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Shocks and Frictions under Right-to-Manage Wage Bargaining: A Transatlantic Perspective*

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Abstract

This paper introduces staggered right-to-manage wage bargaining into a New Keynesian business cycle model. Our key result is that the model is able to generate persistent responses in output, inflation, and total labor input to both neutral technology and monetary policy shocks. Furthermore, we compare the model's dynamic behavior when calibrated to the US and to an European economy. We find that the degree of price rigidity explains most of the differences in response to a monetary policy shock. When the economy is hit by a neutral technology shock, both price and wage rigidities turn out to be important.

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1 Introduction

This paper introduces staggered right-to-manage wage bargaining into a New Keynesian business cycle model. Our key result is that a reasonably calibrated version of the model is able to generate persistent responses in output, inflation, and total labor input to both neutral technology and monetary policy shocks. Furthermore, we compare the model's dynamic behavior when calibrated to the US and to a European economy. We find that the degree of price rigidity explains most of the differences in response to a monetary policy shock. Differences in the degree of wage rigidity, instead, alter the dynamics of the model economy only by little. When the economy is hit by a neutral technology shock, both price and wage rigidities turn out to be important. Apart from that, our results indicate that matching frictions matter primarily for the dynamics of the labor market.

We introduce frictional labor markets into a New Keynesian business cycle model akin to Christiano et al. (2005) and Smets & Wouters (2003). Households' preferences are represented by an additive utility function over consumption, working time, and real money holdings. The composite consumption good consists of a CES aggregate of differentiated intermediate goods. These goods are produced by monopolistically competitive intermediate good firms, facing Calvo (1983) type restrictions in price setting on the product market. Factor markets for capital and labor services, instead, are assumed to be perfectly competitive. Households accumulate physical capital and rent capital services at a variable utilization rate to the intermediate good firms. Labor services are provided by hiring firms searching for workers on frictional labor markets (Christoffel & Kuester 2008). Upon matching, firm-worker pairs first bargain over the real wage rate which is subject to staggered wage contracts. In the second step, hiring firms may choose the number of hours per worker unilaterally. In this setting, which is referred to as "right-to-manage" wage bargaining (Trigari 2006), the real wage rate is allocative for the number of hours per worker. Consequently, any rigidity in the real wage rate is transmitted via the New Keynesian Phillips Curve into persistent movements of inflation. This feature of right-to-manage wage bargaining is referred to as the "wage channel".

We then examine the effects of two structural shocks. The first shock represents a sudden increase in the short term nominal interest rate. Using different identification strategies and data sets, Sims (1992), Leeper et al. (1996), and Christiano et al. (1999, 2005), among others, demonstrate that such a shock leads to distinct U-shaped responses in both output and inflation. Moreover, Ravn & Simonelli (2008) show that also the dynamic time path of total labor input follows a U-shaped pattern in the aftermath of a monetary policy shock.

Second, we examine the impact of a neutral technology shock. Evidence on the effects of technology shocks is rather controversial. As shown by Galí (1999), a positive technology shock generates a persistent rise in output and a persistent decline in the inflation rate. In addition to that, he finds a *negative* correlation between technology and total labor input. The latter observation is in stark contrast to the predictions of the baseline RBC model and, thus, has sparked an intense and still ongoing debate in the literature. While Francis & Ramey (2005) provide evidence in favor of his result, Christiano et al. (2003, 2004) and Uhlig (2004) question its robustness.[1] The study by Ravn & Simonelli (2008) estimates a SVAR model of the US labor market which includes 4 different shocks: A neutral technology shock, an investment specific technology shock, a monetary policy shock, and a government spending shock. They argue that the large set of identified shocks minimizes the problem of mis-specification and, therefore, yields more robust results. Their findings confirm the conventional wisdom that a neutral technology shock leads to a positive and hump-shaped response in output and a negative and U-shaped response in inflation. Furthermore, they provide robust evidence that (*i*) output and total labor input are *positively* correlated at the business cycle frequencies in response to a neutral technology shock and that (*ii*) the impact response of the employment level is positive. The impact response of total labor input, however, depends on the question whether hours per worker are level or difference stationary.[2]

