Capital utilization and the willingness to rest : a general equilibrium analysis

Martial Dupaigne *

January 23, 2000
Submission to the World Congress of the Econometric Society
Preliminary version

Abstract

This paper develops a general equilibrium model acknowledging that greater capital utilization requires either longer hours or unsocial schedules. Contrary to the popular depreciation-in-use models, capital utilization does not only concern the firms' organisational choices but also labor supply behaviours, since an increase in the workweek of capital affects the households' welfare. Capital utilization and shiftworking are endogenously determined as equilibrium outcomes though –this was not the case in previous studies linking capital utilization to work conditions. A number of relevant cases where capital utilization does vary over the cycle are numerically illustrated : factor complementarity, quasi-fixity of input stocks and nominal rigidities.
Keywords: Leisure, Capital operating time, Factor utilization, Business cycle.

JEL Classification: C51, C52, E22, E32

1 Introduction

Variable factor utilization has recently received a renewed attention in the context of stochastic dynamic general equilibrium models. Cooley, Hansen and Prescott [1995], Burnside and Eichenbaum [1996], Fagnart, Licandro and Portier [1998], Burnside [1997], Dupaigne [1998] or Wen [1998], among others, acknowledge that variable factor utilization is a key mechanism to understand how does output increase or decrease after a shock has modified the economic environment agents face. These studies share the same goal of implementing variable factor utilization in general equilibrium framework, to depart from existing partial equilibrium work, as exemplified by quantity rationing models (Sneessens [1987], Licandro [1991]). The methodological issue involved in the description of underutilization is the justification of an increasing cost of factor utilization. Two main justifications compete.

*Université de Cergy-Pontoise, Crest & EUREQua, Maison des Sciences Économiques, 106-112 bd de l'Hôpital, 75647 Paris Cedex 13, France. E-mail: dupaigne@asterix.univ-paris1.fr. Phone number: +33 1 41 17 77 92

The first one is the "depreciation-in-use" hypothesis, introduced in this kind of models by Greenwood, Hercowitz and Huffman [1988]. It states that increasing capital utilization induces an increase in the depreciation rate of the physical capital stock, due to faster wear and tear. A justification of this assumption would be that the longer capital is used, the less it is available for maintenance activities, which are however required to keep equipment as productive as possible (on this point, see Licandro and Puch [2000].). The firm has therefore the opportunity to increase its capital productive flows today, at the expense of a loss in future capital.

Although the depreciation-in-use hypothesis appears as a relevant general equilibrium setup and yields well-defined equilibrium rules for capital utilization, it should however be clear that the capital utilization choices here only concern the firm – they only affect households through variations in the value of the firm they own. Households are otherwise completely indifferent about choices the firm makes, even though these choices are potentially full of consequences for their individual work conditions : some of the margins the firm may use to adjust factor utilization are intensive margins – the workweeks. An increase in the workweek of capital, for example, means that the equipment will be operated longer : earlier in the morning, later in the evening, at night, on sundays.... In which case *somebody* will have to operate it...

This is precisely what gives the second justification of the costs of factor utilization : in the words of Bils and Cho [1994], "firms do not work 100% of their time because it is costly to work labour around the clock". As a matter of fact, operating capital longer may essentially be achieved either by having everybody working longer hours or by adding new shifts ; and both means induce higher labor costs, for example through overtime of shift premia. Robust empirical evidences, including MacNabb [1989], Kostiuk [1990], Anxo and Taddéi [1995] or Bosworth and Pugh [1995] show that multiple shift workers get higher wages than the basic wage rate in their sector. Such shiftwork premia are typically justified by legal regulations or negotiated collective agreements.

Kydland and Prescott [1988] have first pointed out how the complementarity between capital and labor productive flows may be used to introduce capital utilization in a dynamic general equilibrium framework. Nevertheless, existing papers fail to explain how does this reorganization take place. On the contrary, an *ad hoc* relation linking the workweek of capital to individual hours, employment or productive effort is typically assumed in these papers, but without any clear micro-foundations.

The aim of this paper is therefore to investigate how does shiftworking affect agents' welfare by shifting the workday towards more unsocial schedules, and build a general equilibrium model of capital utilization where both type of agents care about the number of shifts. Next section presents a utility function that enabes to take the consequences of shiftworking on households into account ; section 3 describes the stochastic dynamic general equilibrium model and its competitive equilibrium. Section 4 studies how does factor utilization vary in a variety of situations, ranging from complementarity between inputs to nominal rigidities.

2 Capital utilization and shiftworking do affect households' welfare

Longer hours worked by capital require longer hours worked by households or an increase in the number of shifts worked. We argue in this paper that none of these ways to achieve higher capital utilization leaves households' welfare unaffected. Longer hours decrease agent's leisure time and therefore welfare. Shiftworking does not decrease leisure time, but changes its timing : if agents work multiple shifts, an agent will work during nights or week-end and will enjoy leisure during day (instead of nights) or during weeks (instead of week-ends). Due to a number of biological – such as circadian rhythms – or social features, this change in the pattern of work and leisure diminishes the welfare provided to the agents by its leisure. Such facts have been clearly established by an expanding literature on the timing of work and the instantaneous time use (Hamermesh [1995], Hamermesh [1996] or Hamermesh [1998]).

2.1 Preferences vary over the day

To model this idea, we define agents' preferences for leisure on a daily basis, as opposed to preferences for leisure over the whole period (say, a quarter). Our key assumption is that those preferences vary over the day : the disutility of work is higher during early morning, late evening and night than during the bulk of the day[1] : the disutility of labor will therefore depend not only on whether the agent work or not, but also during which moments she works.

Additive instantaneous utility at instant t provided by the consumption of c units of good and leisure (if the agent does not work) is defined as :

$$\mathcal{U}[c,t] = u(c) - \mathbb{1}(t)v(t)$$

where $\mathbb{1}(.)$ equals 1 if the agents works and 0 if she enjoys leisure, and $v(t)$ denotes how leisure is valued at instant t, the instantaneous disutility of work.

In our analysis, we do not assume, as Winston [1982] did, that economic decisions are taken on this continuous time scale. On the contrary we believe that the agent does

[1] In the following, we will focus on variations in the disutility of labor over the day, assuming they are constants over a week. This of course allows us to simplify exposition. It is clear that these results can be extended to a more general framework.

not decide minute after minute whether to work or not the next instant, but that he decides once a day *if*, *how long*, and *when*, he will work during the whole day. Decisions will be twofold : participation and workday are chosen discretely[2], whereas the timing of the workday is set (once a day) according to the continuous utility function.

