year.

We study here production factor adjustment taking into account factor utilization in all its dimensions (labor working time, capital operating time and capital capacity utilization) on micro data through a unique survey among French manufacturing firms. As emphasized in various studies, capital operating time is a crucial instrument to adjust to shocks in the manufacturing sector (Shapiro 1993; Mattey and Strongin 1997; Sakellaris 2004; Gorodnichenko and Shapiro 2011; Cette et al. 2015) but, in our knowledge, it has never been taken into account in interrelated demand factor models at the firm level. This survey also allows us to examine the impact of obstacles to increasing capital operating time on this adjustment path, which had also never been taken into account explicitly at the firm level. This survey, merged with balanced sheet and profit and loss accounts from fiscal reports, yields an unbalanced panel of 6066 observations over 1993–2010. The survey questionnaire is sent to a representative population of the French manufacturing sector, although the effective answers may distort the final sample. Due to this limitation, our sample is not strictly representative from a statistical point of view. Small firms are under represented with respect to large ones in the final dataset. But in the estimates, as usual on micro data, all firms have the same weight, which means that a small one has the same weight than a large one.

We show that factor utilization degrees adjust the most rapidly, first through capital capacity utilization and capital operating time and then through labor working time. The adjustment is slow for the number of employees and even slower for the capital stock. In analysing cyclical fluctuations, changes in factor utilization degrees could hence be used in forecasting future changes in factor volumes. Stronger reactions of factor utilization degrees to a similar shock in one country compared to another may reflect higher adjustment costs, some of which may be policy-induced and could hence be corrected to improve the overall flexibility of the economy. In case of a change in the capital stock target, the three factor utilization degrees, as well as employment in a lesser proportion, adjust to offset the very slow reaction of the capital stock. Similarly, in case of a change in the employment target, the three factor utilization degrees offset the slow adjustment of this factor. Among the three factor utilization degrees, these offsetting reactions are higher for capital utilization rate and capital operating time than for labor working time. These results confirm and deepen those of previous analysis, as those of Nadiri and Rosen (1969, 1973). But to our knowledge, it is the first time that this role of factor utilization degrees adjustment to offset the slow adjustment of factor volumes, and mainly of capital volume, is estimated on firm individual data, and the first time capital operating time is included in this analysis. Obstacles to increasing capital operating time lead to a slower adjustment of capital operating time, the short-term adjustment relying more on capital utilization rate.

Section 2 describes the databases used, Section 3 presents the model and estimation strategy, Section 4 the results and Section 5 some robustness tests.

2 Data set

Our empirical analysis is based on an original and rich French individual dataset on factor utilization. Precisely, we merge two firm-level annual datasets constructed by the Banque de France: the FiBen database and the survey on factor utilization degrees (FUD hereafter).

FiBEn is a very large individual company database that includes balance sheets and profit and loss accounts from annual tax statements. It features all French firms with sales exceeding €750,000 per year or with a credit outstanding higher than €380,000. This database allows computing firm-level value added (Q), the capital stock (K), the volume of employment (L), the labor cost (W) and the user cost of capital (C):

- The value added volume (Q) is computed by dividing value added in value (production in value minus intermediate consumptions) by a national accounting index of value added price at the industry level.
- The volume of capital (K) sums gross capital volumes for buildings and equipment. Gross capital at historical price (as reported in FiBEn) is divided by a national index for investment price, lagged with the mean age of gross capital (itself calculated from the share of depreciated capital in gross capital, at historical price). This measure corresponds to the volume of capital, usually by the end of a fiscal year.
- The average employment level (L) is directly available in FiBEn.
- The labor cost (W) is obtained by summing wages, salaries and social charges (per capita).
- The user cost of capital (C) is calculated from the following formula, from Jorgenson (1963), which stems from the investment decision of a firm maximizing its profit over two periods under simplifying assumptions:

$$\begin{aligned} \text{C} = \text{investment price} \cdot (&\text{interest rate} - \text{growth rate of investment price} \\ &+ \text{capital depreciation rate}) \end{aligned}$$

  The interest rate used is that of government bonds plus a risk premium of 2%. The capital depreciation rate is computed as follows:

$$\text{Capital depreciation rate} = 2.5\% \cdot \frac{\text{Buildings}}{\text{Capital stock}} + 10\% \cdot \frac{\text{Equipment}}{\text{Capital stock}}$$

– The relative factor cost (*RC*) is easily deduced from the ratio of the two previous costs.

The FUD survey has been carried out every September since 1989 by the Banque de France at the plant level. 1500–2500 plants are covered by this survey, depending on the year, representing over 7% of the industry employment. This dataset directly provides for each plant the annual growth rate of capital operating time (*HK*), the level of labor workweek (*HL*), and indirectly the production capacity utilization rate (*CU*). From now on, we denote by Δz the growth rate of a variable Z, Δ being the first difference operator, lower case variables standing for log values and Z^* the firm optimal level of the variable Z (from maximizing profit).

– Data on the annual growth rate of capital operating time or capital operating time (Δhk) stem from the question: "*What is the past evolution, over the last 12 months, of your productive equipment operating time, in percentage?*". A notice attached to the survey explains that productive operating time refers to a specific September full week.
– Data on the level of labor workweek or labor working time (*HL*) stem from the question: "*What is the average usual working time of your employees in hours during the specific poll week…*" and the same specific week as for capital operating time is specified.
– One question in the survey asks "*What is the potential percentage of production increase which would be feasible for your plant without any change in your equipment (possibly augmenting the number of employees and working time if it is consistent with public regulations, but without any modification in the shift work organization)?*". We denote this data by *CA*, and the capital capacity utilization rate *CU* (in %) is approximated as follows: $CU=100-CA$. This approximation provides in fact much more plausible results than those obtained with the exact capital capacity utilization rate (in %) computed from the formula: $\frac{100}{1+\frac{CA}{100}}$. One aspect of factor utilization which capacity utilization is capturing and which is not captured by the two other measures is labor intensity (e.g. the speed of the assembly line).

The survey also gives information on the level of employment (*L*) and percentage of employees organized in shift work (*SW*).

The FUD survey not only provides rich insights about firm-level factor utilization, but also a unique appraisal of rigidities faced by firms in increasing their capital operating time. Firms are directly asked to declare the presence of such rigidities. More precisely, entrepreneurs answered the following question: *"If you had to increase your capital operating time, and if your sales potential could justify it, would you meet obstacles or brakes?"*.

While the FUD survey is carried out at the plant level, FiBEn gives information at the firm level. A difficulty in the data merge lies in the fact that some firms are multi plants. When several plants of a single firm were covered by the FUD survey, we aggregated for each year all plants of this firm, weighting them by their share in the firm's total employment. We considered the FUD survey answers to be representative enough when the employment level corresponding to this aggregation was higher than 50% of the one reported in FiBEn (otherwise, the firm was dropped from the final dataset). The firms we removed tend to be larger than the firms kept in our sample. Each time one observation was missing for a given firm, we interpolated its value taking the average of its one-period past and one-period next observations.

The merger of these two databases results in an unbalanced sample of 6066 observations corresponding to 1597 companies, over the period 1993–2010. To our knowledge, this individual company database is unique for allowing an empirical analysis concerning a Nadiri-Rosen type model of factor adjustment.

Many variables in our dataset may potentially be prone to measurement biases, which are quite standard in firm-level panel data of the FiBEn's type. However, the originality of the FUD proves useful to discuss some of its specific potential measurement issues. First, the questions asked in this survey are uncommon for managers. For this reason, small discrepancies are often not taken into account in the answers. Second, working time measurement is particularly affected by several legal issues. Three notions of working time coexist in the French Labor Code: the legal working time over which hours worked benefit from overtime legal and conventional premiums; the contractual working time which is explicit in the individual labor contracts, and which can differ from the legal working time; and the effective working time which is factually respected and paid, and which can be superior to the contractual time. Plants can answer the survey using any of these three notions. In addition, during the period covered, the legal weekly working time were decreased from 39 to 35 h in 2000 for firms of 20 employees or more and in 2002 for all other firms.[1] This decrease of the legal working time was announced in 1998, and financial incentives were implemented by the French Government this same year 1998 to anticipate the working time decrease. For capital capacity

1 As there is no firm of 20 employees or less in our dataset, this second wave of legal working time decrease in 2002 will no longer be evoked in this study. This threshold of 20 employee firms comes de facto from the FiBEn database.

utilization, an ambiguity may as well exist as the feasible production increase may be relative to the physical capacity of the equipments or relative to the sustainable profitability of the firm. These measurement problems will be dealt with using instrumental variables.

Descriptive statistics are available for all variables in Appendix A and B.

3 Model and estimation strategy

3.1 The model

The model gets mainly its inspiration from Nadiri and Rosen (1969, 1973), Pouchain (1980), or Shapiro (1986).