When we calibrate the model to the US economy, we observe that it is able to generate persistent output responses to monetary policy shocks. This seems to be the main contribution of our paper. New Keynesian models with Nash bargaining (e.g. Walsh 2005), instead, are not able to replicate this pattern once capital accumulation is introduced (Heer & Maussner 2010). This effect is due to the alternative bargaining approach. Right-to-manage wage bargaining establishes a direct link between the real wage rate and real marginal costs. Hence, any rigidity in the average real wage rate dampens the response in real marginal costs. This so-called "wage channel" has two important implications. First, the reduced elasticity of real marginal costs is transmitted via the New Keynesian Phillips Curve into persistent movements of inflation. Second, we note that the sluggish response in real marginal costs dampens additionally the response of the real interest rate. In the case of variable capital utilization, this leads to a hump-shaped decline in the input of capital services. Consequently, given that matching frictions induce a sluggish response in total labor input, we note that the response of aggregate output reaches its minimum not impact, but just in the second period after an innovation in monetary policy.

In response to a neutral technology shock, our model is able to replicate a hump-shaped response in output and a U-shaped response in inflation. Turning to the labor market, we observe that unemployment exhibits a negative impact response and then

[1] As pointed out by Peersman & Straub (2009) and Heer & Maussner (2010), the impact of technology on total labor input depends crucially on the question whether hours per worker are level or difference stationary.

[2] Their results are broadly consistent with the estimates of Braun et al. (2009), who use an alternative identification strategy.

continues to decrease for about 6 quarters. Hours per worker, instead, fall on impact, but then rise for about 2 years before eventually falling. Hence, consistent with the findings of Ravn & Simonelli (2008), we observe a positive correlation between output and total labor input at the business cycle frequencies in response to a neutral technology shock.

Apart from that, we calibrate our model to a European economy and compare its dynamic behavior with the US model economy. The European model economy differs in terms of a greater price rigidity parameter, a greater real wage rigidity parameter, and a larger degree of matching frictions in the labor market. In particular, we account for the fact that European transition rates between employment and unemployment are considerably lower. The higher value of the average European unemployment rate is mainly due to a more generous replacement ratio.

In response to a monetary policy shock, we observe that the decline in output and total labor input is larger and more protracted in the European model economy. The impulse response of inflation, however, shows a smaller impact response and a more persistent adjustment path. These three observations can be attributed to the greater price rigidity parameter. Further, the impulse response of the European unemployment rate exhibits a clear hump-shape. In the US model economy, on the contrary, the unemployment rate spikes on impact and then converges quickly to its steady state value. This pattern is mainly explained by the smaller value of the job separation rate which delays labor market turnover.

When the two model economies are hit by a neutral technology shock, we observe more interdependencies between the three frictions considered. On the one hand, the larger degree of price rigidity raises the amplitude of output and inflation. On the other hand, the larger degree of real wage rigidity dampens the amplitude and delays the speed of convergence. In total, the amplitude of both impulse responses remains almost constant, but convergence is slower under the European calibration. Again, the labor market calibration affects primarily the response of the unemployment rate. First, we note that the percentage impact response of the European unemployment rate is only about 1/4 of the US value. Second, in the same way as above, greater price rigidity increases the amplitude of the unemployment rate, while a large degree of real wage rigidity dampens the fluctuations. As a result, the joint impact of the two Calvo type rigidities raises the persistence of the unemployment rate, but leave its amplitude virtually unchanged.

The remainder of this paper is organized as follows. Section 2 presents the model environment. Section 3 calibrates the model and evaluates its quantitative performance. We investigate the mechanism of the right-to-manage bargaining model based on a calibration to the US economy. In addition, we examine the differences between the US and a European model economy. Section 4 concludes.

2 The Model Environment

2.1 Labor Market Frictions

Labor market frictions are represented by a Cobb-Douglas matching function that relates aggregate job matches M_t to the number of vacancies that are posted by the firms V_t and the number of unemployed job searchers U_{t-1}:[3]

$$M_t(V_t, U_{t-1}) = \chi V_t^{\mu} U_{t-1}^{1-\mu} \leq \min[V_t, U_{t-1}]. \tag{1}$$