To decide on a a daily basis, some aggregation of the instantaneous disutility function is required. Let us define the interval $[\tau, \tau+1]$ as a *day*. The aggregate disutility of work over the day is defined as the cumulative instantaneous disutility of labour over the workday. The cumulative utility over $[\tau, \tau+1[$ can be written :

$$\int_{\tau}^{\tau+1} \mathcal{U}\left[c,t\right] dt = \int_{\tau}^{\tau+1} \left[u\left(c\right) - \mathbb{1}(t)v(t)\right] dt = \int_{\tau}^{\tau+1} u\left(c\right) dt - \int_{T(\tau)} v(t)dt \qquad (1)$$

(the agent has no intraday psychological discount factor).

The workday $T(\tau) = \{\tau \leq t \leq \tau+1 \ / \ \mathbb{1}(t) = 1\}$ can be expressed as

$$T(t) = \{\tau \leq t \leq \tau+1 \ / \ \mathbb{1}(t) = 1\} = [t_0(\tau), t_0(\tau) + H(\tau)[$$

where $t_0(\tau)$ and $H(\tau)$ respectively denote the beginning of the agent's work period and its length on day τ, as soon as there is only on episode of work per day[3].

The household labor supply program is finally close to the standard discrete time one. The two differences are first that the disutility of the workday is defined as the temporal aggregation of instantaneous welfare losses ; and second that the beginning of the workday $t_0(\tau)$ is now a second choice variable.

Such program may become even closer to a standard consumption flow — work time choice if one assumes that instantaneous disutility of labour is symmetrical over the day. In that case, the beginning of the workday, given the length of this workday, is such that the middle of the workday is the point with the smallest instantaneous disutility of work. Analytically, the rationality condition is that the instantaneous disutility is the same at the first and last instant worked, so that the agent does not increase its cumulative welfare by pre or postponing its workday.

Finally, we obtain a discrete time utility functions whose arguments are aggregate consumption and the length of the workday, as would be the case if preferences did not vary over the day.

2.2 Shift working

We now consider multiple shifts : several workers have the same job throughout the day. More over, we assume that every workers operate successively during the different shifts.

[2]As are consumption plans. We have not specified whether consumption flows did vary over the day or not. At least two cases are consistent with the temporal aggregation we present : the first one is a constant flow of consumption over a day of length one ; the second is that all units of goods are consumed during the same instant of the day, for example at the beginning.

[3]Which should be the case if instantaneous disutility is unimodal, or if work requires some kind of fixed costs such as commuting time.

Taking shiftworking into account in this framework induces two major modifications.

The first one is that potential workday increases : every worker is likely to work during the whole workday of capital (which is now larger than the workday of one agent). This workday of capital is equal to the product of the workday of one agent $H(\tau)$ by the number of workers operating the same jobs $NWJ(\cdot)$, which is the number of shifts : $H_K(\tau) = NWJ(\tau) \times H(\tau)$.

But the second modification is that an agent is no longer sure to work during every one of these instants, because only one of the workers operating the same job works at a given time. This probability for a given worker to work at a given instant t within the whole workday $H_K(\tau)$ is $\frac{H(\tau)}{H_K(\tau)} = \frac{1}{NWJ(\tau)}$.[4] The expected cumulative disutility of work for one agent therefore becomes :

$$\int_{t_0(\tau)}^{t_0(\tau)+H_K(\tau)} \frac{H(\tau)}{H_K(\tau)} v(t)dt = \frac{H(\tau)}{H_K(\tau)} \int_{t_0(\tau)}^{t_0(\tau)+H_K(\tau)} v(t)dt$$

Provided that the workday $H_K(\tau)$ is continuous, this cumulative expected disutility reaches a minimum for :

$$\frac{H(\tau)}{H_K(\tau)} \int_{T-\frac{H_K(\tau)}{2}}^{T+\frac{H_K(\tau)}{2}} v(t)dt = \frac{H(\tau)}{H_K(\tau)} V[H_K(\tau)] \tag{2}$$

Expected cumulative disutility of a workday of H hours long in NWJ shifts does depend on both factors and not only on the workday of capital $H \times NWJ$. Hours and shifts are not perfect substitutes from the agent's point of view : the worker is not indifferent to the composition of the workday of capital between its individual workday and the number of shifts. Although both margins have the same effects of potential disutility, because they increase the time during which the agent may work, an increase in individual hours means every worker will work during less convenient hours, whereas an increase in the number of shifts also decrease the share of this potential disutility every worker will undergo.

2.3 An example of functional form : the sine wave

The following function was normalized so that it reaches its minimum, v_1, at 12 (noon), and its maximum, v_2, at 0 or 24.

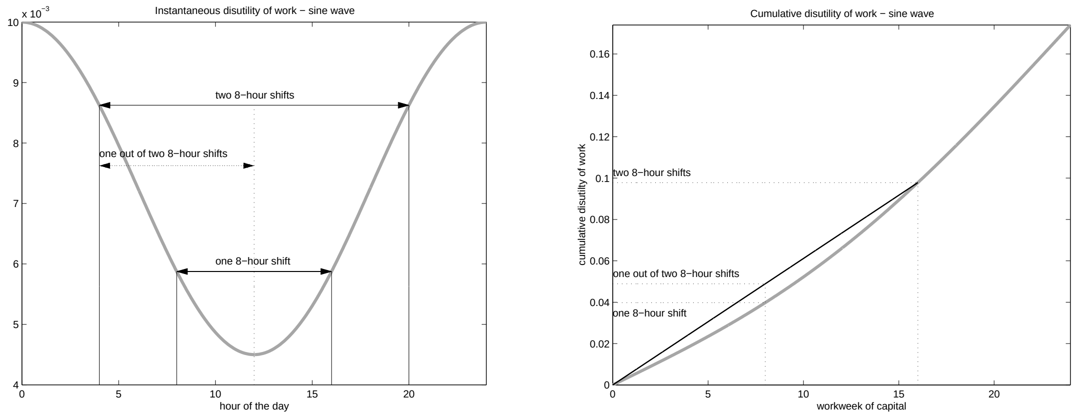
$$v(t) = \frac{v_1 + v_2}{2} + \frac{v_1 - v_2}{2} \cos\left(\frac{\pi}{12} t\right)$$

Expected cumulative disutility becomes in this particular case :

$$\frac{H(\tau)}{H_K(\tau)} V[H_K(\tau)] = \frac{H(\tau)}{H_K(\tau)} \left\{ \frac{v_1 + v_2}{2} H_K(\tau) - \frac{v_1 - v_2}{2} \frac{24}{\pi} \sin\left[\frac{\pi}{24} H_K(\tau)\right] \right\}$$

[4] If three teams operate eight hours each, every member of one team has one chance out of three to work during any minute of the day.

