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How do firms adjust production factors to the cycle? [1]

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Abstract:

We study production factor adjustment taking into account factor utilisation in multiple dimensions (labour and capital working time, capital capacity utilisation) through a unique survey among French manufacturing firms. This survey also allows us to examine the impact of obstacles to increasing capital operating time on this adjustment path. This survey, merged with balanced sheet and profit and loss accounts from fiscal reports, yields an unbalanced panel of 6,066 observations over 1993-2010.

Factor utilisation adjusts the most rapidly, first through capital capacity utilisation and the capital workweek and then labour working time. The adjustment is slow for the number of employees and even slower for the capital stock. In case of a change in factor volume targets, the three factor utilisation degrees adjust to offset the very slow reaction of factor volumes. Obstacles to increasing the capital operating time lead to a slower adjustment of capital operating time, offset by a stronger adjustment of capacity utilisation.

JEL codes: D24; E22; O43
Keywords: production function; factor utilisation; rigidities

Résumé:

Nous étudions l'ajustement des facteurs de production en prenant en compte l'utilisation des facteurs dans ses multiples dimensions (durée de travail, durée d'utilisation des équipements productifs, taux d'utilisation des capacités de production) au travers d'une enquête unique auprès des entreprises manufacturières françaises. Cette enquête nous permet également d'étudier l'impact des obstacles à l'augmentation de la durée d'utilisation des équipements productifs sur cette trajectoire d'ajustement. Cette enquête, fusionnée avec des bilans et des comptes de résultat issus des liasses fiscales, conduit à un panel non cylindré de 6 066 observations sur la période 1993-2010.

L'utilisation des facteurs s'ajuste le plus rapidement, tout d'abord au travers du taux d'utilisation des capacités de production et de la durée d'utilisation des équipements, puis de la durée du travail. L'ajustement est lent pour le nombre d'employés et plus lent encore pour le stock de capital. En cas de changement des niveaux optimaux des volumes de facteurs de production, les trois degrés d'utilisation s'ajustent pour compenser la réaction très lente des volumes de facteur. Les obstacles à l'augmentation de la durée d'utilisation des équipements amènent à un ajustement plus lent de cette durée, compensée par un ajustement du taux d'utilisation des capacités.

codes JEL: D24; E22; O43
Mots-clés: fonction de production; utilisation des facteurs; rigidités

Non-technical summary :

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.

However, it has been shown that firms adjust production factors, and especially capital, with delay (Caballero *et al.*, 1995, and Doms and Dunne, 1998, for capital; Caballero *et al.*, 1997, for employment) due to adjustment costs and the irreversibility of capital spendings. These costs of adjustment and irreversibility of capital spending lead to a suboptimal path of factors level adjustment relying on short-term overreaction of factor utilisation. As factor levels cannot reach their long-term target immediately, the working time of capital and labour or the capital capacity utilisation may differ temporarily from their long-term target in order to produce the desired level of output. Nadiri and Rosen (1969, 1973) have first emphasised this role of factor utilisation in short term adjustment dynamics. They merged empirical capital and labour functions and showed that capital and labour demands were interrelated. They provided an estimation of the factor adjustment path in case of, for example, a demand shock: immediately, factor utilisation degrees overshoot their long-term targets to offset the lack of adjustment of the capital and labour 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 labour and capital stocks, factor utilisations come progressively back to their initial optimal rates.

We study here production factor adjustment taking into account factor utilisation in all its dimensions (labour and capital working time, capital capacity utilisation) through a unique survey among French manufacturing firms. This survey also allows us to examine the impact of obstacles to increasing capital operating time on this adjustment path. This survey, merged with balanced sheet and profit and loss accounts from fiscal reports, yields an unbalanced panel of 6,066 observations over 1993-2010.

We show that factor utilisation degrees adjust the most rapidly, first through capital capacity utilisation and the capital workweek and then labour working time. The adjustment is slow for the number of employees and even slower for the capital stock. In case of a change in the capital stock target, the three factor utilisation 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 utilisation degrees offset the slow adjustment of this factor. Among the three factor utilisation degrees, these balancing reactions are higher for capital utilisation rate than for capital operating time, and higher for capital operating time than for labour 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 utilisation degrees adjustment to offset the slow adjustment of factor volumes, and mainly of capital volume, is estimated on firm individual data. Obstacles to increasing the capital operating time lead to a slower adjustment of capital operating time, the short-term adjustment relying more on capital utilisation rate.

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.

However, it has been shown that firms adjust production factors, and especially capital, with delay (Caballero *et al.*, 1995, and Doms and Dunne, 1998, for capital; Caballero *et al.*, 1997, for employment). First, adjustment costs for capital and labour prevent a smooth change in the level of production factors (Hamermesh and Pfan, 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 labour (Caballero *et al.*, 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 behaviour 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 lead to a suboptimal path of factors level adjustment relying on short-term overreaction of factor utilisation. As factor levels cannot reach their long-term target immediately, the working time of capital and labour or the capital capacity utilisation may differ temporarily from their long-term target in order to produce the desired level of output. Nadiri and Rosen (1969, 1973) have first emphasised this role of factor utilisation in short term adjustment dynamics. They merged empirical capital and labour functions and showed that capital and labour demands were interrelated. They provided an estimation of the factor adjustment path in case of, for example, a demand shock: immediately, factor utilisation degrees overshoot their long-term targets to offset the lack of adjustment of the capital and labour 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 labour and capital stocks, factor utilisations come progressively back to their initial optimal rates.