We assume for each firm *i* the five factors Cobb-Douglas production function:

$$Y_{i,t}=A_i \cdot e^{\gamma_s \cdot t+\nu_t} \cdot \prod_{j=1}^{5} F_{i,j,t}{}^{\alpha_j}$$

where $0<\alpha_j<1 \ \forall \ j$; $Y_{i,t}$ is the volume of value-added; A_i is a scale firm specific parameter; $e^{\gamma_s \cdot t+\nu_t}$ is a term corresponding to a Hicks neutral technological progress impact (sectoral trend and year dummies); $F_{i,1,t}=K_{i,t}$ is the volume of capital stock; $F_{i,2,t}=L_{i,t}$ is the volume of labor stock number of employees; $F_{i,3,t}=CU_{i,t}$ is the capital capacity utilization rate; $F_{i,4,t}=HK_{i,t}$ is the capital operating time; $F_{i,5,t}=HL_{i,t}$ is the labor workweek.

We assume constant returns to scale on the stock of factors ($\alpha_2=1-\alpha_1$), the elasticity of the capital capacity utilization and of the capital operating time to be the same as the one of the capital stock ($\alpha_3=\alpha_4=\alpha_1$) and the elasticity of the labor workweek to be the same as the one of the labor stock ($\alpha_5=\alpha_2$). This constant returns to scale assumption is consistent with the results of empirical studies taking explicitly into account factor utilization (see Cette et al. 2015).

Value added is our output variable. Hence, we do not take into account intermediates consumption as an adjustment factor, which demand would be interrelated with the one of the other five factors. Outsourcing would lead to an increase in intermediates consumption, a decrease in the other factors and in value added. Although they are reflected in a parallel decrease in value added and factors, these substitutions are not explicitly taken into account, which may impact our results if some factors are more substitutable than others with intermediates consumption. Due to its complexity, the model would however be impossible to estimate with six factors. The characterisation of the role of the three factor utilization degrees, as the main short term adjustment tool for firms, is a priority in our estimates which would not be possible if six factors were considered.

The production function is the following:[2]

$$Y_{i,t}=A_i\cdot e^{\gamma_s\cdot t+\nu_t}\cdot(CU_{i,t}\cdot HK_{i,t}\cdot K_{i,t})^{\alpha_1}\cdot(HL_{i,t}\cdot L_{i,t})^{1-\alpha_1}$$

Turning to logs (lower case), the output of the firm *i* at date *t* can be written as:

$$y_{i,t}=a_i+\gamma_s\cdot t+\nu_t+\alpha_1\cdot(cu_{i,t}+hk_{i,t}+k_{i,t})+(1-\alpha_1)\cdot(hl_{i,t}+l_{i,t}) \tag{1}$$

We assume that optimal quantities of utilization degrees are constant, but a discontinuity was introduced in the labor workweek optimal level in the year 2000, when the implementation of the 35-h workweek became compulsory for medium and large firms:

$$CU^*_{i,t}=\overline{CU}_i,\ HK^*_{i,t}=\overline{HK}_i,\ HL^*_{i,t}=\overline{HL}_i=\overline{HL}_{i,b00}\cdot 1_{t<2000}+\overline{HL}_{i,a00}\cdot 1_{t\geq 2000}$$

Where $\overline{HL}_{i,b00}$ and $\overline{HL}_{i,a00}$ refer to labor workweek optimal levels before and from 2000; $1_{t<2000}$ and $1_{t\geq 2000}$ are dummies for years before and from 2000.

This assumption is consistent with the fact that the average and the median change of these three degrees are nil over the period (see Appendix A).

At the optimum, from the profit optimization program of the firm we get:

$$K^*_{i,t}=\overline{CU}_i^{\,-\alpha_1}\cdot\overline{HK}_i^{\,-\alpha_1}\cdot\overline{HL}_i^{\,-(1-\alpha_1)}\cdot A^{-1}\cdot\left(\frac{\alpha_1}{1-\alpha_1}\right)^{1-\alpha_1}\cdot Y_{i,t}\cdot\left(\frac{W_{i,t}}{C_{i,t}}\right)^{1-\alpha_1}\cdot e^{-\gamma_s\cdot t-\nu_t}$$

$$L^*_{i,t}=\overline{CU}_i^{\,-\alpha_1}\cdot\overline{HK}_i^{\,-\alpha_1}\cdot\overline{HL}_i^{\,-(1-\alpha_1)}\cdot A^{-1}\cdot\left(\frac{1-\alpha_1}{\alpha_1}\right)^{\alpha_1}\cdot Y_{i,t}\left(\frac{W_{i,t}}{C_{i,t}}\right)^{-\alpha_1}\cdot e^{-\gamma_s\cdot t-\nu_t}$$

With $W_{i,t}$: compensation per employee and $C_{i,t}$; user cost of capital.

Turning in logs and matrix notation we get, from previous relations:

$$\begin{gathered} f^*_{i,t}=C1\cdot d_{i,t} \\ (5,1)=(5,7)\cdot(7,1) \end{gathered} \tag{2}$$

2 One issue here is whether capacity utilization is as relevant for buildings as for equipments. We assume here that both capital types are not separable in terms of utilization and have hence to be treated similarly.

$$\text{With: } f^*_{i,t} = \begin{pmatrix} k^*_{i,t} \\ l^*_{i,t} \\ cu^*_{i,t} \\ hk^*_{i,t} \\ hl^*_{i,t} \end{pmatrix}; \; d_{i,t} = \begin{pmatrix} \overline{cu}_i \\ \overline{hk}_i \\ \overline{hl}_i \\ y_{i,t} \\ (w_{i,t} - c_{i,t}) \\ -\gamma_s \cdot t - \nu_t \\ 1 \end{pmatrix}$$

$$\text{and } C1 = \begin{pmatrix} -\alpha_1 & -\alpha_1 & -(1-\alpha_1) & 1 & 1-\alpha_1 & -1 & -a+(1-\alpha_1)\cdot\log\left(\dfrac{\alpha_1}{1-\alpha_1}\right) \\ -\alpha_1 & -\alpha_1 & -(1-\alpha_1) & 1 & -\alpha_1 & -1 & -a+\alpha_1\cdot\log\left(\dfrac{1-\alpha_1}{\alpha_1}\right) \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{pmatrix}$$

$f^*_{i,t}$ being the vector of factor optimal levels, in log, $d_{i,t}$ the vector of factor optimal level determinants, in log, and $C1$ a matrix of coefficients.

Concerning factor adjustments, the firm minimizes the sum of two costs: the cost of deviation from the optimum factor mix ($CD_{i,t}$) and the cost of change in factors ($CC_{i,t}$). Each of these costs is assumed to be symmetric, and can be for example represented by a quadratic sum:

$$CD_{i,t} = \sum_j cd_j \cdot [f^*_{i,j,t} - f_{i,j,t}]^2 \text{ and } CC_{i,t} = \sum_j cc_j \cdot [f_{i,j,t} - f_{i,j,t-1}]^2$$

From this, variations of each factor will depend on deviation from the optimum of this factor and other factors:

$$f_{i,j,t} - f_{i,j,t-1} = \sum_{k=1}^{5} \beta_{j,k} \cdot (f^*_{i,k,t} - f_{i,k,t-1})$$

$\beta_{j,k}$ corresponds to the adjustment of the factor j correcting the adjustment gap of factor k observed in the previous period. We have:

$$\beta_{j,k} \geq 0, \; \forall j, k \tag{3}$$

Turning in matrix notation:

$$\begin{gathered} \Delta f_{i,t} = \beta \cdot (f^*_{i,t} - f_{i,t-1}) \\ (5,1) = (5,5) \cdot (5,1) \end{gathered} \tag{4}$$

With:

$$\Delta f_{i,t}=\begin{pmatrix} k_{i,t}-k_{i,t-1} \\ l_{i,t}-l_{i,t-1} \\ cu_{i,t}-cu_{i,t-1} \\ hk_{i,t}-hk_{i,t-1} \\ hl_{i,t}-hl_{i,t-1} \end{pmatrix}, \beta=\begin{pmatrix} \beta_{1,1} & \cdots & \beta_{1,5} \\ \vdots & \ddots & \vdots \\ \beta_{5,1} & \cdots & \beta_{5,5} \end{pmatrix} \text{ and}$$

$$f^{*}_{i,t}-f_{i,t-1}=\begin{pmatrix} k^{*}_{i,t}-k_{i,t-1} \\ l^{*}_{i,t}-l_{i,t-1} \\ cu^{*}_{i,t}-cu_{i,t-1} \\ hk^{*}_{i,t}-hk_{i,t-1} \\ hl^{*}_{i,t}-hl_{i,t-1} \end{pmatrix}$$

Thus, $\Delta f_{i,t}$ is the vector of factor variations, $f^{*}_{i,t}-f_{i,t-1}$ the vector of factor deviations from their optimum levels and β the matrix of adjustment parameters.

For some estimates, we also consider another version of the model where the capital operating time is, for the firms which declared having met with an obstacle to increasing capital operating time, corrected by an extra adjustment of the four other production factors.