Figure 1: Disutility of work along the day



3 The competitive equilibrium

Taking the consequences on agents' welfare of variations in capital utilization and shiftworking enables a central planner to carry out an optimal endogenous choice of these two variables within this model, whereas Kydland and Prescott [1988], Bils and Cho [1994] or Dupaigne [1998] had to assume an *ad hoc* evolution rule of the workweek of capital. The competitive equilibrium is however harder to define, since a missing market arises. What should be made explicit is how both firms and households do perceive the consequences of their shiftworking choice : how does the firm know that working at night is painful for its employees?

There is no market for shiftworking, which means that the reward to late shift workers will be part of the wage rate, as a shift premium for example[5]. Equilibrium is achieved through a system of hedonic prices (see Rosen [1974]) : every job has a specific *quality*, and there exist a continuum of markets (hence an infinity of wage rates) for jobs with every possible quality. The household has first to decide whether to work or not ; having chosen to work to work, an agent has then to decide on which specific labor market and for which wage rate.

Throughout the paper, we will denote $W\left(H_{K,t}\right)$ the (nominal) wage rate associated with the market of labour with a workweek of capital of $H_{K,t}$ hours.

3.1 Households

As emphasized in the previous section, the welfare loss of an agent working H_t hours when the workweek of capital is $H_{K,t}$ hours is $\frac{H(\tau)}{H_K(\tau)}V[H_K(\tau)]$. Assuming that the households trade lotteries on their work, its static objective will be $\mathcal{U}\left(C_t, N_t, H_{L,t}, H_{K,t}\right) = \log(C_t) - NJ\,N_t\,\frac{H_{L,t}}{H_{K,t}}V[H_{K,t}]$, with NJ the numbers of days within the period. This

[5]Note however that such a shift premium is here a pure endogenous market outcome. It does not rely on any legal requirement. On the normative side, an analysis aiming to determine an optimal legal night shift premia rate could easily be undertaken in this framework.

means that besides consumption flows, agents care about the workweek of capital $H_{K,t}$ and the share of this workweek they actually work $\frac{N_t\,H_{L,t}}{H_{K,t}}$.

The household holds two kinds of assets : contingent claims and money. In any given state of nature $s_t \in \Omega$, the price in terms of consumption goods of one of the contingent claims is $\frac{\rho_t(s_t)}{\rho_{t-1}}$. The agent holds $B_t\,(s_t)$ units of this assets for a state of nature s_t. He agent is required to hold money at the beginning of the period in order to process transactions. E_t denotes its nominal money demand used for transactions at time t.

The intertemporal program of the representative household writes :

$$
\begin{aligned}
\mathcal{V}^H(B_t, E_t) \quad = \quad & \max_{\{C_t,\,N_t,\,H_{L,t},\,H_{K,t}\}} \quad \log\left(C_t\right) - N J\, N_t\,\frac{H_{L,t}}{H_{K,t}}\,V\left[H_{K,t}\right] + \beta\,\mathcal{E}_t\,\mathcal{V}^H\left(B_{t+1}, E_{t+1}\right) \\
& s.t. \quad \left\{ \begin{array}{rcl} \int_\Omega \frac{\rho_{t+1}(s_{t+1})}{\rho_t} B_{t+1}(s_{t+1})\mathrm{d}s_{t+1} \;+\; E_{t+1} & \leq & B_t + \frac{T_t+E_t}{f_t} + \frac{W(H_{K,t})}{f_t}\,N_t\,H_{L,t} \\ & & -C_t - G_t \\ C_t & \leq & \frac{T_t+E_t}{f_t} \end{array} \right.
\end{aligned}
$$

f_t is a price index relative to $t-1$. T_t denotes the monetary transfer to the households. These monetary transfer are equal to the increase in the money supply $T_t = M_{t+1} - M_t = (m_t - 1)\,M_t$. The stochastic growth rate of the money supply follows an AR(1) process:

$$
(1-\rho_m L)\log(m_t) = (1-\rho_m)\log(\overline{m}) + \varepsilon_{mt} \tag{3}
$$

G_t denotes government expenditures whose stationary component, g_t, is assumed to follow as well an exogenous covariance stationary AR(1) process:

$$
(1-\rho_g L)\log(g_t) = (1-\rho_g)\log(\overline{g}) + \varepsilon_{gt} \tag{4}
$$

where $|\rho_g| < 1$, and $\varepsilon_{gt} \rightsquigarrow \mathcal{N}(0, \sigma_g)$.

3.2 Firms

A general production function can be written as $F(\Gamma_t, H_{L,t}, N_t, H_{K,t}, K_t)$, where Γ_t denotes an exogenous productivity term, N_t employment, K_t the physical capital stock and $H_{L,t}$ and $H_{K,t}$ the number of hours worked during each period, respectively by labor and capital. The use of models embedding factor utilization margin allows to define the flows of productive factors provided by factors, namely labor and capital. Such flows can be expressed in man $\times$ hours unit in the case of labor. We do not assume that factor stocks and workweek have different contributions to those factor productive flows. Regarding labor, existing empirical evidence[6] are mixed : longer hours might increase average hourly product (because of the smaller share of unproductive time in the workday) as well as decrease it (because tired workers lack of attention,...).

[6]Briefly reviewed in Hamermesh [1993].