Regulation may alter the adjustment process. Eslava *et al.* (2010) have showed on the Colombian case how deregulation of labour and financial markets in 1990 and 1991 has lead to a quicker adjustment of production factors, and especially a faster downward adjustment of labour 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 hours to 35 hours 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 utilisation throughout the year.

We study here production factor adjustment taking into account factor utilisation in all its dimensions (labour and capital working time, capital capacity utilisation) through a unique survey among French manufacturing firms. As emphasised in various studies, capital working time is a crucial instrument to adjust to shocks in the manufacturing sector (Shapiro, 1993, Mattey and Strongin, 1995, Cette *et alii*, forthcoming) This survey also allows us to examine the impact of obstacles to increasing capital operating time on this adjustment path. This survey, merged with balanced sheet and profit and loss accounts from fiscal reports, yields an unbalanced panel of 6,066 observations over 1993-2010.

We show that factor utilisation degrees adjust the most rapidly, first through capital capacity utilisation and the capital workweek and then labour working time. The adjustment is slow for the number of employees and even slower for the capital stock. In case of a change in the capital stock target, the three factor utilisation 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 utilisation degrees offset the slow adjustment of this factor. Among the three factor utilisation degrees, these balancing reactions are higher for capital utilisation rate than for capital operating time, and higher for capital operating time than for labour 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 utilisation degrees adjustment to offset the slow adjustment of factor volumes, and mainly of capital volume, is estimated on firm individual data. Obstacles to increasing the capital operating time lead to a slower adjustment of capital operating time, the short-term adjustment relying more on capital utilisation 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 utilisation. Precisely, we merge two firm-level annual datasets constructed by the Banque de France: the FiBen database and the survey on factor utilisation 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 labour 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 labour 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:

$$C = investment\ price.(interest\ rate - growth\ rate\ of\ investment\ price + capital\ depreciation\ rate)$$

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

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

- 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. 1,500 to 2,500 plants are covered by this survey, depending on the year. This dataset directly provides for each plant the annual growth rate of capital workweek (*HK*), the level of labour workweek (*HL*), and indirectly the production capacity utilisation 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 workweek or capital operating time (Δhk) stem from the question: "*What is the past evolution, over the last twelve 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 labour workweek or labour 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 workweek 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 organisation)?*". We denote this data by *CA*, and the capital capacity utilisation 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 utilisation rate (in %) computed from the formula: $\frac{100}{1+\frac{CA}{100}}$. One aspect of factor utilisation which capacity utilisation is capturing and which is not captured by the two other measures is labour intensity (*e.g.* the speed of the assembly line).

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

The FUD survey not only provides rich insights about firm-level factor utilisation, but also a unique appraisal of rigidities faced by firms in increasing their capital workweek. 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). 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 6,066 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 Labour 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 labour 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 hours in 2000 for firms of 20 employees or more and in 2002 for all other firms[2]. 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 utilisation, 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.

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:

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

Where $0 < \alpha_j < 1 \; \forall \, j$; $Y_{i,t}$ is the volume of value-added ; A_i is a scale firm specific parameter; $e^{\gamma_s.t+\nu_t}$ 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 labour stock number of employees; $F_{i,3,t} = CU_{i,t}$ is the capital capacity utilisation rate; $F_{i,4,t} = HK_{i,t}$ is the capital workweek; $F_{i,5,t} = HL_{i,t}$ is the labour workweek.

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

From this, the production function becomes[3]:

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

2 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.

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

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

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

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

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

Where $\overline{HL}_{i,b00}$ and $\overline{HL}_{i,a00}$ refer to labour workweek optimal levels before and from 2000; $I_{t<2000}$ and $I_{t\geq 2000}$ 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).

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

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

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

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

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

$$(2) \quad f^*_{i,t} = C1 . d_{i,t}$$
$$(5,1) = (5,7) . (7,1)$$

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

and $C1 = \begin{pmatrix} -\alpha_1 & -\alpha_1 & -(1-\alpha_1) & 1 & 1-\alpha_1 & -1 & -a + (1-\alpha_1) . \log (\frac{\alpha_1}{1-\alpha_1}) \\ -\alpha_1 & -\alpha_1 & -(1-\alpha_1) & 1 & -\alpha_1 & -1 & -a + \alpha_1 . \log (\frac{1-\alpha_1}{\alpha_1}) \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{pmatrix}$

$f^*_{i,t}$ 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:

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

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

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

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

(3) $\beta_{j,k} \geq 0, \forall j,k$

Turning in matrix notation:

(4) $\Delta f_{i,t} = \beta . (f^*_{i,t} - f_{i,t-1})$
$(5,1) = (5,5).(5,1)$

With: $\Delta f_{i,t} = \begin{pmatrix} k_{i,t} - k_{i,t-1} \\ l_{i,t} - l_{i,t-1} \\ cu_{i,t} - cu_{i,t-1} \\ hk_{i,t} - hk_{i,t-1} \\ hl_{i,t} - hl_{i,t-1} \end{pmatrix}$, $\beta = \begin{pmatrix} \beta_{1,1} & \cdots & \beta_{1,5} \\ \vdots & \ddots & \vdots \\ \beta_{5,1} & \cdots & \beta_{5,5} \end{pmatrix}$ and $f^*_{i,t} - f_{i,t} = \begin{pmatrix} k^*_{i,t} - k_{i,t-1} \\ l^*_{i,t} - l_{i,t-1} \\ cu^*_{i,t} - cu_{i,t-1} \\ hk^*_{i,t} - hk_{i,t-1} \\ hl^*_{i,t} - hl_{i,t-1} \end{pmatrix}$

Thus, $\Delta f_{i,t}$ is the vector of factor variations, $f^*_{i,t} - f_{i,t}$ 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:

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

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 $\beta''_{j,4} = \beta_{j,4} + (I_{Obstacles} . \beta'_{j,4}), j = 1,\ldots,5$

$I_{Obstacles}$ being equal to one for firms facing obstacles and to zero for others.