The ratio between vacancies and unemployed job searchers ($V_t/U_{t-1} = \theta_t$) measures the tightness of the labor market. By linear homogeneity of the matching function, the vacancy filling rate $q(\theta_t)$ and the job finding rate $q(\theta_t)\theta_t$ depend solely on the value of labor market tightness:

$$q(\theta_t) \equiv \frac{M_t}{V_t} = \chi \left(\frac{U_{t-1}}{V_t}\right)^{1-\mu}, \qquad q(\theta_t)\theta_t \equiv \frac{M_t}{U_{t-1}} = \chi \left(\frac{V_t}{U_{t-1}}\right)^{\mu}. \tag{2}$$

The tighter the labor market, the longer the expected time to fill a vacancy, but the shorter the expected search for a job (and vice versa). The fact that firms and households do not internalize these adverse effects on the aggregate return rates gives rise to congestion externalities.

At the end of each period, new job matches are formed and a fraction of pre-existing jobs is terminated. Consistent with the results of Shimer (2007), we assume a constant job destruction rate ρ. Hence, the law of motion for the aggregate level of employment is given by:

$$N_t = (1-\rho)N_{t-1} + M_t. \tag{3}$$

Moreover, we assume that the real wage rate is subject to staggered wage contracts (Calvo 1983). This implies that — new and ongoing — firm-worker pairs are able to bargain over the real wage rate w_t^* only with probability $(1-\omega_w)$. Otherwise, the real wage rate in ongoing firm-worker pairs remains constant. New firm-worker pairs that are unable to negotiate simply adopt the average real wage rate of the previous period w_{t-1}.[4] Hence, the evolution of the average real wage rate w_t is governed by following law of motion:

$$w_t = \omega_w w_{t-1} + (1-\omega_w) w_t^*. \tag{4}$$

[3]We follow the textbook job matching model (Pissarides 1985, 2000) that abstracts from movements into and out of the labor force. Hence, $U_t = 1 - N_t$ holds.

[4]As demonstrated by Haefke et al. (2009) and Pissarides (2009), wages in new hires are significantly more volatile than wages in incumbent matches. Under right-to-manage wage bargaining, however, accounting for this aspect hardy changes the quantitative results (Christoffel et al. 2009). For this reason, we choose the described set-up for analytical convenience.

2.2 Households

There is a large number of households, each of which consists of a continuum of individuals. Household members derive utility from the composite consumption good $C_{j,t}$ and real money holdings $(M/P)_{j,t}$. Employed household members additionally suffer disutility from working time $h_{j,t}$. Hence, preferences of an individual household member j are given as:

$$U\left(C_{j,t},(M/P)_{j,t},h_{j,t}\right)=\frac{\left(C_{j,t}-\psi_c C_{j,t-1}\right)^{1-\sigma_c}}{1-\sigma_c}+\psi_q\frac{(M/P)_{j,t}^{1-\sigma_q}}{1-\sigma_q}-\psi_f\left(\frac{h_{j,t}^{1+\sigma_f}}{1+\sigma_f}\right), \quad (5)$$

where ψ_c measures the degree of habit persistence in consumption and $1/\sigma_f$ denotes the elasticity of intertemporal substitution in the supply of hours worked.

Employed and unemployed household members insure each other completely against idiosyncratic income risk from unemployment (Merz 1995, Andolfatto 1996). Thus, the budget constraint of the representative household can be written as:

$$\begin{aligned} C_t+I_t+(M/P)_t+B_t+a\left(x_t\right)\bar{k}_{t-1} &= \int_0^{N_{t-1}} w_{j,t}h_{j,t}dj+bU_{t-1}+\Pi_t+r_tK_t \\ &+\frac{(M/P)_{t-1}}{\pi_t}+\frac{R_{t-1}}{\pi_t}B_{t-1}-T_t. \quad (6)\end{aligned}$$

Employed household members earn the real wage rate $w_{j,t}$ per working hour $h_{j,t}$, while unemployed household members U_{t-1} receive unemployment benefits b. The lump-sum transfer T_t imposed by the government finances unemployment benefits, governmental consumption, and rebates any seigniorage revenue to the households (see section 2.6). Government bonds B_t pay a nominal interest rate R_t in period $t+1$. Moreover, households receive lump-sum dividends[5] Π_t remitted by firms and capital income r_tK_t. Effective capital services K_t are given by the physical capital stock $\bar{K}_{t-1}$ times the capital utilization rate x_t. Following (Schmitt-Grohe & Uribe 2004), the costs of variations in the degree of capital utilization are given as:

$$a\left(x_t\right)=\frac{\chi_a}{2}\left(x_t-1\right)^2+\chi_b(x_t-1). \quad (7)$$

Hence, provided that the steady state value of capital utilization is normalized to unity, the steady state of the model economy will be independent of $a(x_t)$, i.e. $a(1)=0$. Nevertheless, capital adjustment costs affect the utilization elasticity with respect to the rental rate of capital: $[a'(x)/(a''(x)\ x)]|_{x=1}=\chi_b/\chi_a$.