We will thus restrict to the following class of production function

$$Y_t = \Gamma_t \, F(N_t \, H_{L,t}, K_t \, H_{K,t}).$$

The representative firm maximises its present discounted value subject to the accumulation constraint.

$$\begin{aligned}
\mathcal{V}^F(K_t) \quad &= \quad \max_{\{N_t, H_{L,t}, H_{K,t}, I_t\}} \quad \Gamma_{t+i} F\left(N_{t+i} H_{L,t+i}, K_{t+i} H_{K,t+i}\right) - \frac{W\left(H_{K,t+i}\right)}{f_{t+i}} N_{t+i} \, H_{L,t+i} \\
& \qquad -I_{t+i} + \mathcal{E}_t \int_{\Omega} \frac{\rho_{t+1}(s_{t+1})}{\rho_t} \mathrm{d}s_{t+1} \, \mathcal{V}^F(K_{t+1}) \\
& \quad s.t. \quad K_{t+1} \leq (1-\delta) \, K_t + I_t
\end{aligned}$$

The process of the technological shock writes :

$$(1 - \rho_a L) \log(\Gamma_t) = (1 - \rho_a) \log(\overline{\Gamma}) + \mu_a + \varepsilon_{at} \tag{5}$$

with $0 < \rho_a \leq 1$

3.3 A competitive equilibrium with a missing price

A competitive equilibrium is a set of consumption, investment, labor supply and labor demand plans that fulfill the first order conditions of the household and firm programs given a distribution of wage rates $W(\cdot)$ among the different labor markets indexed by their workweek of capital and a price index. These prices must be such that the transversality conditions and the aggregate resource constraint are verified.

4 Endogenous capital utilization

This framework is well suited to study factor utilization : longer hours for any of the two factors entail welfare loss but yield higher income for the households, and enable higher level of output at the expense of a higher hourly wage rate to firms. It must be emphasized that all three variables employment, individual hours and the number of shifts cannot be determined simultaneously, since employment an individual hours for example only appear as product. Remember that what affect households' welfare is the share of total hours worked that they individually work[7] and that firms only care about factor productive flows. Total hours worked therefore appear here as the only determined quantity. For any employment level, the individual workweek is set so as to match the equilibrium level of total hours worked. Given this workday, the number of shifts is determined by the equilibrium workweek of capital.

[7] This share is equal to the numbers of jobs J_t, *i.e.* the number of employees working simultaneously during the same shifts –Hours worked by the two factors are equal, which means $H_{K,t} \, J_t \equiv H_{L,t} \, N_t$.

At the competitive equilibrium, both marginal product of labor and marginal disutility of labor are equal to the real wage. The complete system of labor markets and the hedonic prices ensure that the competitive equilibrium is an optimum. The optimality condition on hours work and the workweek of capital take the general form :

$$NJ\,\frac{V\left[H_{K,t}\right]}{H_{K,t}} = \Gamma_t\,\frac{\partial F\left(N_tH_{L,t},K_tH_{K,t}\right)}{\partial N_tH_{L,t}}\,\lambda_t \tag{6}$$

$$NJ\,N_tH_{L,t}\,\frac{\frac{\partial V\left[H_{K,t}\right]}{\partial H_{K,t}}H_{K,t}-V\left[H_{K,t}\right]}{H_{K,t}^2} = K_t\Gamma_t\,\frac{\partial F\left(N_tH_{L,t},K_tH_{K,t}\right)}{\partial K_tH_{K,t}}\,\lambda_t \tag{7}$$

where λ_t is the expected marginal value of wealth/the asset for the household.

4.1 The Cobb-Douglas production function

Assume that the production function is a constant returns to scale Cobb-Douglas on productive flows :

$$Y_t = \Gamma_t\,\left[N_tH_{L,t}\right]^{\alpha}\,\left[K_tK_{L,t}\right]^{1-\alpha},0<\alpha<1$$

The arbitrage condition between hours and the workweek of capital, obtained using (6) and (7), becomes:

$$V\left[H_{K,t}\right] = \alpha\,H_{K,t}\,\frac{\partial V\left[H_{K,t}\right]}{\partial H_{K,t}} \tag{8}$$

This condition obviously gives an equilibrium value of the workweek of capital $H_K^{\star}$ which is constant over time, as can be seen from figure 2, in appendix. In this particular case, the common practice of neglecting capital utilization and only focusing on the capital stock seems valid.

The remainder of the paper presents four situations, relevant for business cycle analysis, where this result is no longer true.

4.2 The CES production function

As soon as the elasticity of substitution between factor productive flows is different of one, variations in capital utilization do occur along the business cycle.

$$Y_t = \Gamma_t\left[\nu\left(N_tH_{L,t}\right)^{-\varrho}+(1-\nu)\left(K_tH_{K,t}\right)^{-\varrho}\right]^{-\frac{1}{\varrho}}$$

The arbitrage condition between hours and the workweek of capital, obtained using (6) and (7), becomes:

$$\frac{H_{K,t}\,\frac{\partial V\left[H_{K,t}\right]}{\partial H_{K,t}}}{V\left[H_{K,t}\right]} = 1+\frac{1-\nu}{\nu}\left[\frac{K_tH_{K,t}}{N_tH_{L,t}}\right]^{-\varrho} \tag{9}$$

Any variation of total hours worked yields in this case a variation in the ratio of marginal products. The optimal workweek of capital is no longer constant : for example, a technological shock causing an increase in hours worked also induces an increase in the workweek of capital (figure 3).

4.3 Labor hoarding

Another natural explanation of factor utilization is the quasi-fixed nature of inputs. When factors stocks are roughly constant over short periods of time, utilization rates remain the only margin along which the firm may respond to (aggregate) shocks. As a stock, quasi–fixity of the capital stock is widely accepted in the literature. Quasi–fixity of employment is more controversial. However, as soon as hours and labor are disentangled, labor hoarding phenomena, as described in Burnside, Eichenbaum and Rebelo [1993], or high adjustment costs justify the quasi–fixity of labor as a variable intensive margin is introduced in the model.

We have already emphasized that employment was not a key variable in this model. As a matter of fact, nothing would change in this economy if the level of employment was predetermined : individual hours and the number of shifts would adjust to obtain the equilibrium levels of hours worked and the workweek of capital. This does not mean that labor hoarding and quasi-fixed input do not play any role, but that the technological process is not described by employment (and capital), but by the number of jobs. Once again, what is important in this economy is how many jobs are available and how long will they be operated, should it be by a large number of shifts working few hours or few shifts working long hours. Accordingly, what should be costly to adjust and therefore chosen at the beginning of the period (before contemporaneous innovations to shocks occur) is the number of jobs J_t.

If the number of jobs is chosen according to a limited information set, and that the workweek of capital is chosen afterwards, the arbitrage condition does no longer hold – agents cannot proceed to any arbitrage between variables chosen at different dates. As soon as a shock occurs between the two decisions, the intensive margin will adjust and the workweek of capital will thus display short-term fluctuations – even with a Cobb-Douglas production function (see figure 4).