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

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

With: *C2* = β . *C1*

In case of obstacles, *C2* become *C2''*, with *C2''* = β'' * *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 behavioural 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[4]:

$$(6)\ \begin{cases} \beta_{1,1} + \frac{1-\alpha_1}{\alpha_1}.\beta_{2,1} + \beta_{3,1} + \beta_{4,1} + \frac{1-\alpha_1}{\alpha_1}.\beta_{5,1} = 1 \\ \frac{\alpha_1}{1-\alpha_1}.\beta_{1,2} + \beta_{2,2} + \frac{\alpha_1}{1-\alpha_1}.\beta_{3,2} + \frac{\alpha_1}{1-\alpha_1}.\beta_{4,2} + \beta_{5,2} = 1 \\ \beta_{1,3} + \frac{1-\alpha_1}{\alpha_1}.\beta_{2,3} + \beta_{3,3} + \beta_{4,3} + \frac{1-\alpha_1}{\alpha_1}.\beta_{5,3} = 1 \\ \beta_{1,4} + \frac{1-\alpha_1}{\alpha_1}.\beta_{2,4} + \beta_{3,4} + \beta_{4,4} + \frac{1-\alpha_1}{\alpha_1}.\beta_{5,4} = 1 \\ \frac{\alpha_1}{1-\alpha_1}.\beta_{1,5} + \beta_{2,5} + \frac{\alpha_1}{1-\alpha_1}.\beta_{3,5} + \frac{\alpha_1}{1-\alpha_1}.\beta_{4,5} + \beta_{5,5} = 1 \end{cases}$$

In case of firms facing obstacles, $\beta_{j,1}$becomes $\beta''_{j,4} = \beta_{j,4} + (I_{Obstacles}.\beta'_{j,4})$.
Regarding capital elasticity α_1, we observe that the share of the capital in the value added is equal to 0.3037 in average. So, in most of the estimates, we assume the constraint:

$$(7)\ \alpha_1 = 0.3$$

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 $\beta_{i,j}$) 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.

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

3.2 The estimation strategy

To estimate the model, we first eliminate the individual 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)[5] :

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

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

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

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 organisation in shift work (or not) of the firm (cf. Appendix D). 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, 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 labour” which was instrumented by its level of third order. In addition, to tackle the endogeneity of the labour 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.

5 The estimated model is developed in Appendix B and C.

4. Results

Estimation results of model (6) with constraints (3), (7) and (8) 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 labour volume ($\beta_{2,2}$ = 0.250), 30% for the labour working time ($\beta_{5,5}$ = 0.292), 35% for the capital working time ($\beta_{4,4}$ = 0.345) and 85% for the capital utilisation rate ($\beta_{3,3}$ = 0.845). This hierarchy is the same as in Nadiri and Rosen (1969, 1973) and it is consistent with the supposed ranking of factor adjustment costs. It appears also that capital volume gaps are slightly corrected by adjustments of labour volume ($\beta_{2,1}$ = 0.116) and mostly by adjustments of the capital utilisation rate ($\beta_{3,1}$ = 0.272) and by adjustments of capital operating time ($\beta_{4,1}$ = 0.254), while labour working time is not used to offset this gap. The labour volume adjustment gaps are slightly corrected by adjustments of labour 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 utilisation 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 utilisation 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.). Labour 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 utilisation rate ($\beta_{3,1}$ = 0.845). Labour working time adjustment gaps are corrected by adjustments of the labour volume, but mostly by the capital operating time and the capital utilisation rate ($\beta_{1,5} \approx 0$, $\beta_{2,5}$ = 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 the capital utilisation rate ($\beta_{1,4} \approx \beta_{2,4} \approx \beta_{5,4} \approx 0$ and $\beta_{3,4} \approx$ 0.384) and capital utilisation rate adjustment gaps are also very slightly corrected by adjustments of the labour working time and of the capital operating time ($\beta_{1,3} \approx \beta_{2,3} \approx 0$ 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 utilisation degrees[6]; ii) the adjustment gaps of factor volumes are slowly corrected by their own adjustment and in a first stage by adjustments of the capital operating time and of the capital utilisation rate; iii) changes in factor utilisation degrees correct their own adjustment gaps and the adjustment gaps of other factors with a clear hierarchy in terms of flexibility, labour working time being the less flexible degree, correcting only slightly other factor adjustment gaps, capital utilisation rate being the most flexible and contributing to correct in an important proportion all other factor adjustment gaps, and capital operating time being only slightly less flexible than capital utilisation rate. These results are consistent with the ones obtained by Nadiri and Rosen (1969, 1973). 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 presents 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 labour) increase also each by 1% and the targets of the three factor utilisation degrees do not change (see relation (2)). Factor volumes adjust slowly to their targets, capital adjusting much slower than employment. Factor utilisation degrees increase immediately to offset the slow adjustment of factor volumes, this immediate reaction being stronger for capital utilisation rate and for capital operating time than for labour working time. It means that during the whole process of slow capital adjustment, capital is below its target and factor utilisation degrees above their targets. It even appears that the capital adjustment process is so slow that labour volume offset the capital gap for several years,

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

leading employment to overshoot its target during this sub-period. The adjustment process is slow: it takes more than 10 years for capital and for labour to fully adjust to their new targets, and consequently for the three factor utilisation degrees to come back to their initial levels which correspond to their own targets.