[5] Aggregate dividends $\Pi_t=\Pi_y+\Pi_n$ are given as the sum of dividends remitted by intermediate good firms and hiring firms, respectively.

Furthermore, the law of motion for the physical capital stock is given by:

$$\bar{K}_t = (1-\delta)\bar{K}_{t-1} + \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t, \tag{8}$$

$$\text{where } S(\cdot) = \frac{\chi_s}{2}\left(\frac{I_t - I_{t-1}}{I_{t-1}}\right)^2, \tag{9}$$

is restricted to satisfy $S(1) = S'(1) = 0$ and $S''(1) = \chi_s > 0$. The law of motion for the household's employment share reads as follows:

$$N_t = (1-\rho)N_{t-1} + q_t\theta_t U_{t-1}. \tag{10}$$

2.2.1 First Order Conditions

Provided stochastic time paths for $\left\{R_t, r_t, \Pi_t, \pi_t, \theta_t, T_t, \tilde{h}_t | \geq 0\right\}$, and a set of initial conditions for the state variables $\left\{\bar{K}_0, N_0, \tilde{w}_0\right\}$, the representative household chooses contingency plans $\left\{C_t, x_t, B_t, M_t, I_t, \bar{K}_t | t \geq 0\right\}$ that maximize its expected discounted utility:[6]

$$\mathcal{U}_t\left(\bar{K}_{t-1}, N_{t-1}, \tilde{w}_t\right) = \max_{C_t, x_t, B_t, M_t, I_t, \bar{k}_t} \left\{U(C_t, (M/P)_t, \tilde{h}_t) + \beta\mathcal{U}_{t+1}(\bar{K}_t, N_t, \tilde{w}_{t+1})\right\} \tag{11}$$

These choices have to satisfy following first order conditions:

$$\lambda_{c,t} = (C_t - \psi_c C_{t-1})^{-\sigma_c} - \beta E_t\left[\psi_c(C_{t+1} - \psi_c C_t)^{-\sigma_c}\right], \tag{12}$$

$$r_t = a'(x_t) = \chi_a(x_t - 1) + \chi_b, \tag{13}$$

$$\lambda_{c,t} = \beta E_t\left[\frac{\lambda_{c,t+1}}{\pi_{t+1}}\right] R_t, \tag{14}$$

$$\lambda_{c,t} = \left[\psi_q(M/P)_t^{-\sigma_q}\right] + \beta E_t\left[\frac{\lambda_{c,t+1}}{\pi_{t+1}}\right] \Leftrightarrow \left(\frac{M}{P}\right)^{\sigma_q} = \frac{\psi_q}{\lambda_{c,t}}\frac{R_t}{R_t - 1}, \tag{15}$$

$$\begin{aligned}\lambda_{c,t} &= \lambda_{k,t}\left[\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) - \left(\frac{I_t}{I_{t-1}}\right)\chi_s\left(\frac{I_t - I_{t-1}}{I_{t-1}}\right)\right] \\ &+ \beta E_t\left[\lambda_{k,t+1}\chi_s\left(\frac{I_{t+1} - I_t}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right],\end{aligned} \tag{16}$$

$$Q_t = \frac{\lambda_{k,t}}{\lambda_{c,t}} = \beta E_t\left\{\left(\frac{\lambda_{c,t+1}}{\lambda_{c,t}}\right)(Q_{t+1}(1-\delta) - a(x_{t+1}) + r_{t+1}x_{t+1})\right\}. \tag{17}$$

The first order conditions describe the marginal utility of consumption (12), the relation between the rental rate of capital r and the utilization rate x_t (13), the Euler equation for government bonds (14), the demand for real money holdings (15), optimal investment (16), and the real value of physical capital (17).