4.4 Adjustment costs on the number of jobs

This argument is largely consistent with the view supported previously that the number of jobs and the physical capital stock are the two variables that describe how does the firm produces, that they involve major technological changes and that they are costly to modify. The difference between these two descriptions of such an adjustment process may be viewed as follow. Labor hoarding hypothesis states that any adjustment after shocks have occurred is *impossible*. This impossibility must be interpreted as a technical one – it *cannot* be done, at any cost. However, adjustment is not only possible next period, but also does not seem costly any longer since the number of jobs gets back to its desired (anticipated) value from the very next period. As opposed, adjustment costs focus on economic costs more than technical impossibilities. Since adjustment is more costly when instantaneous, the agent smoothes its adjustment path over several periods.

Bils and Cho [1994] introduced a specification of adjustment costs on the capital/employment ratio. In that case, adjustment costs caused by adoption of a new technology would be smaller if two shifts operate it (*i.e.* if a new shift is added) than if only one does. Adjustment costs on the capital stock per job, instead of the capital stock per worker, remove this inconsistency. The specification presented below assumes that is costly to modify the stock of physical capital embedded in every job quicker than its deterministic growth rate :

$$\Phi(K_t, J_t, K_{t-1}, J_{t-1}) = \frac{\varphi}{2}\left(\frac{K_t/J_t}{K_{t-1}/J_{t-1}} - \overline{\Gamma}\right)^2 K_t \tag{10}$$

This structure of adjustment costs provides the model with some *clay–clay flavor*: as adjustment costs increase the cost of not modifying employment together with capital, capital and labor covary positively along the business cycle.

When such costs are introduced (figure 5), the determination of the number of jobs desired by the firm is no longer static, since the firm knows that its choices today will have consequences on its future states and choices. J_t therefore becomes a forward variable, and the arbitrage between the extensive and intensive margins involve (anticipated) future values of a large set of variables.

4.5 Nominal rigidities

Finally, we study how "‘demand-side" impulses may affect factor utilization in this model. According to the traditional view, demand shocks are the main impulse that explain variations in factor utilization. In such models, utilization rates act as buffers between a highly volatile demand and a more or less fixed capacity.

The (limited) effects of monetary shocks in perfectly competitive general equilibrium models are well known : an inflation tax lowers the opportunity cost of leisure relative to consumption. Households work less and consume less. In our setting, households will also enjoy their leisure during more favorable periods of the day– they choose *higher quality* leisure –, inducing a smaller workweek of capital. In order to get both qualitatively more appealing and quantitatively more significant effects require to introduce nominal rigidities. Monetary shocks then affect the real wage rate, and hence the output supply as well as the demand for output, yielding larger real effects.

As in Fairise [1994], Cho and Cooley [1995] or Cooley and Hansen [1998], we investigate the existence of nominal wage contracts. Firms and households sign labor contracts which specify the nominal wage rate one period ahead. Actually, each contract specify a set of nominal wage rates according to the workweek of capital, since labour market is best described as a continuum of specific labor market for every value the workweek of capital may take. For any given value of $H_{K,t}$, the contractual wage rate is equal the anticipated equilibrium nominal wage rate on this particular specific labour market. After shocks have occurred, the firm has to pay the nominal wage but is allowed to choose employment unilaterally. Here, the firm is also entitled to set the workweek of capital, which means the shiftworking conditions.

As a monetary shock induces an increase in the price level, the distribution of real wage rates across specific labour market shifts downward ; the firm has the opportunity not only to hire more labor (to create new jobs), but also to use higher quality employment, as the real value of the unsocial hours premium embedded in contractual nominal wages decreases (figure 6).

5 Conclusion

This paper is an attempt to show that choices regarding capital utilization should be related to those regarding leisure. These organisational decisions need not be treated separately, as is the case in the depreciation-in-use setup. On the contrary, sound and simple enough microeconomic justifications are given to the cost of increasing capital utilization: it deprives workers from resting precisely when households most value leisure. Labor on unsocial schedules is a different good from labor on office hours, hence its equilibrium price is different. This is why workers get wage premia for unsocial schedules and shiftworking. In turn, this increase in labor, which is a factor required to produce, explains that the capital stock remains unused during large fractions of the week.

Although a simple business cycle like analysis was performed to illustrate the properties of this model, it could easily be implemented to tackle other issues dealing with capital utilization: the long term increase in the workweek of capital mentioned in growth accounting (Foss [1981]), labor regulations imposing overtime premia and their extension to shiftworking in European countries...

References

Anxo, D. and D. Taddéi, Travail posté et durée d'utilisation des équipements dans l'industrie : un essai de comparaison internationale, in D. Anxo, G. Bosch, D. Bosworth, G. Cette, T. Sterner, and D. Taddéi, editors, *Utilisation des équipements et horaires de travail – Comparaison internationale*, INSEE Méthodes 49-50-51, 1995, chapter 5, pp. 133–158.

Bils, M. and J-O. Cho, Cyclical factor utilization, *Journal of Monetary Economics*, 1994, *33*, 319–354.

Bosworth, D. and C. Pugh, Multiple rhythmically varying prices, the timing of factor demands and induced technological change, *Labour*, 1995, *1*, 45–72.

Burnside, C., *Depreciation in use, shifts and the workweek of capital*, mimeo, The World Bank July 1997.

—— and M. Eichenbaum, Factor hoarding and the propagation of business cycle shocks, *American Economic Review*, December 1996, *86* (5), 1154–1176.

——, ——, and S. Rebelo, Labor hoarding and the business cycle, *Journal of Political Economy*, 1993, *101* (2), 245–273.

Cho, J-O. and T.F. Cooley, The business cycle with nominal contracts, *Economic Theory*, 1995, *6* (1), 13–33.

Collard, F. and M. Dupaigne, *Output dynamics and the workweek of capital*, Document de travail 9928, CREST 1999.

Cooley, T.F. and G.D. Hansen, The role of monetary shocks in equilibrium business cycle theory : three examples, *European Economic Review*, May 1998, *42* (3-5), 605–617.

——, ——, and E.C. Prescott, Equilibrium business cycles with idle resources and variable capacity utilization, *Economic Theory*, June 1995, *6* (1), 35–50.

Dupaigne, M., Capital operating time and economic fluctuations, *Recherches Économiques de Louvain*, 1998, *64* (3), 243–267.