The results obtained for OLS estimates of the same model are qualitatively close to the ones obtained with the GMM estimates (Table 1, columns 3 and 4 compared to column 1 and 2), 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 increase in 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-hour workweek (1998, 1999 and 2000). The regulatory change from the 39-hour to the 35-hour workweek may indeed have biased the estimates of the role of labour utilisation, although change in the target workweek may have alleviated that problem. Without these years, labour volume no longer offsets labour working time gaps ($\beta_{2,5} \approx 0$), which tends to support the idea that the implementation of the 35-hour workweek led firms to hire workers in order to offset the reduction in working time. Labour working time gaps are no longer offset by capital utilisation but more by capital operating time. Finally, labour working time tends to adjust faster to its own target without the 35-hour workweek implementation years, in a way which is more in line with the adjustment of the two other utilisation degrees.

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, labour or labour workweek. Employment tends to substitute for capital operating time gaps for 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 utilisation. Hence, substitution of capital operating time gap by capacity utilisation, 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.

5. 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 labour and capacity utilisation for labour workweek gaps are no longer significant. Both labour and capacity utilisations now substitute more strongly to capital operating time gaps. Overall, capital operating time is at the center of stronger adjustments and labour 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 labour 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.

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

6. Conclusion

Using a very original dataset of an unbalanced panel of 6,066 observations on French firms over 1993-2010, we have studied production factor adjustment taking into account factor utilisation degrees in all their dimensions (labour and capital working time, capital capacity utilisation).

Our main results are the following: i) Factor utilisation degrees adjust the most rapidly, first through capital capacity utilisation, then the capital workweek and finally labour 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 utilisation 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 utilisation degrees offset the slow adjustment of this factor; iii) Among the three factor utilisation degrees, these balancing reactions are stronger for capital utilisation rate than for capital operating time, and stronger for capital operating time than for labour working time; iv) Obstacles to increasing the capital operating time lead to a slower adjustment of capital operating time, the short-term adjustment relying more on capacity utilisation.

These results confirm and deepen those of previous analysis, as those of Nadiri and Rosen (1969, 1973). But in our knowledge, it is the first time that the role of factor utilisation 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.

These results lead to several policy conclusions. Flexible factor utilisation 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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Table 1: Benchmark estimate results

Parameters	Adjusted factor:	to offset gap in:	GMM Benchmark	GMM Benchmark-non null coef.	OLS
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)	
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	

Note: 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.

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
β_{11}	k	k	0.207***	0.177***	0.242***	0.193***
			(0.035)	(0.037)	(0.04)	(0.035)
β_{12}	k	l	0	0	0.017	0
					(0.049)	
β_{13}	k	cu	0	0	0.011	0
					(0.02)	
β_{14}	k	hk	0	0	0	0
β_{15}	k	hl	0	0	0	0
β_{21}	l	k	0.139***	0.105***	0.081**	0.106***
			(0.025)	(0.03)	(0.034)	(0.029)
β_{22}	l	l	0.277***	0.346***	0.26***	0.279***
			(0.041)	(0.052)	(0.05)	(0.044)
β_{23}	l	cu	0	0	0	0
β_{24}	l	hk	0	0.007	0.157*	0.048
				(0.074)	(0.083)	(0.113)
β_{25}	l	hl	0.203***	0	0.164**	0.207***
			(0.06)		(0.077)	(0.064)
β_{31}	cu	k	0.238***	0.295***	0.288***	0.298***
			(0.051)	(0.062)	(0.06)	(0.054)
β_{32}	cu	l	0.806***	0.808***	0.782***	0.863***
			(0.083)	(0.1)	(0.089)	(0.081)
β_{33}	cu	cu	0.844***	0.86***	0.895***	0.855***
			(0.034)	(0.035)	(0.036)	(0.033)
β_{34}	cu	hk	0.55***	0.342**	0.285**	0
			(0.095)	(0.167)	(0.139)	
β_{35}	cu	hl	0.461***	0.04	0.455***	0.498***
			(0.111)	(0.263)	(0.12)	(0.116)
β_{41}	hk	k	0.232***	0.283***	0.281***	0.261***
			(0.041)	(0.046)	(0.054)	(0.043)
β_{42}	hk	l	0.742***	0.565***	0.822***	0.719***
			(0.067)	(0.074)	(0.081)	(0.07)
β_{43}	hk	cu	0.112***	0.1***	0.08***	0.108***
			(0.027)	(0.031)	(0.028)	(0.028)
β_{44}	hk	hk	0.45***	0.642***	0.349***	0.888***
			(0.095)	(0.136)	(0.135)	(0.263)
β_{45}	hk	hl	0.724***	1.255***	0.838***	0.705***
			(0.091)	(0.256)	(0.116)	(0.094)
β_{51}	hl	k	0	0	0	0
β_{52}	hl	l	0.06***	0.065***	0.046*	0.043**
			(0.019)	(0.018)	(0.024)	(0.021)
β_{53}	hl	cu	0.019**	0.017**	0.006	0.016**
			(0.008)	(0.008)	(0.007)	(0.008)
β_{54}	hl	hk	0	0	0	0
β_{55}	hl	hl	0.289***	0.445***	0.282***	0.277***
			(0.032)	(0.089)	(0.042)	(0.036)
β'_{14}	k	hk				0
β'_{24}	l	hk				0.013
						(0.163)
β'_{34}	cu	hk				0.657***
						(0.216)
β'_{44}	hk	hk				-0.888***
						(0.263)
β'_{54}	hl	hk				0.086
						(0.053)
Nb. Obs.			6066	4776	3856	5683
Hansen J-stat			48.11	35.29	54.35	52.29
P-value			0.6276	0.4072	0.1363	0.183

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.