In this case, we have:

$$\Delta f_{i,t}=\beta''\cdot(f^{*}_{i,t}-f_{i,t-1}) \\ (5,1)=(5,5)\cdot(5,1) \tag{4'}$$

With: $\beta''=\begin{pmatrix} \beta_{1,1} & \cdots & \beta''_{1,4} & \beta_{1,5} \\ \vdots & \ddots & \vdots & \vdots \\ \beta_{5,1} & \cdots & \beta''_{5,4} & \beta_{5,5} \end{pmatrix}$ and $\beta''_{j,4}=\beta_{j,4}+(1_{\text{Obstacles}}\cdot\beta'_{j,4})$, j=1, …, 5

$1_{\text{Obstacles}}$ being equal to one for firms facing obstacles and to zero for others.

From relations (2) and (4) we get:

$$f_{i,t}=C2\cdot d_{i,t}+(I-\beta)\cdot f_{i,t-1}+\varepsilon_{i,t} \tag{5}$$

With: $C2=\beta\cdot C1$

In case of obstacles, $C2$ becomes $C2''$, with $C2''=\beta''{}^{*}C1$.

We introduce a vector of error terms $\varepsilon_{i,t}$ in model (5). More precisely, in each equation, the perturbation is assumed to be the sum of a component specific to the firm constant through time and a time varying component:

$$\varepsilon_{i,t}=u_i+e_{i,t}=\begin{pmatrix}\varepsilon_{i,t}^{\ k}\\ \varepsilon_{i,t}^{\ l}\\ \varepsilon_{i,t}^{\ cu}\\ \varepsilon_{i,t}^{\ hk}\\ \varepsilon_{i,t}^{\ hl}\end{pmatrix}=\begin{pmatrix}u_i^{k}+e_{i,t}^{\ k}\\ u_i^{l}+e_{i,t}^{\ l}\\ u_i^{cu}+e_{i,t}^{\ cu}\\ u_i^{hk}+e_{i,t}^{\ hk}\\ u_i^{hl}+e_{i,t}^{\ hl}\end{pmatrix}$$

Therefore, u_i is the vector of unobserved heterogeneities and $e_{i,t}$ the vector of idiosyncratic errors varying cross i and t. The components of u_i depend only on the firm i and do not vary over time. Thus, they summarize permanent behavioral differences between firms, which are not taken into account by the explanatory variables and that nevertheless influence the dependent variable.

We assume that the fixed effect is correlated with the explanatory variables. This assumption is also obvious as we are dealing with a dynamic panel model. By definition, the autoregressive model implies a correlation between the error term and the lagged dependent variable. We also assume weak exogeneity: only past values of explanatory variables are uncorrelated with time varying components. And finally, individual effects are uncorrelated with the time varying component.

The coefficients to be estimated are the adjustment ones $\beta_{j,k}$ and the capital elasticity α_1.

Regarding the coefficients $\beta_{j,k}$, in most of the estimates, we assume that the impact on the output of the adjustment gap of each factor (in terms of difference with its optimal level) is exactly offset by the adjustment gap of the four other factors. This constraint means:[3]

$$\begin{cases}\beta_{1,1}+\dfrac{1-\alpha_1}{\alpha_1}\cdot\beta_{2,1}+\beta_{3,1}+\beta_{4,1}+\dfrac{1-\alpha_1}{\alpha_1}\cdot\beta_{5,1}=1\\ \dfrac{\alpha_1}{1-\alpha_1}\cdot\beta_{1,2}+\beta_{2,2}+\dfrac{\alpha_1}{1-\alpha_1}\cdot\beta_{3,2}+\dfrac{\alpha_1}{1-\alpha_1}\cdot\beta_{4,2}+\beta_{5,2}=1\\ \beta_{1,3}+\dfrac{1-\alpha_1}{\alpha_1}\cdot\beta_{2,3}+\beta_{3,3}+\beta_{4,3}+\dfrac{1-\alpha_1}{\alpha_1}\cdot\beta_{5,3}=1\\ \beta_{1,4}+\dfrac{1-\alpha_1}{\alpha_1}\cdot\beta_{2,4}+\beta_{3,4}+\beta_{4,4}+\dfrac{1-\alpha_1}{\alpha_1}\cdot\beta_{5,4}=1\\ \dfrac{\alpha_1}{1-\alpha_1}\cdot\beta_{1,5}+\beta_{2,5}+\dfrac{\alpha_1}{1-\alpha_1}\cdot\beta_{3,5}+\dfrac{\alpha_1}{1-\alpha_1}\cdot\beta_{4,5}+\beta_{5,5}=1\end{cases}\tag{6}$$

3 For example, concerning the capital stock, this assumption means (see relation (4)) that: $\left(\beta_{1,1}+\frac{1-\alpha_1}{\alpha_1}\cdot\beta_{2,1}+\beta_{3,1}+\beta_{4,1}+\frac{1-\alpha_1}{\alpha_1}\cdot\beta_{5,1}\right)\cdot(k_{i,t}^{*}-k_{i,t-1})=k_{i,t}^{*}-k_{i,t-1}$ which means: $\beta_{1,1}+\frac{1-\alpha_1}{\alpha_1}\cdot\beta_{2,1}+\beta_{3,1}+\beta_{4,1}+\frac{1-\alpha_1}{\alpha_1}\cdot\beta_{5,1}=1$.

In case of firms facing obstacles, $\beta_{j,4}$ becomes $\beta''_{j,4}=\beta_{j,4}+(1_{\text{Obstacles}}\cdot\beta'_{j,4})$.

Regarding capital elasticity α_1, we observe that the share of the capital in the value added is equal to 0.3037 in average, although it varies significantly across sectors. As it would be difficult to use sector-varying α_1, in most of the estimates, we assume the constraint:

$$\alpha_1=0.3 \tag{7}$$

We will see later in the robustness checking section that if we estimate α_1 and do not calibrate this parameter, the estimated values of the other coefficients (and then of the $\beta_{j,k}$) are not modified. Given the potential bias in the estimate of this coefficient (see Griliches and Mairesse 1998), our preferred specification relies on the calibrated α_1.

3.2 The estimation strategy

To estimate the model, we first eliminate the individual fixed effect by differentiation, so that estimation is consistent. However, it is not sufficient for solving the estimation biases. As fixed effect and weak exogeneity are by construction present in our case due to the dynamic character of the model, usual estimators are not consistent.

In this framework, estimation of model (5) can be performed using the First-difference GMM estimator. The difference GMM uses first-differences to transform model (5) into model (8):[4]

$$\Delta f_{i,t}=C2\cdot\Delta d_{i,t}+(I-\beta)\cdot\Delta f_{i,t-1}+\Delta\varepsilon_{i,t} \tag{8}$$

In case of firms facing obstacles, the estimated model becomes:

$$\Delta f_{i,t}=C2\cdot\Delta d_{i,t}+(I-\beta'')\cdot\Delta f_{i,t-1}+\Delta\varepsilon_{i,t} \tag{9}$$

Thus, fixed firm-specific effects are removed by differencing instead of within-transforming, but in each equation, there remains a problem of correlation between the lagged dependent variable and the error term in first difference. The first-differenced lagged dependent variable is then instrumented with its past levels from 2 periods or more, by averages computed at the sector level, annual average working hours and a dummy reflecting the organization in shift work (or not) of the firm (cf. Appendix E). By this method, efficient estimates are obtained.

Performance of the First-difference GMM estimator depends strongly on the validity of the instruments. In fact, as Blundell and Bond (1998) have shown,

4 The estimated model is developed in Appendix C and D.

the First-difference GMM estimator gives biased results in finite samples when instruments are weak. The System-GMM estimator is much more powerful than the First-difference GMM estimator to tackle the problem of weak instruments. In our case, we cannot directly implement the System-GMM estimator because the latter combines first-difference equations with equations in levels: differences are instrumented with levels and levels with differences. We use in fact a variable that is not available in level in our sample: it is the capital operating time (Δhk). We must therefore pay particular attention to the relevance of the instruments (correlation with the endogenous variables). The relevance condition may be easily tested by examining the fit of the first-stage regressions. The first-stage regressions correspond to regressions of the endogenous variables on the full set of instruments. We focus on the explanatory power of the excluded instruments in these regressions. The F-statistic of the joint significance of the excluded instruments in the first-stage regressions is not sufficiently informative for models with multiple endogenous variables. Thus, we focus on partial tests of significance (see Appendix D for results).

The results show that the instruments used can be accepted from the point of view of their explanatory power insofar as there is at least one instrument which significantly affects each endogenous variable. In order to avoid the issue of bias of the GMM estimator, which increases at finite distance with the number of lags of instruments, only lags 2 and 3 of the endogenous variables have been initially included. However, weak correlations, as shown by the first-stage regressions, between lags 3 of instruments and the endogenous variables led us to retain finally lags of order 2, except the variable "relative cost of labor" which was instrumented by its level of third order. In addition, to tackle the endogeneity of the labor workweek, which is vitiated by measurement errors, we made use of other instruments that have proved effective. There are annual average working hours (provided by national accounts data), sectoral average net sales and sectoral external staff.

4 Results

Estimation results of model (6) with constraints (3), (6) and (7) are reported in Table 1.

Column (1) presents the GMM results. It appears that the adjustment of each factor to its own previous-year gap differs a lot among factors. Within a year, this adjustment would be close to 20% for the capital volume ($\beta_{1,1}$=0.205), 25% for the labor volume ($\beta_{2,2}$=0.250), 30% for the labor working time ($\beta_{5,5}$=0.292),

Table 1: Benchmark estimate results.