Fagnart, J-F., O. Licandro, and F. Portier, Firm heterogeneity, capacity utilization and the business cycle, *Review of Economic Dynamics*, April 1998, *2* (2), 433–435.

Fairise, X., La dynamique de l'emploi et des salaires : un approfondissement de la théorie des cycles réels. PhD dissertation, Université Paris-I Panthéon-Sorbonne May 1994.

Foss, M., Long-run changes in the workweek of fixed capital, *American Economic Review*, May 1981, *71* (2), 59–63.

Greenwood, J., Z. Hercowitz, and G. Huffman, Investment, capacity utilization and the real business cycle, *American Economic Review*, 1988, *78* (3), 402–417.

Hamermesh, D.S., *Labor demand*, Princeton: Princeton University Press, 1993.

——, *Who works when ? Evidence from the US and germany*, Working paper 5208, NBER August 1995.

——, *The timing of work time over time*, Working paper 5855, NBER December 1996.

——, When we work, *American Economic Review*, May 1998, *88* (2), 321–325.

Kostiuk, P.F., Compensating differentials for shift work, *Journal of Political Economy*, 1990, *98* (5), 1054–1075.

Kydland, F.E. and E.C. Prescott, The workweek of capital and its cyclical implications, *Journal of Monetary Economics*, 1988, *21* (2/3), 343–360.

Licandro, O., Q investment models, factor complementarity and monopolistic competition, *Recherches Économiques de Louvain*, 1991, *58* (1), 51–73.

—— and L.A. Puch, Capital utilization, maintenance costs and the business cycle, *Annales d'Économie et de Statistiques*, à paraître 2000.

MacNabb, R., Compensating wage differentials : some evidence from Britain, *Oxford Economic Papers*, 1989, *41*, 327–338.

Rosen, S., Hedonic prices and implicit markets : product differentiation in pure competition, *Journal of Political Economy*, 1974, *82*, 34–55.

Sneessens, H., Investment and the inflation-unemployment tradeoff in a macroeconomic rationing model with monopolistic competition, *European Economic Review*, 1987, *31*, 781–815.

Wen, Y., Capacity utilization under increasing returns to scale, *Journal of Economic Theory*, July 1998, *81* (1), 7–36.

Winston, G.C., *The timing of economic activities*, New-York: Cambridge University Press, 1982.

A Numerical experiments

In order to illustrate in figures (2) to (6) the qualitative effects mentioned, we did run a variety of numerical experiments. The figure we used in these experiments are the following.

v_1 and v_2, the maximum and minimum level of instantaneous disutility of work were set so that, at the steady-state, the workday of labour equals 8 hours, the workday of capital is 12 hours and the employment rate is .58 (recall this three steady state values only give two exogenous, nh and j). Five days out of every thirteen week of a quarter are asumed to be worked, yielding $NJ = 65$. The share of labour in the Cobb-Douglas production function is .58, while ν was set to .21 and ϱ to .1 in the constant elasticity of substitution experiment. The value of the adjustment costs parameter, $\phi = .0343$ follows Collard and Dupaigne [1999].

Other parameters are standards in the RBC literature. The depreciation rate δ was set to .025 on a quarterly basis, the psychological discount factor $\beta = .99$. Government spending are the most persistant shock while money supply is the least: $\rho_g = .97$, $\rho_a = .95$, $\rho_m = .377$.