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
alpha1			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)
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)
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.

Appendix A: Descriptive statistics

Variable	Description	Unit	Source	P10	Q1	Mean	Median	Q3	P90	Standard Error
y	Value added in volume per year	Log '000 €	FiBEn	7.0198	7.5231	8.4376	8.3017	9.2368	10.1005	1.1923
k	Capital stock in volume	Log '000 €	FiBEn	6.7898	7.5350	8.5686	8.4303	9.5390	10.6309	1.4862
l	Average number of employees	Log full-time equivalent	FiBEn	3.3322	3.7842	4.6654	4.5850	5.3660	6.2046	1.0795
cu	Capital capacity utilisation	%	FUDS	65.0000	75.0000	82.3523	85.0000	90.0000	97.0000	13.2252
hl	Employee workweek length	Log hours	FUDS	3.5554	3.5554	3.6144	3.6310	3.6636	3.6636	0.0551
w	Annual wage per employee	Log '000 €	FiBEn	3.1875	3.3336	3.4952	3.4893	3.6479	3.8126	0.2434
c	User cost of capital	Log		-2.4040	-2.2482	-2.1540	-2.1247	-2.0200	-1.9420	0.1962
cr	Relative cost of labour	Log		5.2626	5.4428	5.6492	5.6294	5.8410	6.0579	0.3172
Δy	Change in log value added	ΔLog '000 €	FiBEn	-0.1870	-0.0727	0.0107	0.0200	0.1062	0.2070	0.2012
Δk	Change in log capital stock	ΔLog '000 €	FiBEn	-0.0403	-0.0041	0.0376	0.0278	0.0715	0.1405	0.1703
Δl	Change in log number of employees	ΔLog full-time equivalent	FiBEn	-0.1011	-0.0445	-0.0089	0.0000	0.0293	0.0788	0.0939
Δcu	Change in capital capacity utilisation	Δ%	FUDS	-13.3531	-3.6368	-0.0028	0.0000	3.1749	13.3531	17.5648
Δhk	Change in the workweek of capital	%	FUDS	-6.0000	0.0000	0.8757	0.0000	0.0000	10.0000	8.3004
Δhl	Change in log employee workweek	ΔLog hours	FUDS	-0.0382	0.0000	-0.0052	0.0000	0.0000	0.0078	0.0341
Δw	change in log annual wage per employee	ΔLog '000 €	FiBEn	-0.0566	-0.0118	0.0230	0.0230	0.0578	0.1012	0.0757
Δc	change in log capital user cost	ΔLog		-0.2882	-0.1029	0.0015	-0.0068	0.0940	0.3141	0.2570
Δcr	Change in the relative cost of labour	ΔLog		-0.3131	-0.0954	0.0215	0.0303	0.1486	0.3275	0.2687

Appendix B: Model (8)

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

$$\Delta l_{i,t} = (-\beta_{21}.\alpha_5 - \beta_{22}.\alpha_5 + \beta_{25}).\Delta\overline{hl}_i + (\beta_{21} + \beta_{22}).\Delta y_{i,t} + \left((1-\alpha_1).\beta_{21} - \alpha_1 * \beta_{22}\right).\Delta\left(w_{i,t} - c_{i,t}\right) - (\beta_{21} + \beta_{22}).(\gamma_s + \nu_t - \nu_{t-1})$$

$$-\beta_{21}.\Delta k_{i,t-1} - (1-\beta_{22}).\Delta l_{i,t-1} - \beta_{23}.\Delta cu_{i,t-1} - \beta_{24}.\Delta hk_{i,t-1} - \beta_{25}.\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}{}^{l}$$

$$\Delta cu_{i,t} = (-\beta_{31}.\alpha_5 - \beta_{32}.\alpha_5 + \beta_{35}).\Delta\overline{hl}_i + (\beta_{31} + \beta_{32}).\Delta y_{i,t} + \left((1-\alpha_1).\beta_{31} - \alpha_1 * \beta_{32}\right).\Delta\left(w_{i,t} - c_{i,t}\right) - (\beta_{31} + \beta_{32}).(\gamma_s + \nu_t - \nu_{t-1})$$

$$-\beta_{31}.\Delta k_{i,t-1} - \beta_{32}.\Delta l_{i,t-1} + (1-\beta_{33}).\Delta cu_{i,t-1} - \beta_{34}.\Delta hk_{i,t-1} - \beta_{35}.\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}{}^{cu}$$

$$\Delta hk_{i,t} = (-\beta_{41}.\alpha_5 - \beta_{42}.\alpha_5 + \beta_{45}).\Delta\overline{hl}_i + (\beta_{41} + \beta_{42}).\Delta y_{i,t} + \left((1-\alpha_1).\beta_{41} - \alpha_1.\beta_{42}\right).\Delta\left(w_{i,t} - c_{i,t}\right) - (\beta_{41} + \beta_{42}).(\gamma_s + \nu_t - \nu_{t-1})$$