Parameters	Adjusted factor:	To offset gap in:	GMM		OLS
			Benchmark	Benchmark-non null coef.	
β_{11}	*k*	*k*	0.205***	0.207***	0.261***
			(0.035)	(0.035)	(0.008)
β_{12}	*k*	*l*	0	0	0.072***
					(0.011)
β_{13}	*k*	*cu*	0	0	0
β_{14}	*k*	*hk*	0	0	0
β_{15}	*k*	*hl*	0	0	0
β_{21}	*l*	*k*	0.116***	0.139***	0.106***
			(0.03)	(0.025)	(0.005)
β_{22}	*l*	*l*	0.25***	0.277***	0.536***
			(0.046)	(0.041)	(0.006)
β_{23}	*l*	*cu*	0	0	0
β_{24}	*l*	*hk*	0.116	0	0
			(0.072)		
β_{25}	*l*	*hl*	0.168**	0.203***	0.107 ***
			(0.066)	(0.06)	(0.024)
β_{31}	*cu*	*k*	0.272***	0.238***	0.077***
			(0.056)	(0.051)	(0.007)
β_{32}	*cu*	*l*	0.845***	0.806***	0.192***
			(0.086)	(0.083)	(0.01)
β_{33}	*cu*	*cu*	0.845***	0.844***	1
			(0.033)	(0.034)	
β_{34}	*cu*	*hk*	0.384***	0.55***	0.117***
			(0.137)	(0.095)	(0.013)
β_{35}	*cu*	*hl*	0.51***	0.461***	0
			(0.116)	(0.111)	

Table 1 (continued)

Parameters	Adjusted factor:	To offset gap in:	GMM		OLS
			Benchmark	Benchmark-non null coef.	
β_{41}	*hk*	*k*	0.254***	0.232***	0.083***
			(0.045)	(0.041)	(0.004)
β_{42}	*hk*	*l*	0.761***	0.742***	0.181***
			(0.071)	(0.067)	(0.005)
β_{43}	*hk*	*cu*	0.113***	0.112***	0
			(0.028)	(0.027)	
β_{44}	*hk*	*hk*	0.345***	0.45***	0.883***
			(0.119)	(0.095)	(0.013)
β_{45}	*hk*	*hl*	0.748***	0.724 ***	0
			(0.096)	(0.091)	
β_{51}	*hl*	*k*	0	0	0.142***
					(0.004)
β_{52}	*hl*	*l*	0.061***	0.06***	0.273***
			(0.019)	(0.019)	(0.005)
β_{53}	*hl*	*cu*	0.018**	0.019**	0
			(0.008)	(0.008)	
β_{54}	*hl*	*hk*	0	0	0
β_{55}	*hl*	*hl*	0.292***	0.289***	0.893***
			(0.032)	(0.032)	(0.024)
Nb. Obs.			6066	6066	6066
Hansen J-stat			45.24	48.11	
p-Value			0.4199	0.6276	

Standard errors in parentheses; $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$. Estimates of equation 6 by GMM and OLS. $\beta_{41}=0.254$ in the first column means that the capital operating time makes up for 25% of the capital stock gap.

35% for the capital operating time ($\beta_{4,4}$=0.345) and 85% for the capital utilization rate ($\beta_{3,3}$=0.845). This hierarchy is the same, for the factors included in both studies, as in Nadiri and Rosen (1969, 1973) and it is consistent with the supposed ranking of factor adjustment costs. Capital utilization and capital operating time changes should hence be viewed as the most reactive indicators of the cycle. It appears also that capital volume gaps are slightly corrected by adjustments of labor volume ($\beta_{2,1}$=0.116) and mostly by adjustments of capital utilization rate ($\beta_{3,1}$=0.272) and by adjustments of capital operating time ($\beta_{4,1}$=0.254), while labor working time is not used to offset this gap. The labor volume adjustment gaps are slightly corrected by adjustments of labor working time ($\beta_{5,2}$=0.061), which may seem low, but has to be put in perspective with the limited legal leeway in adjusting this utilization in year average level. The working time flexibility is greater in a shorter time dimension (week, month or even quarter), although not as great as for other factor utilization due to legal constraints (maximum daily and weekly working time), cost of overtime pay and potential employee opposition. Our workweek measure may capture only a yearly measure if corresponding to legal or contractual working time, which could be often the case (cf. Section 2.). Labor volume adjustment gaps are hence offset by adjustments in the capital operating time ($\beta_{4,2}$=0.761) but mostly by adjustment in the capital utilization rate ($\beta_{3,2}$=0.845). Hence, changes in capital utilization and capital operating time could be seen as good predictors of investment and employment changes. Labor working time adjustment gaps are corrected by adjustments of labor volume, but mostly of capital operating time and of capital utilization rate ($\beta_{1,5}$≈0, $\beta_{2,5}$=0.168 and $\beta_{4,5}$=0.748 and $\beta_{3,5}$=0.510), capital operating time adjustment gaps are mostly corrected by adjustments of capital utilization rate ($\beta_{1,4}$≈$\beta_{2,4}$≈$\beta_{5,4}$≈0 and $\beta_{3,4}$≈0.384) and capital utilization rate adjustment gaps are also very slightly corrected by adjustments of labor working time and of capital operating time ($\beta_{1,3}$≈$\beta_{2,3}$≈0 and $\beta_{5,3}$=0.018 and $\beta_{4,3}$=0.113).

So, the main significant results of these estimates are that: i) factor volumes do not correct the adjustment gaps of factor utilization degrees;[5] ii) the adjustment gaps of factor volumes are slowly corrected by their own adjustment and in a first stage by adjustments of capital operating time and of capital utilization rate; iii) changes in factor utilization degrees correct their own adjustment gaps and the adjustment gaps of other factors with a clear hierarchy in terms of flexibility, labor working time being the less flexible degree, correcting only slightly other factor adjustment gaps, capital utilization rate being the most flexible and contributing to correct in an important proportion all other factor adjustment

5 Apart from employment to labor workweek, but this result may hinge on the 35-h week implementation, see later the comment of Table 2, column 2.

gaps, and capital operating time being only slightly less flexible than capital utilization rate. These results are consistent with the ones obtained by Nadiri and Rosen (1969, 1973) for common factors in terms of relative factor flexibility and speed of adjustment. When constraining insignificant coefficients in this first column to zero, in order to limit multicollinearity (Table 1, column 2), the results barely change: capital operating time self-adjustment is only slightly larger.

These results are illustrated by Figures 1 and 2 which present in levels and changes the impact of a 1% positive shock on value added. Due to this shock, the targets for the factor volumes (capital and labor) increase also each by 1% and the targets of the three factor utilization degrees do not change (see relation (2)). Factor volumes adjust slowly to their targets, capital adjusting much slower than employment. Factor utilization degrees increase immediately to offset the slow adjustment of factor volumes, this immediate reaction being stronger for capital utilization rate and for capital operating time than for labor working time. It means that during the whole process of slow capital adjustment, capital is below its target and factor utilization degrees above their targets. It even appears that the capital adjustment process is so slow that labor volume offset the capital gap for several years, leading employment to overshoot its target during this sub-period. The adjustment process is slow: it takes 3 years for the capital stock to adjust about 72% of its new target, 10 years to fully adjust and consequently for the three factor utilization degrees to come back to their initial levels which

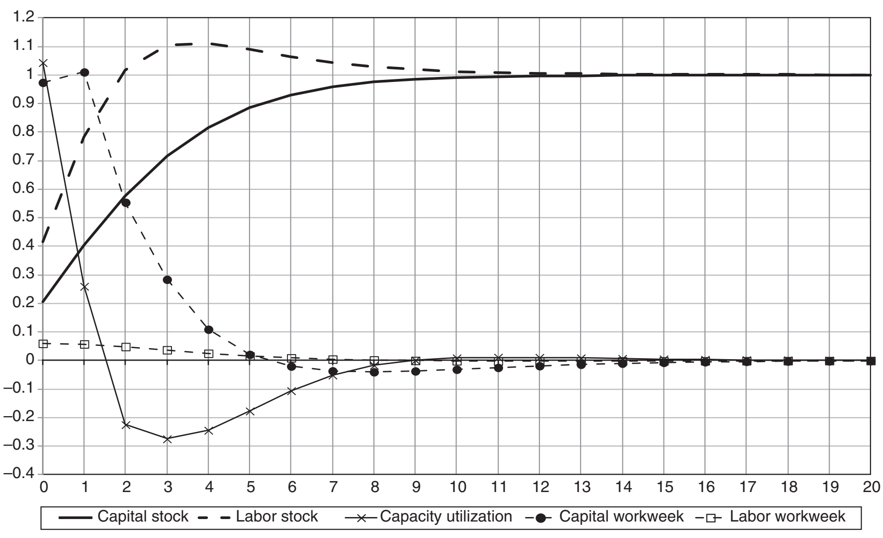

Figure 1: Simulation of the impact of a 1% increase in value added, level (% gap with the benchmark levels) from benchmark estimate results.