Figure 2: Cobb–Douglas – Technological shock

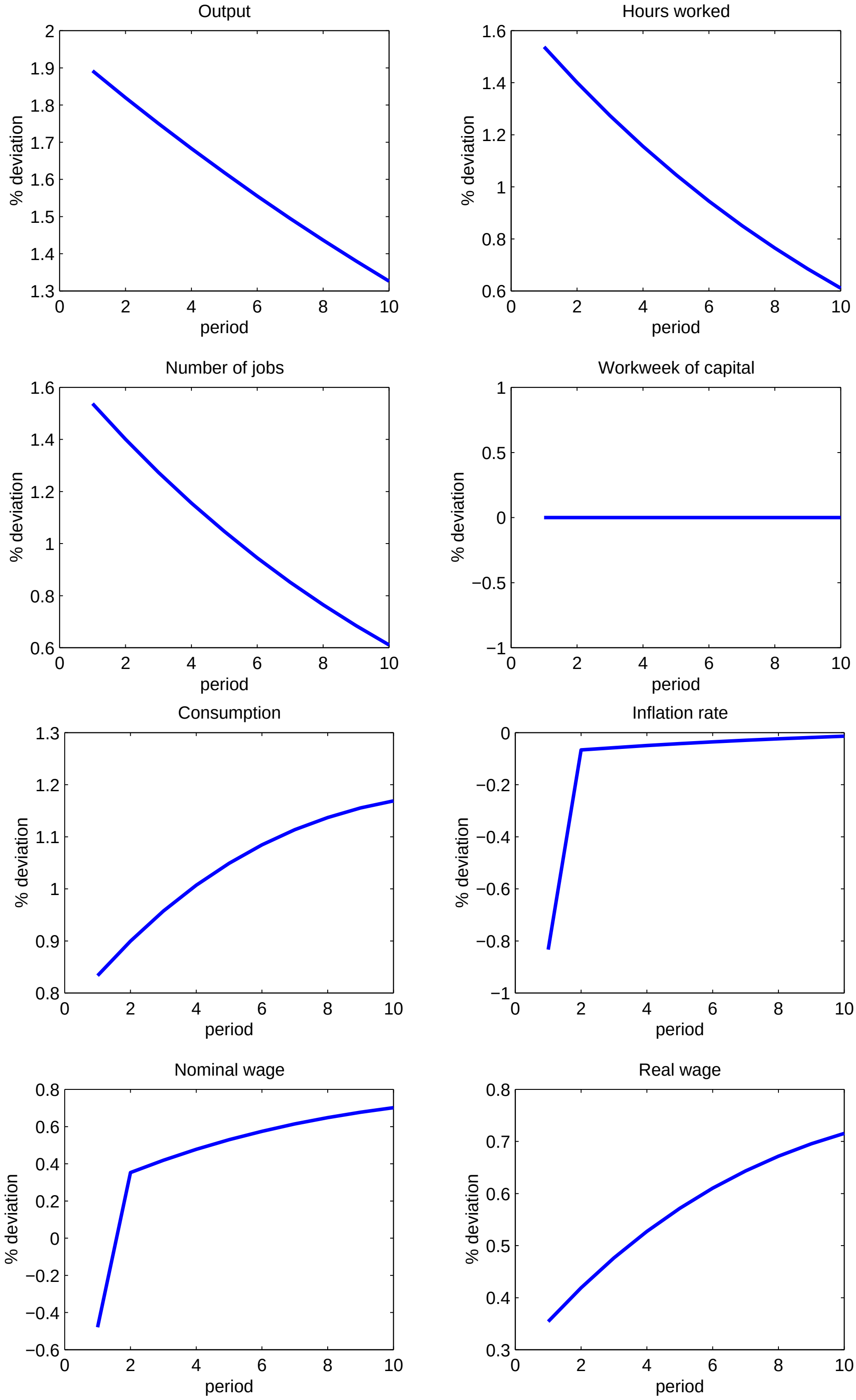


Figure 3: Constant elasticity of substitution – Technological shock

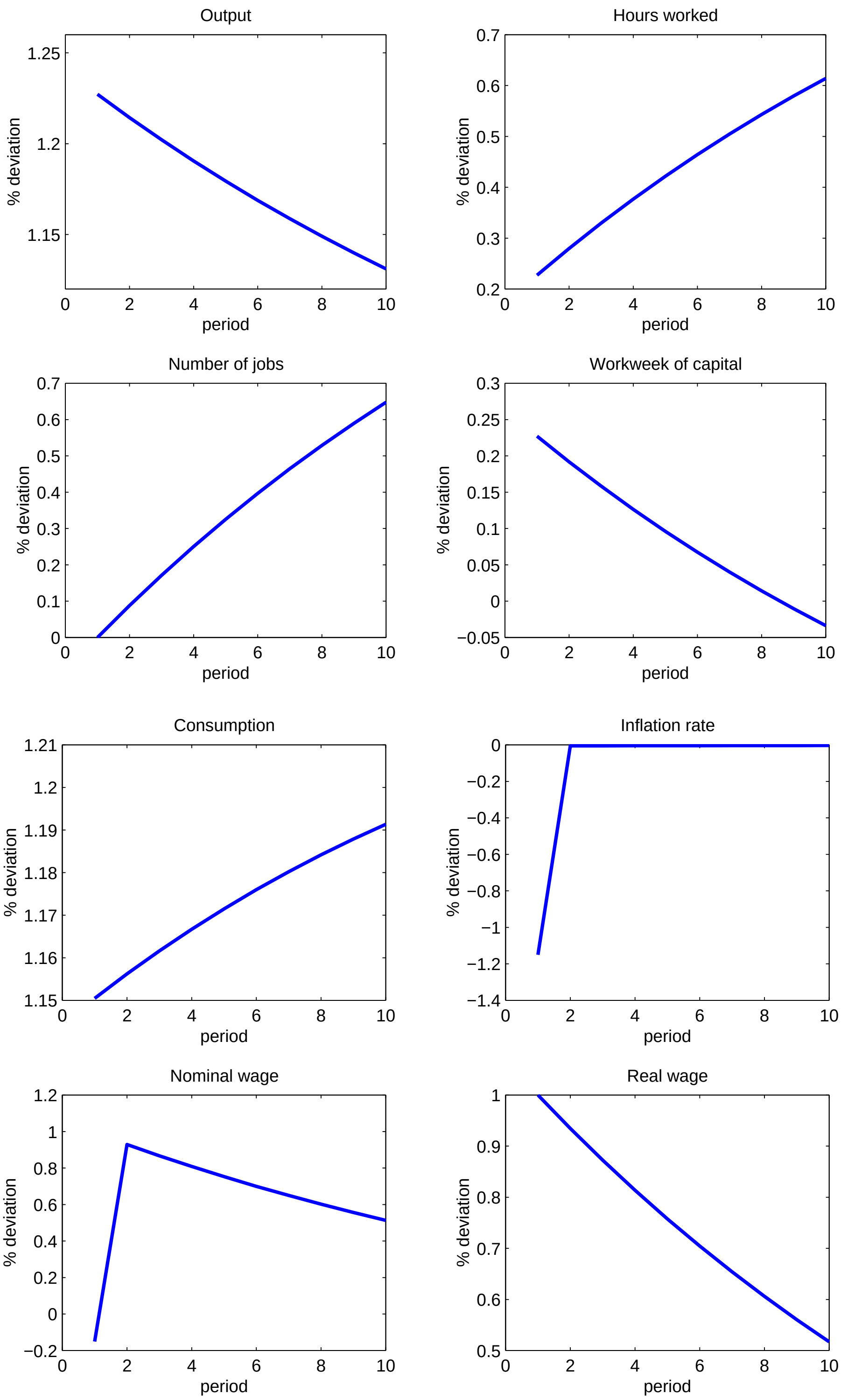