$$-\beta_{41}.\Delta k_{i,t-1} - \beta_{42}.\Delta l_{i,t-1} - \beta_{43}.\Delta cu_{i,t-1} + (1-\beta_{44}).\Delta hk_{i,t-1} - \beta_{45}.\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}{}^{hk}$$

$$\Delta hl_{i,t} = (-\beta_{51}.\alpha_5 - \beta_{52}.\alpha_5 + \beta_{55}).\Delta\overline{hl}_i + (\beta_{51} + \beta_{52}).\Delta y_{i,t} + \left((1-\alpha_1).\beta_{51} - \alpha_1.\beta_{52}\right).\Delta\left(w_{i,t} - c_{i,t}\right) - (\beta_{51} + \beta_{52}).(\gamma_s + \nu_t - \nu_{t-1})$$

$$-\beta_{51}.\Delta k_{i,t-1} - \beta_{52}.\Delta l_{i,t-1} - \beta_{53}.\Delta cu_{i,t-1} - \beta_{54}.\Delta hk_{i,t-1} + (1-\beta_{55}).\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}{}^{hl}$$

Appendix C: Model (9)

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

$$\Delta l_{i,t} = (-\beta_{21}.\alpha_5 - \beta_{22}.\alpha_5 + \beta_{25}).\Delta\overline{hl}_i + (\beta_{21} + \beta_{22}).\Delta y_{i,t} + \big((1-\alpha_1).\beta_{21} - \alpha_1.\beta_{22}\big).\Delta\big(w_{i,t} - c_{i,t}\big) - (\beta_{21} + \beta_{22}).(\gamma_s + \nu_t - \nu_{t-1})$$

$$-\beta_{21}.\Delta k_{i,t-1} - (1-\beta_{22}).\Delta l_{i,t-1} - \beta_{23}.\Delta cu_{i,t-1} - (\beta_{24} + \beta'_{24}.I_{Obstacles}).\Delta hk_{i,t-1} - \beta_{25}.\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}{}^{l}$$

$$\Delta cu_{i,t} = (-\beta_{31}.\alpha_5 - \beta_{32}.\alpha_5 + \beta_{35}).\Delta\overline{hl}_i + (\beta_{31} + \beta_{32}).\Delta y_{i,t} + \big((1-\alpha_1).\beta_{31} - \alpha_1.\beta_{32}\big).\Delta\big(w_{i,t} - c_{i,t}\big) - (\beta_{31} + \beta_{32}).(\gamma_s + \nu_t - \nu_{t-1})$$

$$-\beta_{31}.\Delta k_{i,t-1} - \beta_{32}.\Delta l_{i,t-1} + (1-\beta_{33}).\Delta cu_{i,t-1} - (\beta_{34} + \beta'_{34}.I_{Obstacles}).\Delta hk_{i,t-1} - \beta_{35}.\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}{}^{cu}$$

$$\Delta hk_{i,t} = (-\beta_{41}.\alpha_5 - \beta_{42}.\alpha_5 + \beta_{45}).\Delta\overline{hl}_i + (\beta_{41} + \beta_{42}).\Delta y_{i,t} + \big((1-\alpha_1).\beta_{41} - \alpha_1.\beta_{42}\big).\Delta\big(w_{i,t} - c_{i,t}\big) - (\beta_{41} + \beta_{42}).(\gamma_s + \nu_t - \nu_{t-1})$$

$$-\beta_{41}.\Delta k_{i,t-1} - \beta_{42}.\Delta l_{i,t-1} - \beta_{43}.\Delta cu_{i,t-1} + \big(1 - \beta_{44} - \beta'_{44}.I_{Obstacles}\big).\Delta hk_{i,t-1} - \beta_{45}.\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}{}^{hk}$$

$$\Delta hl_{i,t} = (-\beta_{51}.\alpha_5 - \beta_{52}.\alpha_5 + \beta_{55}).\Delta\overline{hl}_i + (\beta_{51} + \beta_{52}).\Delta y_{i,t} + \big((1-\alpha_1).\beta_{51} - \alpha_1.\beta_{52}\big).\Delta\big(w_{i,t} - c_{i,t}\big) - (\beta_{51} + \beta_{52}).(\gamma_s + \nu_t - \nu_{t-1})$$

$$-\beta_{51}.\Delta k_{i,t-1} - \beta_{52}.\Delta l_{i,t-1} - \beta_{53}.\Delta cu_{i,t-1} - (\beta_{54} + \beta'_{54}.I_{Obstacles}).\Delta hk_{i,t-1} + (1-\beta_{55}).\Delta hl_{i,t-1} + \Delta\varepsilon_{i,t}{}^{hl}$$

Appendix D: First stage results

First stage regressions

Δy	Coefficient	Standard-error	P-value
fl(t-1)	-0,01313	0,01004	0,191
yu(t-1)	0,02078	0,00749	**0,0056**
k(t-2)	-0,00067717	0,0036	0,8506
l(t-2)	-0,00186	0,00461	0,6866
cu(t-2)	-0,03386	0,01377	**0,0139**
cr(t-2)	0,01323	0,01028	0,1981
SW(t-2)	0,00967	0,00608	0,1115
awh(t-2)	-0,09893	0,05093	**0,0521**
cr(t-3)	-0,00388	0,00986	0,6937

F-statistic : 19,42
Prob > F : <.0001

Δcr	Coefficient	Standard-error	P-value
fl(t-1)	-0,02186	0,01355	0,1067
yu(t-1)	0,00954	0,01011	0,3455
k(t-2)	-0,00141	0,00485	0,7708
l(t-2)	0,00084139	0,00622	0,8925
cu(t-2)	0,00982	0,01858	0,5973
cr(t-2)	0,1077	0,01387	**<.0001**
SW(t-2)	0,00019539	0,00821	0,981
awh(t-2)	-0,22596	0,06874	**0,001**
cr(t-3)	-0,06963	0,01331	**<.0001**