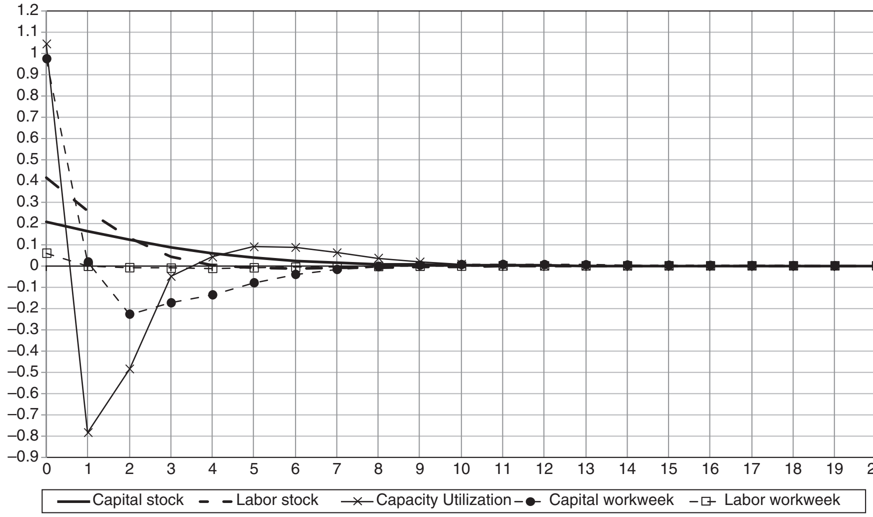

Figure 2: Simulation of the impact of a 1% increase in value added, changes (% change over the previous period) from benchmark estimate results.

correspond to their own targets. These paces are in line with Nadiri and Rosen's estimates on US data, but slightly slower than in Shapiro (1986), where capital fully adjusts after 4 years.

The results obtained for OLS estimates of the same model are qualitatively close to the ones obtained with the GMM estimates (Table 1, columns 1 and 2 compared to column 3), although self-adjustment coefficients tend to be higher, which gives a first robustness check of the results.

Table 2 presents alternative specification and the specific question of the impact of obstacles to increasing capital operating time. The comparison with the benchmark results may be tricky as the samples are smaller in these alternative estimates, but we can see that the main results are unchanged.

Column (2) presents the estimation results without the implementation years of the 35-h workweek (1998, 1999 and 2000). The regulatory change from the 39-h to the 35-h workweek may indeed have biased the estimates of the role of labor utilization, although change in the target workweek may have alleviated that problem. Without these years, labor volume no longer offsets labor working time gaps ($\beta_{2,5}\approx 0$), which tends to support the idea that the implementation of the 35-h workweek led firms to hire workers in order to offset the reduction in working time. Labor working time gaps are no longer offset by capital utilization but more by capital operating time. Finally, labor working time tends to adjust faster to its own target without the 35-h workweek implementation years, in a way which is more in line with the adjustment of the two other utilization degrees.

Table 2: Estimate results of alternative specifications.

Parameters	Adjusted factor:	To offset gap in:	Benchmark-non null coef.	Without 1998, 1999 and 2000	Shiftwork≠0	With obstacles	With ICT
β_{11}	*k*	*k*	0.207***	0.177***	0.242***	0.193***	0.203***
			(0.035)	(0.037)	(0.04)	(0.035)	(0.033)
β_{12}	*k*	*l*	0	0	0.017	0	0
					(0.049)		
β_{13}	*k*	*cu*	0	0	0.011	0	0
					(0.02)		
β_{14}	*k*	*hk*	0	0	0	0	0
β_{15}	*k*	*hl*	0	0	0	0	0
β_{21}	*l*	*k*	0 139***	0.105***	0.081**	0.106***	0.151***
			(0.025)	(0.03)	(0.034)	(0.029)	(0.025)
β_{22}	*l*	*l*	0.277***	0.346***	0.26***	0.279***	0.271***
			(0.041)	(0.052)	(0.05)	(0.044)	(0.041)
β_{23}	*l*	*cu*	0	0	0	0	0
β_{24}	*l*	*hk*	0	0.007	0.157*	0.048	0
				(0.074)	(0.083)	(0.113)	
β_{25}	*l*	*hl*	0.203***	0	0.164**	0.207***	0.134*
			(0.06)		(0.077)	(0.064)	(0.079)
β_{31}	*cu*	*k*	0.238***	0.295***	0.288***	0.298***	0.230***
			(0.051)	(0.062)	(0.06)	(0.054)	(0.051)
β_{32}	*cu*	*l*	0.806***	0.808***	0.782***	0.863***	0.829***
			(0.083)	(0.1)	(0.089)	(0.081)	(0.081)
β_{33}	*cu*	*cu*	0.844***	0.86***	0.895***	0.855***	0.848***
			(0.034)	(0.035)	(0.036)	(0.033)	(0.033)
β_{34}	*cu*	*hk*	0.55***	0.342**	0.285**	0	0.517***
			(0.095)	(0.167)	(0.139)		(0.096)

Table 2 (continued)

Parameters	Adjusted factor:	To offset gap in:	Benchmark-non null coef.	Without 1998, 1999 and 2000	Shiftwork≠0	With obstacles	With ICT
β_{35}	*cu*	*hl*	0.461***	0.04	0.455***	0.498***	0.350**
			(0.111)	(0.263)	(0.12)	(0.116)	(0.139)
β_{41}	*hk*	*k*	0.232***	0.283***	0.281***	0.261***	0.216***
			(0.041)	(0.046)	(0.054)	(0.043)	(0.041)
β_{42}	*hk*	*l*	0.742***	0.565***	0.822***	0.719***	0.752***
			(0.067)	(0.074)	(0.081)	(0.07)	(0.066)
β_{43}	*hk*	*cu*	0.112***	0.1***	0.08***	0.108***	0.112***
			(0.027)	(0.031)	(0.028)	(0.028)	(0.027)
β_{44}	*hk*	*hk*	0.45***	0.642***	0.349***	0.888***	0.483***
			(0.095)	(0.136)	(0.135)	(0.263)	(0.096)
β_{45}	*hk*	*hl*	0.724***	1.255***	0.838***	0.705***	0.776***
			(0.091)	(0.256)	(0.116)	(0.094)	(0.114)
β_{51}	*hl*	*k*	0	0	0	0	0
β_{52}	*hl*	*l*	0.06***	0.065***	0.046*	0.043**	0.051***
			(0.019)	(0.018)	(0.024)	(0.021)	(0.018)
β_{53}	*hl*	*cu*	0.019**	0.017**	0.006	0.016**	0.017**
			(0.008)	(0.008)	(0.007)	(0.008)	(0.007)
β_{54}	*hl*	*hk*	0	0	0	0	
β_{55}	*hl*	*hl*	0.289***	0.445***	0.282***	0.277***	0.384***
			(0.032)	(0.089)	(0.042)	(0.036)	(0.042)
β'_{14}	*k*	*hk*	–	–	–	0	–
β'_{24}	*l*	*hk*	–	–	–	0.013	–
						(0.163)	
β'_{34}	*cu*	*hk*	–	–	–	0.657***	–
						(0.216)	

Table 2 (continued)

Parameters	Adjusted factor:	To offset gap in:	Benchmark-non null coef.	Without 1998, 1999 and 2000	Shiftwork≠0	With obstacles	With ICT
β'_{44}	*hk*	*hk*	–	–	–	−0.888***	–
						(0.263)	
β'_{54}	*hl*	*hk*	–	–	–	0.086	–
						(0.053)	
Nb. Obs.			6066	4776	3856	5683	6066
Hansen J-stat			48.11	35.29	54.35	52.29	46.77
p-Value			0.6276	0.4072	0.1363	0.183	0.3595

Standard errors in parentheses; *$p<0.1$, **$p<0.05$, ***$p<0.01$. “With obstacles” refers to the sample of firms which declared having met with an obstacle to increasing capital operating time.

Column (3) presents the results on the subsample of firms organized in shift work. These firms may have more leeway in changing their capital operating time. Coefficients are only slightly different from the ones of the benchmark result, although capital operating time tends to more strongly offset gaps in capital, labor or labor workweek. Employment tends to substitute for capital operating time gaps in these firms.

Column (4) presents the estimates taking into account obstacles to increases in capital operating time through obstacles dummies interacted with the capital operating time gaps. In that way, we can see how other factors are substituting for capital operating time gaps when increases in capital operating time are constrained. It shows that, compared to firms not facing any obstacles, firms facing obstacles cannot adjust their capital operating time to return to target ($\beta_{4,4}+\beta'_{4,4}\approx 0$) and offset that rigidity through capacity utilization. Hence, substitution of capital operating time gap by capacity utilization, which appears significant in the benchmark results, hinges entirely on firms facing obstacles to increase their capital operating time, as shown by $\beta_{3,4}\approx 0$ in column (4) of Table 2.