Figure 4: Labor hoarding – Technological shock

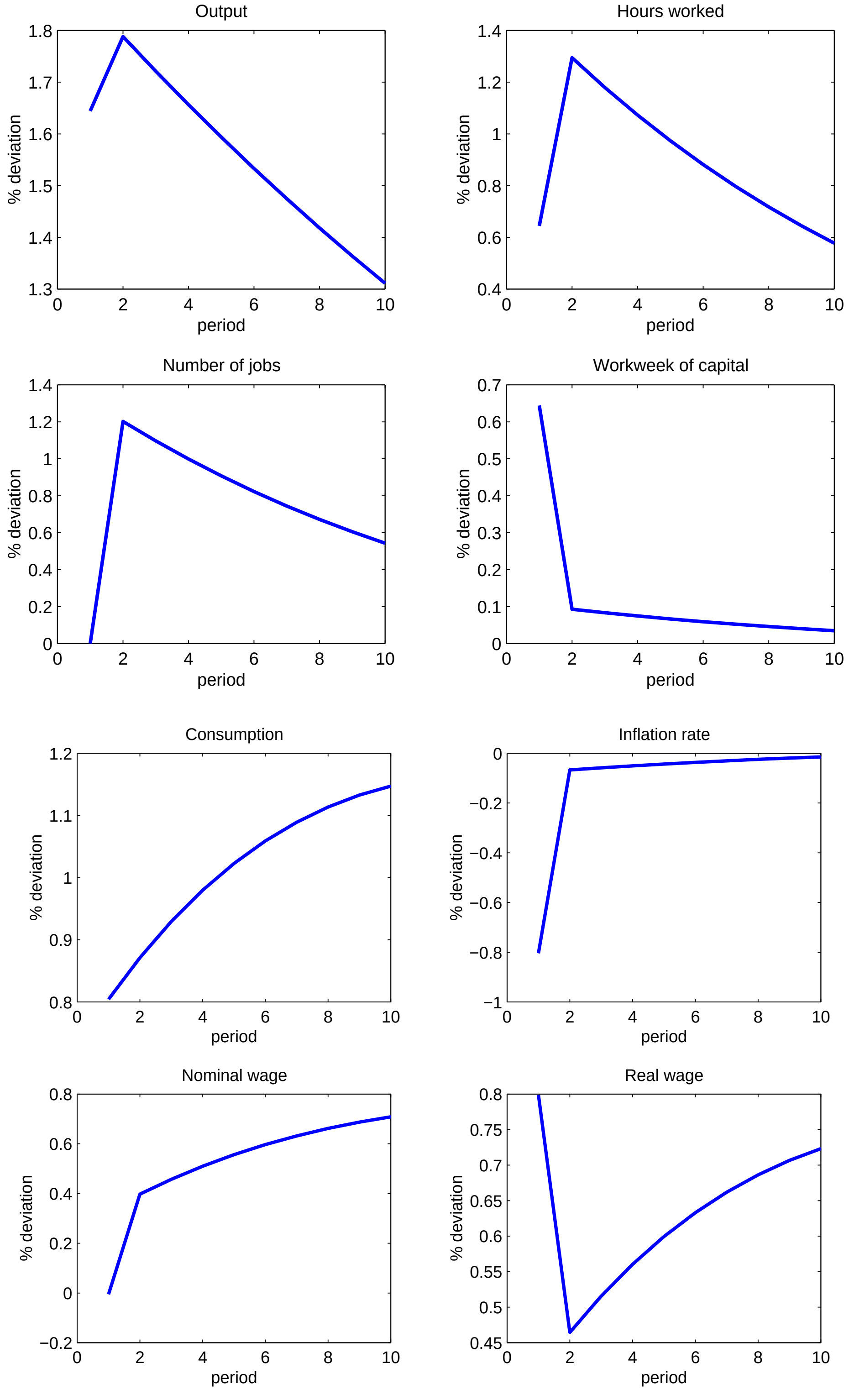


Figure 5: $\varphi = 0.0343$ – Technological shock

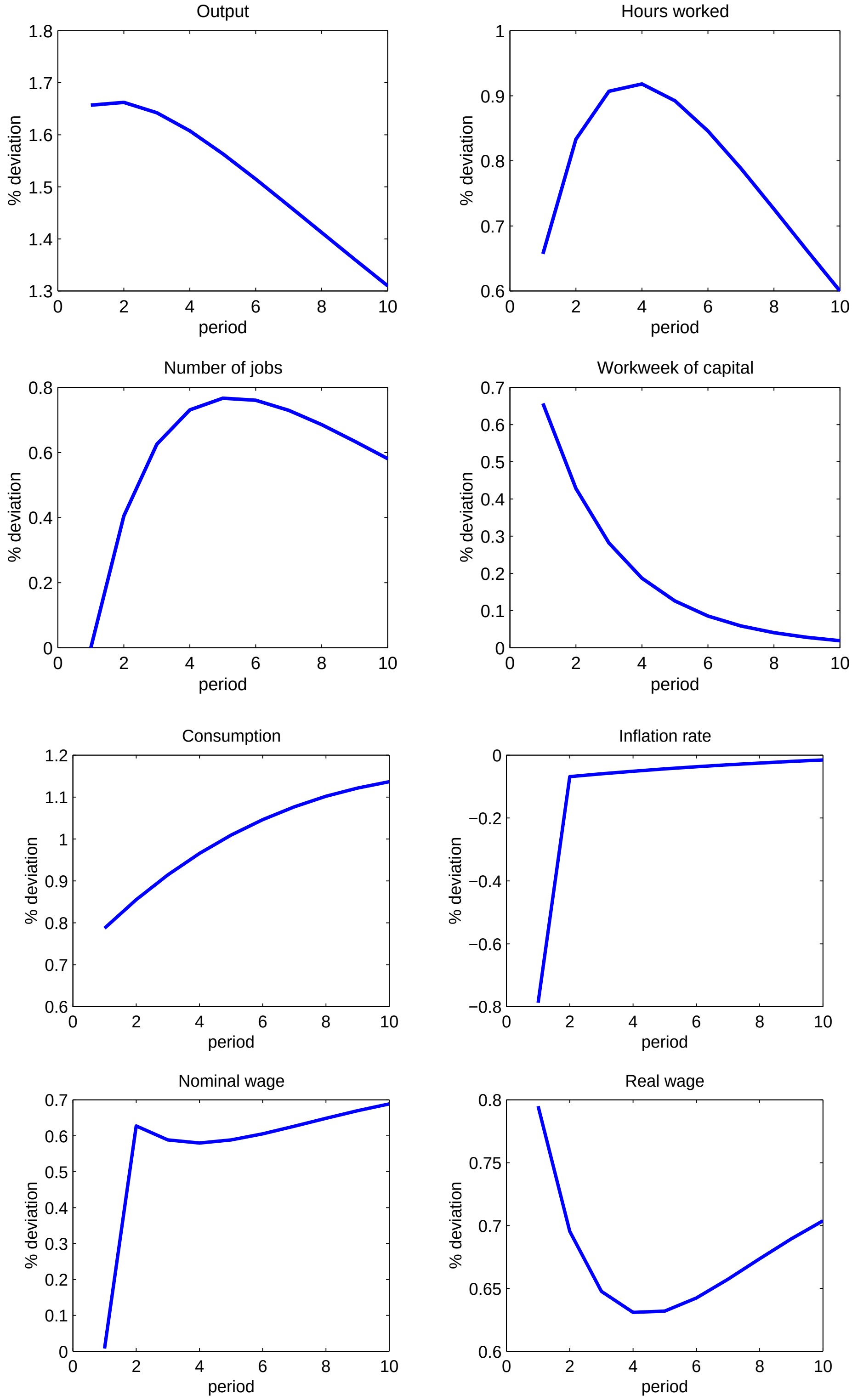


Figure 6: Nominal wage contracts – Monetary shock