F-statistic : 10,86
Prob > F : <.0001

L.Δk	Coefficient	Standard-error	P-value
fl(t-1)	-0,01115	0,00572	**0,0516**
yu(t-1)	0,02697	0,00427	**<.0001**
k(t-2)	-0,00959	0,00205	**<.0001**
l(t-2)	0,0045	0,00263	**0,0871**
cu(t-2)	0,02378	0,00785	**0,0025**
cr(t-2)	-0,02131	0,00586	**0,0003**
SW(t-2)	0,01688	0,00347	**<.0001**
awh(t-2)	0,02738	0,02905	0,346
cr(t-3)	0,00344	0,00562	0,5404

F-statistic : 10,96
Prob > F : <.0001

L.Δl	Coefficient	Standard-error	P-value
fl(t-1)	0,00606	0,00467	0,1944
yu(t-1)	0,00969	0,00348	**0,0055**
k(t-2)	0,00323	0,00167	**0,0536**
l(t-2)	-0,01131	0,00215	**<.0001**
cu(t-2)	0,04293	0,0064	**<.0001**
cr(t-2)	0,01303	0,00478	**0,0065**
SW(t-2)	0,00361	0,00283	0,2024
awh(t-2)	0,11884	0,02369	**<.0001**
cr(t-3)	-0,00196	0,00459	0,6699

F-statistic : 16,12
Prob > F : <.0001

L.Δcu	Coefficient	Standard-error	P-value
fl(t-1)	-0,02789	0,00773	**0,0003**
yu(t-1)	0,00827	0,00577	0,152
k(t-2)	0,00425	0,00277	0,125
l(t-2)	0,00819	0,00355	**0,0212**
cu(t-2)	-0,44548	0,01061	**<.0001**
cr(t-2)	-0,00533	0,00792	0,5007
SW(t-2)	0,00887	0,00468	**0,0583**
awh(t-2)	-0,08809	0,03924	**0,0248**
cr(t-3)	0,00731	0,0076	0,3362

F-statistic : 137,37
Prob > F : <.0001

L.Δhk	Coefficient	Standard-error	P-value
fl(t-1)	0,00646	0,0039	**0,0982**
yu(t-1)	0,00241	0,00291	0,4079
k(t-2)	-0,00144	0,0014	0,3019
l(t-2)	0,00119	0,00179	0,5059
cu(t-2)	-0,00447	0,00535	0,4041
cr(t-2)	0,00322	0,004	0,421
SW(t-2)	0,00527	0,00236	**0,0257**
awh(t-2)	0,06656	0,01981	**0,0008**
cr(t-3)	-0,00246	0,00383	0,521

F-statistic : 23,78
Prob > F : <.0001

L.Δhl	Coefficient	Standard-error	P-value
fl(t-1)	-0,00466	0,00173	**0,0072**
yu(t-1)	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 : <.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