Column (5) uses an alternative decomposition of the capital stock, including sector-level data on shares for three types of capital, communication equipment, softwares and information technology, from Cette, Clerc and Bresson (2015) combined with firm-level information on building and equipment capital shares to compute capital depreciation. For these three types of capital, we use specific and higher depreciation rates taken from Cette and Lopez (2012). The results display only one limited differences: the adjustment of employment to offset labor working time gap is lower and almost non-significant, which is more satisfactory than the benchmark results.

5 Other robustness tests

We focus here on the robustness of our benchmark estimation reported in Table 1, column 1. We test the robustness of this benchmark to the relaxation of the constraints. These robustness estimates are reported in Table 3.

We relax the constraints one by one. First, we relax constraint (7), which sets that the impact on the output of the adjustment gap of each factor (in terms of difference with its optimal level) is exactly offset by the adjustment gap of the four other factors (column 2). Hence, we allow here an overreaction of some factors to the adjustment gap of other factors, which would have no impact on output. It turns out that the main changes are that the adjustment to its target of capital operating time is much faster than before and that substitution of labor and

Table 3: Robustness to constraints estimate results.

Parameters	Adjusted factor:	To offset gap in:	Benchmark-non null coef.	Without equality constraints (=1)	Without positivity constraints	α_1 unconstrained
α_1			0.3	0.3	0.3	0.278***
						(0.06)
β_{11}	*k*	*k*	0.207***	0.246***	0.247***	0.207***
			(0.035)	(0.053)	(0.041)	(0.036)
β_{12}	*k*	*l*	0	0.068	0.002	0
				(0.068)	(0.069)	
β_{13}	*k*	*cu*	0	0.009	−0.001	0
				(0.023)	(0.023)	
β_{14}	*k*	*hk*	0	0	−0.203	0
					(0.124)	
β_{15}	*k*	*hl*	0	0	−0.055	0
					(0.103)	
β_{21}	*l*	*k*	0.139***	0.112**	0.103***	0.112***
			(0.025)	(0.046)	(0.032)	(0.031)
β_{22}	*l*	*l*	0.277***	0.301***	0.225***	0.277***
			(0.041)	(0.086)	(0.05)	(0.073)
β_{23}	*l*	*cu*	0	0	−0.024	0
					(0.016)	
β_{24}	*l*	*hk*	0	0.348***	0.176**	0.099
				(0.134)	(0.081)	(0.072)
β_{25}	*l*	*hl*	0.203***	0.141	0.14**	0.187**
			(0.06)	(0.1)	(0.07)	(0.078)
β_{31}	*cu*	*k*	0.238***	0.291**	0.268***	0.257***
			(0.051)	(0.136)	(0.057)	(0.066)

Table 3 (continued)

Parameters	Adjusted factor:	To offset gap in:	Benchmark-non null coef.	Without equality constraints (=1)	Without positivity constraints	α_1 unconstrained
β_{32}	*cu*	*l*	0.806***	1.026***	0.86***	0.895***
			(0.083)	(0.305)	(0.095)	(0.207)
β_{33}	*cu*	*cu*	0.844***	0.9***	0.877***	0.838***
			(0.034)	(0.073)	(0.039)	(0.036)
β_{34}	*cu*	*hk*	0.55***	1.03**	0.415***	0.417***
			(0.095)	(0.427)	(0.157)	(0.15)
β_{35}	*cu*	*hl*	0.461***	0.525	0.552***	0.552***
			(0.111)	(0.321)	(0.129)	(0.193)
β_{41}	*hk*	*k*	0.232***	0.271**	0.242***	0.244***
			(0.041)	(0.114)	(0.047)	(0.055)
β_{42}	*hk*	*l*	0.742***	0.931***	0.788***	0.819***
			(0.067)	(0.265)	(0.078)	(0.175)
β_{43}	*hk*	*cu*	0.112***	0.147**	0.127***	0.118***
			(0.027)	(0.06)	(0.032)	(0.029)
β_{44}	*hk*	*hk*	0.45***	0.935**	0.388***	0.326**
			(0.095)	(0.372)	(0.128)	(0.13)
β_{45}	*hk*	*hl*	0.724***	0.78***	0.785***	0.806***
			(0.091)	(0.267)	(0.104)	(0.165)
β_{51}	*hl*	*k*	0	0	0.001	0
					(0.014)	
β_{52}	*hl*	*l*	0.06***	0.071**	0.068***	0.064***
			(0.019)	(0.03)	(0.023)	(0.022)
β_{53}	*hl*	*cu*	0.019**	0.023**	0.023***	0.017**
			(0.008)	(0.009)	(0.009)	(0.008)

Table 3 (continued)

Parameters	Adjusted factor:	To offset gap in:	Benchmark-non null coef.	Without equality constraints (=1)	Without positivity constraints	α_1 unconstrained
β_{54}	*hl*	*hk*	0	0.034	−0.005	0
				(0.039)	(0.04)	
β_{55}	*hl*	*hl*	0.289***	0.284***	0.31***	0.291***
			(0.032)	(0.042)	(0.036)	(0.033)
Nb. Obs.			6066	6066	6066	6066
Hansen J-stat			48.11	40.97	38.7	41.08
p-Value			0.6276	0.6022	0.6976	0.3373

Standard errors in parentheses; $*p<0.1$, $**p<0.05$, $***p<0.01$. Estimates of benchmark equation in Table 1 column 1 with alleviated constraints.

capacity utilization for labor workweek gaps are no longer significant. Both labor and capacity utilizations now substitute more strongly to capital operating time gaps. Overall, capital operating time is at the center of stronger adjustments and labor workweek of weaker adjustments when relaxing this constraint. We may note however that most coefficients are less precisely estimated that way.

We then relax the positivity constraint on the coefficients β (column 3). This means that we may reveal complementarities between two factors. Most coefficients are unaltered. No coefficients turn out to be significantly negative: substitution of capital stock for capital operating time gap is negative but not significant, although it could make sense that these two factors may be complementary. Substitution of labor for capital operating gaps turns out in this context to be significantly positive, which appears in several robustness checks and may hence be considered as a relevant alternative results.

Finally, we relax the constraint on α_1 to be equal to the capital share in revenue (column 4). Due to measurement errors, this coefficient may be particularly difficult to estimate and downward biased (Griliches and Mairesse 1998). The estimate of α_1 is significant, only slightly below 0.3 but not significantly different from it. Other coefficients are hence almost unaltered in sign, significance or magnitude. We also set α_1 to be equal to the maximum and minimum capital share in revenue across sectors: the estimated speeds of adjustment are affected but not their ranking.

As said in the data section, each time one observation was missing for a given firm, we interpolated its value taking the average of its one-period past and one-period next observations. About 9% of the observations are interpolated that way. To see if this treatment could influence the estimates, we ran the estimates without the interpolated data. Results are broadly unchanged and not qualitatively altered.

The robustness to alternative initialization values of the coefficients in the estimation procedure was tested and the coefficients were strictly unaltered.

6 Conclusion

Using a very original survey yielding an unbalanced panel of 6066 observations of French firms over 1993–2010, we have studied production factor adjustment taking into account factor utilization degrees in all their dimensions (labor working time, capital operating time and capital capacity utilization).

Our main results are the following: i) Factor utilization degrees adjust the most rapidly, first through capital capacity utilization and capital operating time, finally through labor working time. The adjustment is slow for the number of employees and even slower for the capital stock; ii) In case of a change in the capital stock target, the three factor utilization degrees, as well as employment in a lesser proportion, adjust to offset the very slow reaction of the capital stock. Similarly, in case of a change in the employment target, the three factor utilization degrees offset the slow adjustment of this factor; iii) Among the three factor utilization degrees, these balancing reactions are stronger for capital utilization rate than for capital operating time, and stronger for capital operating time than for labor working time; iv) Obstacles to increasing capital operating time lead to a slower adjustment of capital operating time, the short-term adjustment relying more on capacity utilization.

These results confirm and deepen those of previous analysis, as those of Nadiri and Rosen (1969, 1973). But to the best of our knowledge, it is the first time that the role of factor utilization degrees to offset the slow adjustment of factor volumes, and mainly of capital volume, is shown on individual firm data, and that the role of different types of obstacles to changes in the production process is empirically raised. Although we cannot certify our sample is representative, the convergence of our results with Nadiri and Rosen's supports their macroeconomic significance. One limitation of our model is the absence of intermediates consumption as an adjustment factor.

These results lead to several policy conclusions. Flexible factor utilization degrees are essential to offset the inertia of factor volumes, and mostly capital. Obstacles to this flexibility could prevent output adjustment, which could lead to higher production costs (if factor volumes or inventories are oversized) or inflationary pressures (if firms are unable to adapt their production to demand fluctuations). Means to ease this flexibility have to be considered. For example, regulatory obstacles should, whenever possible, be replaced by collective agreements between social partners. Thanks to a better adaptation to each firm specificities and needs, social collective bargaining is more appropriate than regulations to allow firm to get the most appropriate factor adjustments to external shocks as for example demand ones.

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Appendix A: Descriptive statistics

Variable	Description	Unit	Source	P10	Q1	Mean	Median	Q3	P90	Standard error
y	Value added in volume per year	’000 €	FiBEn	1118.54	1850.27	10436.85	4030.76	10268.08	24354.0500	22767.5300
k	Capital stock in volume	’000 €	FiBEn	888.73	1872.34	17209.06	4583.85	13890.45	41394.8100	43093.0200
l	Average number of employees	Full-time equivalent	FiBEn	28.00	44.00	203.97	98.00	214.00	495.0001	365.1808
cu	Capital capacity utilization	%	FUDS	65.00	75.00	82.35	85.00	90.00	97.0000	13.2252
hl	Employee workweek length	hours	FUDS	3.56	3.56	3.61	3.63	3.66	3.6636	0.0551
w	Annual wage per employee	’000 €	FiBEn	24.2	28.0	34.0	32.8	38.4	45.3	8.6
c	User cost of capital	Log		−2.40	−2.25	−2.15	−2.12	−2.02	−1.9420	0.1962
cr	Relative cost of labor	Log		5.26	5.44	5.65	5.63	5.84	6.0579	0.3172
Δy	Change in log value added	ΔLog ’000 €	FiBEn	−0.19	−0.07	0.01	0.02	0.11	0.2070	0.2012
Δk	Change in log capital stock	ΔLog ’000 €	FiBEn	−0.04	0.00	0.04	0.03	0.07	0.1405	0.1703
Δl	Change in log number of employees	ΔLog full-time equivalent	FiBEn	−0.10	−0.04	−0.01	0.00	0.03	0.0788	0.0939
Δcu	Change in capital capacity utilization	Δ%	FUDS	−13.35	−3.64	0.00	0.00	3.17	13.3531	17.5648
Δhk	Change in the workweek of capital	%	FUDS	−6.00	0.00	0.88	0.00	0.00	10.0000	8.3004
Δhl	Change in log employee workweek	ΔLog hours	FUDS	−0.04	0.00	−0.01	0.00	0.00	0.0078	0.0341
Δw	Change in log annual wage per employee	ΔLog ’000 €	FiBEn	−0.06	−0.01	0.02	0.02	0.06	0.1012	0.0757
Δc	Change in log capital user cost	ΔLog		−0.29	−0.10	0.00	−0.01	0.09	0.3141	0.2570
Δcr	Change in the relative cost of labor	ΔLog		−0.31	−0.10	0.02	0.03	0.15	0.3275	0.2687

Appendix B: Industry coverage

Share of industries in total sample (%)			
Classification DA38	**Share in value added**	**Share in production**	**Share in employment**
CA-Food industries	11.7	20.6	10.9
CB-Textiles	4.2	3.4	6.8
CC-Wood, paper, printing	9.4	8.9	9.3
CE-Chemicals	8.3	9.2	5.0
CF-Pharmaceuticals	1.0	0.9	0.6
CG-Rubber	8.9	6.7	9.0
CH-Metal products	17.3	14.8	18.8
CI-Computer, electronics	3.9	2.9	3.7
CJ-Electric equipment	5.5	4.8	5.4
CK-Machines	13.7	12.4	13.2
CL-Transport	8.4	8.6	8.6
CM-Other manufacturing	7.7	6.8	8.7

Share of the sample in the total manufacturing sector	
Industry	**Coverage rates (%, employees, 2010)**
Manufacturing	7.2
Food industries	6.1
Electric and electronic equipment	7.5
Transport equipment	7.0
Other	7.3

Appendix C: Model (8)

$$\Delta k_{i,t} = (-\beta_{11}\cdot\alpha_5 - \beta_{12}\cdot\alpha_5 + \beta_{15})\cdot\Delta\overline{hl}_i + (\beta_{11}+\beta_{12})\cdot\Delta y_{i,t} + ((1-\alpha_1)\cdot\beta_{11} - \alpha_1 * \beta_{12})\cdot\Delta(w_{i,t} - c_{i,t})$$
$$-(\beta_{11}+\beta_{12})\cdot(\gamma_s + \nu_t - \nu_{t-1}) + (1-\beta_{11})\cdot\Delta k_{i,t-1} - \beta_{12}\cdot\Delta l_{i,t-1} - \beta_{13}\cdot\Delta cu_{i,t-1} - \beta_{14}\cdot\Delta hk_{i,t-1}$$
$$-\beta_{15}\cdot\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}^{k}$$

$$\Delta l_{i,t} = (-\beta_{21}\cdot\alpha_5 - \beta_{22}\cdot\alpha_5 + \beta_{25})\cdot\Delta\overline{hl}_i + (\beta_{21}+\beta_{22})\cdot\Delta y_{i,t} + ((1-\alpha_1)\cdot\beta_{21} - \alpha_1 * \beta_{22})\cdot\Delta(w_{i,t} - c_{i,t})$$
$$-(\beta_{21}+\beta_{22})\cdot(\gamma_s + \nu_t - \nu_{t-1}) - \beta_{21}\cdot\Delta k_{i,t-1} - (1-\beta_{22})\cdot\Delta l_{i,t-1} - \beta_{23}\cdot\Delta cu_{i,t-1} - \beta_{24}\cdot\Delta hk_{i,t-1}$$
$$-\beta_{25}\cdot\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}^{l}$$

$$\Delta cu_{i,t} = (-\beta_{31}\cdot\alpha_5 - \beta_{32}\cdot\alpha_5 + \beta_{35})\cdot\Delta\overline{hl}_i + (\beta_{31}+\beta_{32})\cdot\Delta y_{i,t} + ((1-\alpha_1)\cdot\beta_{31} - \alpha_1 * \beta_{32})\cdot\Delta(w_{i,t} - c_{i,t})$$
$$-(\beta_{31}+\beta_{32})\cdot(\gamma_s + \nu_t - \nu_{t-1}) - \beta_{31}\cdot\Delta k_{i,t-1} - \beta_{32}\cdot\Delta l_{i,t-1} + (1-\beta_{33})\cdot\Delta cu_{i,t-1} - \beta_{34}\cdot\Delta hk_{i,t-1}$$
$$-\beta_{35}\cdot\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}^{cu}$$

$$\Delta hk_{i,t}=(-\beta_{41}\cdot\alpha_5-\beta_{42}\cdot\alpha_5+\beta_{45})\cdot\Delta\overline{hl}_i+(\beta_{41}+\beta_{42})\cdot\Delta y_{i,t}+((1-\alpha_1)\cdot\beta_{41}-\alpha_{1.}\beta_{42})\cdot\Delta(w_{i,t}-c_{i,t})$$
$$-(\beta_{41}+\beta_{42})\cdot(\gamma_s+\nu_t-\nu_{t-1})-\beta_{41}\cdot\Delta k_{i,t-1}-\beta_{42}\cdot\Delta l_{i,t-1}-\beta_{43}\cdot\Delta cu_{i,t-1}+(1-\beta_{44})\cdot\Delta hk_{i,t-1}$$
$$-\beta_{45}\cdot hl_{i,t-1}+\Delta\varepsilon_{i,t}^{hk}$$

$$\Delta hl_{i,t}=(-\beta_{51}\cdot\alpha_5-\beta_{52}\cdot\alpha_5+\beta_{55})\cdot\Delta\overline{hl}_i+(\beta_{51}+\beta_{52})\cdot\Delta y_{i,t}+((1-\alpha_1)\cdot\beta_{51}-\alpha_1\cdot\beta_{52})\cdot\Delta(w_{i,t}-c_{i,t})$$
$$-(\beta_{51}+\beta_{52})\cdot(\gamma_s+\nu_t-\nu_{t-1})-\beta_{51}\cdot\Delta k_{i,t-1}-\beta_{52}\cdot\Delta l_{i,t-1}-\beta_{53}\cdot\Delta cu_{i,t-1}-\beta_{54}\cdot\Delta hk_{i,t-1}$$
$$+(1-\beta_{55})\cdot\Delta hl_{i,t-1}+\Delta\varepsilon_{i,t}^{hl}$$