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

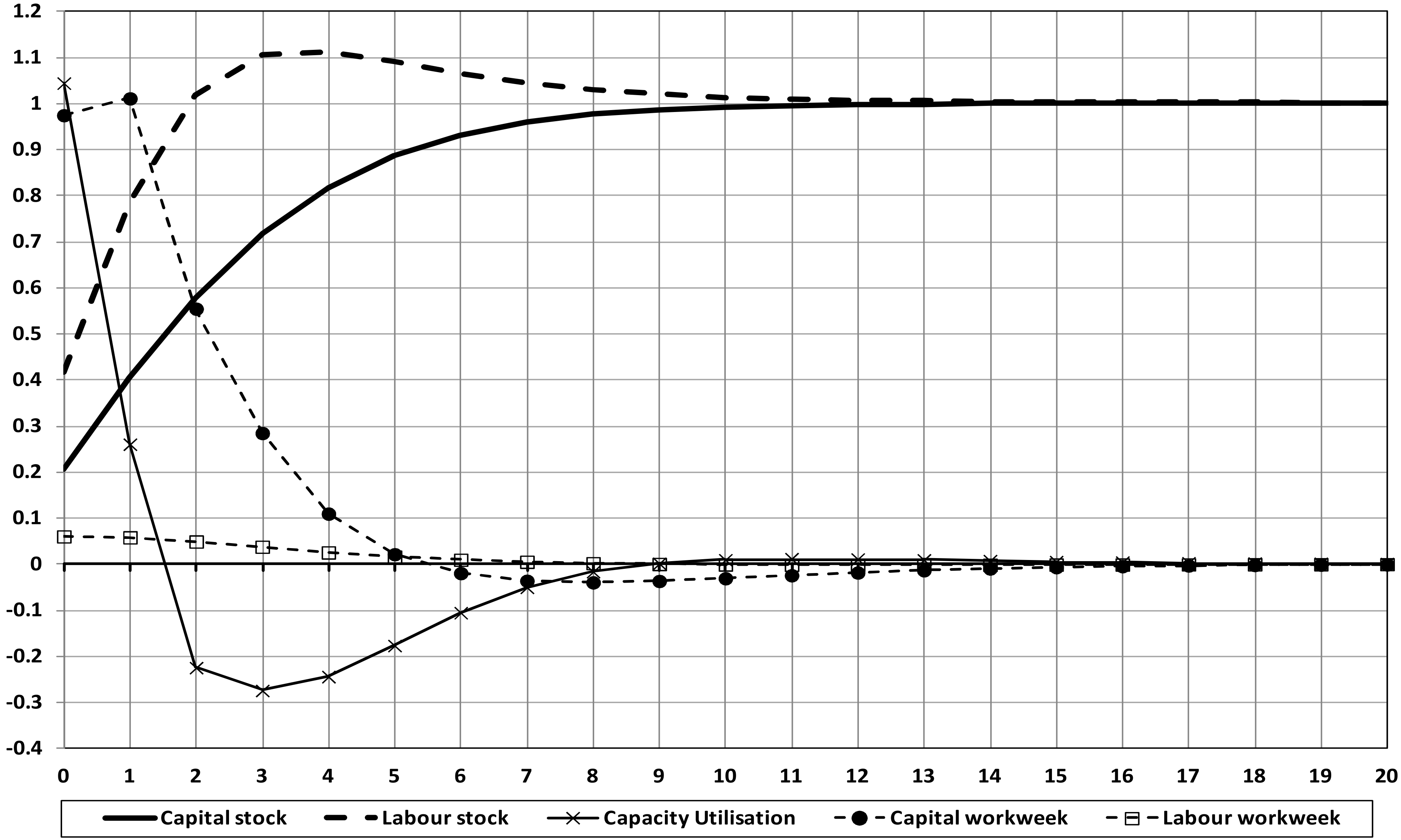
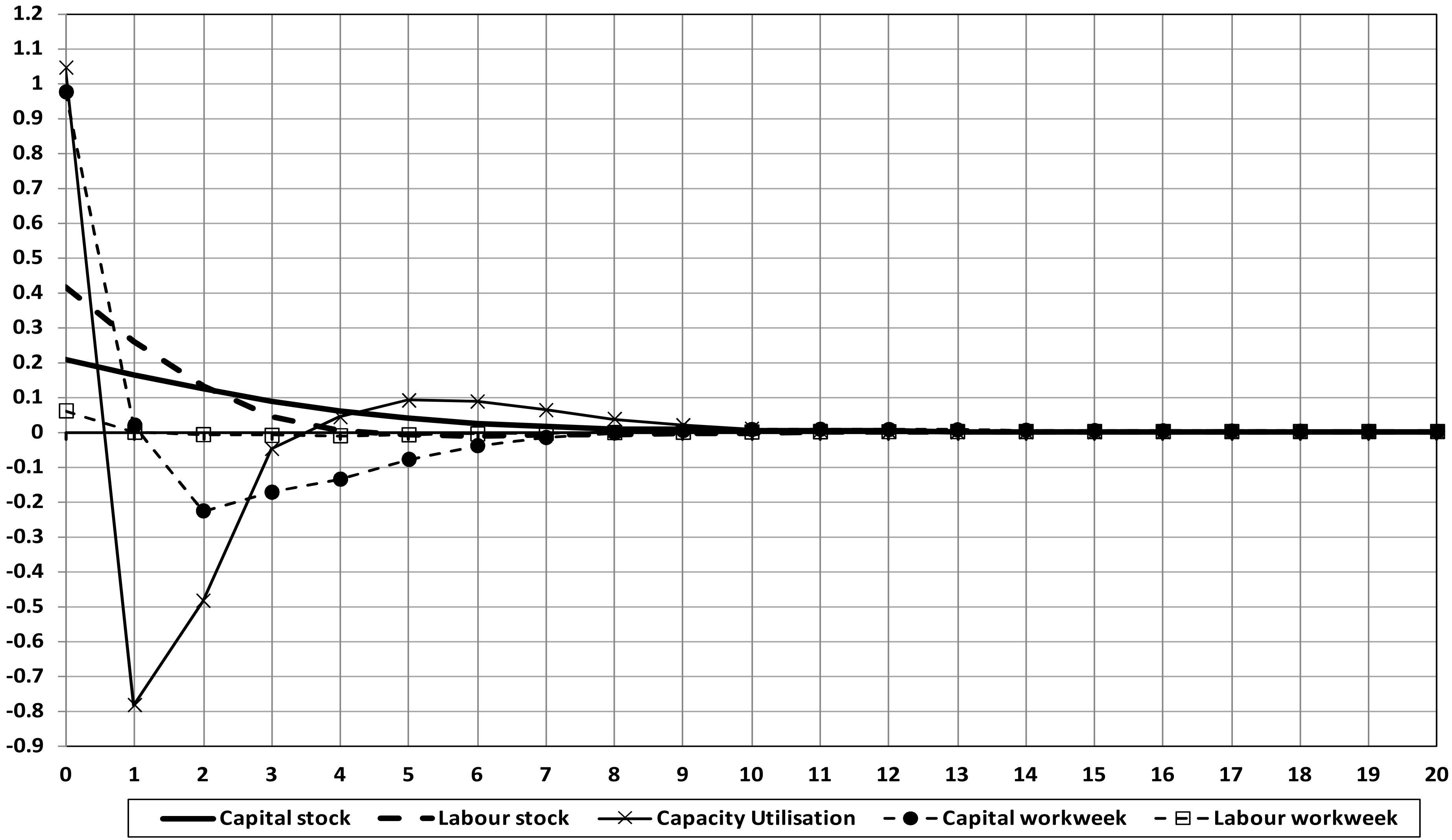


Figure 2: Simulation of the impact of a 1% increase in value added, changes (% change over the previous period)
From benchmark estimate results



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