Appendix D: Model (9)

$$\Delta k_{i,t}=(-\beta_{11}\cdot\alpha_5-\beta_{12}.\alpha_5+\beta_{15})\cdot\Delta\overline{hl}_i+(\beta_{11}+\beta_{12})\cdot\Delta y_{i,t}+((1-\alpha_1)\cdot\beta_{11}-\alpha_1\cdot\beta_{12})\cdot\Delta(w_{i,t}-c_{i,t})$$
$$-(\beta_{11}+\beta_{12})\cdot(\gamma_s+\nu_t-\nu_{t-1})+(1-\beta_{11})\cdot\Delta k_{i,t-1}-\beta_{12}\cdot\Delta l_{i,t-1}-\beta_{13}\cdot\Delta cu_{i,t-1}$$
$$-(\beta_{14}+\beta'_{14}\cdot 1_{\text{Obstacles}})\cdot\Delta hk_{i,t-1}-\beta_{15}\cdot\Delta hl_{i,t-1}+\Delta\varepsilon_{i,t}^{k}$$

$$\Delta l_{i,t}=(-\beta_{21}\cdot\alpha_5-\beta_{22}\cdot\alpha_5+\beta_{25})\cdot\Delta\overline{hl}_i+(\beta_{21}+\beta_{22})\cdot\Delta y_{i,t}+((1-\alpha_1)\cdot\beta_{21}-\alpha_1\cdot\beta_{22})\cdot\Delta(w_{i,t}-c_{i,t})$$
$$-(\beta_{21}+\beta_{22})\cdot(\gamma_s+\nu_t-\nu_{t-1})-\beta_{21}\cdot\Delta k_{i,t-1}-(1-\beta_{22})\cdot\Delta l_{i,t-1}-\beta_{23}\cdot\Delta cu_{i,t-1}$$
$$-(\beta_{24}+\beta'_{24}\cdot 1_{\text{Obstacles}})\cdot\Delta hk_{i,t-1}-\beta_{25}\cdot\Delta hl_{i,t-1}+\Delta\varepsilon_{i,t}^{l}$$

$$\Delta cu_{i,t}=(-\beta_{31}\cdot\alpha_5-\beta_{32}\cdot\alpha_5+\beta_{35})\cdot\Delta\overline{hl}_i+(\beta_{31}+\beta_{32})\cdot\Delta y_{i,t}+((1-\alpha_1)\cdot\beta_{31}-\alpha_1\cdot\beta_{32})\cdot\Delta(w_{i,t}-c_{i,t})$$
$$-(\beta_{31}+\beta_{32})\cdot(\gamma_s+\nu_t-\nu_{t-1})-\beta_{31}\cdot\Delta k_{i,t-1}-\beta_{32}\cdot\Delta l_{i,t-1}+(1-\beta_{33})\cdot\Delta cu_{i,t-1}$$
$$-(\beta_{34}+\beta'_{34}\cdot 1_{\text{Obstacles}})\cdot\Delta hk_{i,t-1}-\beta_{35}\cdot\Delta hl_{i,t-1}+\Delta\varepsilon_{i,t}^{cu}$$

$$\Delta hk_{i,t}=(-\beta_{41}\cdot\alpha_5-\beta_{42}\cdot\alpha_5+\beta_{45})\cdot\Delta\overline{hl}_i+(\beta_{41}+\beta_{42})\cdot\Delta y_{i,t}+((1-\alpha_1)\cdot\beta_{41}-\alpha_1\cdot\beta_{42})\cdot\Delta(w_{i,t}-c_{i,t})$$
$$-(\beta_{41}+\beta_{42})\cdot(\gamma_s+\nu_t-\nu_{t-1})-\beta_{41}\cdot\Delta k_{i,t-1}-\beta_{42}\cdot\Delta l_{i,t-1}-\beta_{43}\cdot\Delta cu_{i,t-1}$$
$$+(1-\beta_{44}-\beta'_{44}\cdot 1_{\text{Obstacles}})\cdot\Delta hk_{i,t-1}-\beta_{45}\cdot\Delta hl_{i,t-1}+\Delta\varepsilon_{i,t}^{hk}$$

$$\Delta hl_{i,t}=(-\beta_{51}\cdot\alpha_5-\beta_{52}\cdot\alpha_5+\beta_{55})\cdot\Delta\overline{hl}_i+(\beta_{51}+\beta_{52})\cdot\Delta y_{i,t}+((1-\alpha_1)\cdot\beta_{51}-\alpha_1\cdot\beta_{52})\cdot\Delta(w_{i,t}-c_{i,t})$$
$$-(\beta_{51}+\beta_{52})\cdot(\gamma_s+\nu_t-\nu_{t-1})-\beta_{51}\cdot\Delta k_{i,t-1}-\beta_{52}\cdot\Delta l_{i,t-1}-\beta_{53}\cdot\Delta cu_{i,t-1}$$
$$-(\beta_{54}+\beta'_{54}\cdot 1_{\text{Obstacles}})\cdot\Delta hk_{i,t-1}+(1-\beta_{55})\cdot\Delta hl_{i,t-1}+\Delta\varepsilon_{i,t}^{hl}$$

Appendix E: First stage results

First stage regressions

Δy	**Coefficient**	**Standard-error**	***p*-Value**	**Δcr**	**Coefficient**	**Standard-error**	***p*-Value**	**L.Δk**	**Coefficient**	**Standard-error**	***p*-value**
fl(t−1)	−0.01313	0.01004	0.191	fl(t−1)	−0.02186	0.01355	0.1067	fl(t−l)	−0.01115	0.00572	**0.0516**
yu(t−1)	0.02078	0.00749	**0.0056**	yu(t−l)	0.00954	0.01011	0.3455	yu(t−l)	0.02697	0.00427	**<0.0001**
k(t−2)	−0.00067717	0.0036	0.8506	k(t−2)	−0.00141	0.00485	0.7708	k(t−2)	−0.00959	0.00205	**<0.0001**
l(t−2)	−0.00186	0.00461	0.6866	l(t−2)	0.00084139	0.00622	0.8925	l(t−2)	0.0045	0.00263	**0.0871**
cu(t−2)	−0.03386	0.01377	**0.0139**	cu(t−2)	0.00982	0.01858	0.5973	cu(t−2)	0.02378	0.00785	**0.0025**
cr(t−2)	0.01323	0.01028	0.1981	cr(t−2)	0.1077	0.01387	**<0.0001**	cr(t−2)	−0.02131	0.00586	**0.0003**
SW(t−2)	0.00967	0.00608	0.1115	SW(t−2)	0.00019539	0.00821	0.981	SW(t−2)	0.01688	0.00347	**<0.0001**
awh(t−2)	−0.09893	0.05093	**0.0521**	awh(t−2)	−0.22596	0.06874	**0.001**	awh(t−2)	0.02738	0.02905	0.346
cr(t−3)	−0.00388	0.00986	0.6937	cr(t−3)	−0.06963	0.01331	**<0.0001**	cr(t−3)	0.00344	0.00562	0.5404
F-statistic: 19.42				F-statistic: 10.86				F-statistic: 10.96			
Prob>F: <0.0001				Prob>F: <0.0001				Prob>F: <0.0001			
L.Δl	**Coefficient**	**Standard-error**	***p*-Value**	**L.Δcu**	**Coefficient**	**Standard-error**	***p*-Value**	**L.Δhk**	**Coefficient**	**Standard-error**	***p*-Value**
fl(t−1)	0.00606	0.00467	0.1944	fl(t−1)	−0.02789	0.00773	**0.0003**	fl(t−1)	0.00646	0.0039	**0.0982**
yu(t−1)	0.00969	0.00348	**0.0055**	yu(t−1)	0.00827	0.00577	0.152	yu(t−1)	0.00241	0.00291	0.4079
k(t−2)	0.00323	0.00167	**0.0536**	k(t−2)	0.00425	0.00277	0.125	k(t−2)	−0.00144	0.0014	0.3019
l(t−2)	−0.01131	0.00215	**<0.0001**	l(t−2)	0.00819	0.00355	**0.0212**	l(t−2)	0.00119	0.00179	0.5059
cu(t−2)	0.04293	0.0064	**<0.0001**	cu(t−2)	−0.44548	0.01061	**<0.0001**	cu(t−2)	−0.00447	0.00535	0.4041
cr(t−2)	0.01303	0.00478	**0.0065**	cr(t−2)	−0.00533	0.00792	0.5007	cr(t−2)	0.00322	0.004	0.421
SW(t−2)	0.00361	0.00283	0.2024	SW(t−2)	0.00887	0.00468	**0.0583**	SW(t−2)	0.00527	0.00236	**0.0257**

Appendix E (continued)

First stage regressions

L.Δl	**Coefficient**	**Standard-error**	***p*-Value**	**L.Δcu**	**Coefficient**	**Standard-error**	***p*-Value**	**L.Δhk**	**Coefficient**	**Standard-error**	***p*-Value**
awh(t−2)	0.11884	0.02369	**<0.0001**	awh(t−2)	−0.08809	0.03924	**0.0248**	awh(t−2)	0.06656	0.01981	**0.0008**
cr(t−3)	−0.00196	0.00459	0.6699	cr(t−3)	0.00731	0.0076	0.3362	cr(t−3)	−0.00246	0.00383	0.521
F-statistic: 16.12				F-statistic: 137.37				F-statistic: 23.78			
Prob>F: <0.0001				Prob>F: <0.0001				Prob>F: <0.0001			

L.Δhl	**Coefficient**	**Standard-error**	***p*-Value**
fl(t−l)	−0.00466	0.00173	**0.0072**
yu(t−l)	0.00333	0.00129	**0.0101**
k(t−2)	−0.00013141	0.00062101	0.8324
l(t−2)	0.00116	0.00079656	0.1439
cu(t−2)	0.00721	0.00238	**0.0024**
cr(t−2)	0.00327	0.00177	**0.0656**
SW(t−2)	−0.00036178	0.00105	0.7305
awh(t−2)	−0.02174	0.0088	**0.0135**
cr(t−3)	−0.00376	0.0017	**0.0272**
F-statistic: 3			
Prob>F: <0.0001			

fl: Sectoral average net sales.
yu: Sectoral average external staff.
SW: Shiftwork dummy.
awh: Annual average working hours.
Sector and year dummies included but not reported.
p-Values in bold when significant at the 10% threshold.

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