[6] The distribution of real wages and hours over matched firm-worker pairs is denoted by $\tilde{w}_t$ and $\tilde{h}_t$, respectively.

2.2.2 The Net Benefit of Additional Employment

The net marginal benefit to the household when an unemployed household member finds a job is given by the following expression:

$$\begin{aligned} \mathcal{W}_t\left(w_{j,t}\right) = \left(\frac{\partial \mathcal{U}_t}{\partial N_{t-1}}\right) - \left(\frac{\partial \mathcal{U}_t}{\partial U_{t-1}}\right) \quad = \quad & \lambda_{c,t}[w_{j,t}h_{j,t} - b] - \psi_f \left(h_{j,t}^{1+\sigma_f}/1+\sigma_f\right) \\ & + \omega_w \beta E_t \left[(1-\rho)\mathcal{W}(w_{j,t}) - q(\theta_t)\theta_t \mathcal{W}(w_t)\right] \\ & + (1-\omega_w)(1-\rho - q(\theta_t)\theta_t)\beta E_t \left[\mathcal{W}_2(w^*_{t+1})\right]. \end{aligned} \tag{18}$$

One additional employed household member increases the net income of the household, but suffers disutility from working time. Besides that, the household gains the continuation value of the current real wage rate $\mathcal{W}(w_{j,t})$ with probability $(1-\rho)\omega_w$, the continuation value of the re-negotiated real wage rate $\mathcal{W}(w^*_{j,t+1})$ with probability $(1-\rho)(1-\omega_w)$, and loses the continuation value of unemployment. The latter is determined by the job finding rate $q(\theta_t)\theta_t$, the expected value of a job that pays the average real wage rate $\mathcal{W}(w_t)$, and the expected value of a job that pays the re-negotiated real wage rate $\mathcal{W}(w^*_{j,t+1})$.

2.3 The Composite Consumption Good

The composite consumption good consists of a CES aggregate of differentiated intermediate goods:

$$C_t = \left[\int_0^1 C_{it}^{(\xi_p-1)/\xi_p} di\right]^{\xi_p/(\xi_p-1)}, \tag{19}$$

where $\xi_p > 1$ is the elasticity of substitution between differentiated intermediate goods C_{it}. Given that P_{it} denotes the price for intermediate good i, equation (19) implies that its relative demand is given as:

$$\frac{C_{i,t}}{C_t} = \left(\frac{P_{it}}{P_t}\right)^{-\xi_p}. \tag{20}$$

Integrating (20) and imposing (19), we obtain the associated minimum expenditure price index:

$$P_t = \left[\int_0^1 P_{i,t}^{1-\xi_p} di\right]^{1/(1-\xi_p)}. \tag{21}$$

2.4 Intermediate Good Firms

Each intermediate good $i \in [0,1]$ is produced by a single firm and sold in a market characterized by monopolistic competition.[7] The productive process in this sector can be described by a Cobb-Douglas production function with constant returns to scale:

$$Y(K_t, L_t) = \epsilon^z_t K_t^\alpha L_t^{1-\alpha}, \tag{22}$$

[7] Given symmetry, we will drop the subscript i in the following.

where ϵ_t^z represents total factor productivity subject to an exogenous shock specified by the following autoregressive process:

$$\epsilon_t^z = \rho_z \epsilon_{t-1}^z + \iota_t^z, \text{ where } \iota_t^z \sim N(0, \sigma_{\iota^z}^2). \tag{23}$$

Following de Walque et al. (2009), we assume perfect competition on the factor markets. Intermediate good firms rent capital services K_t directly from the households and labor services L_t from hiring firms. Constant returns to scale in production in combination with price-taking behavior on the factor markets yield following factor prices for capital (r_t) and labor services (W_t), respectively:

$$r_t = \lambda_{y,t} Y_1(K_t, L_t), \tag{24}$$

$$W_t = \lambda_{y,t} Y_2(K_t, L_t). \tag{25}$$

This implies that the real marginal cost $\lambda_{y,t}$ can be written as:

$$\lambda_{y,t} = \frac{1}{\epsilon_t^z} \left(\frac{r_t}{\alpha}\right)^{\alpha} \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}. \tag{26}$$

On the product market, intermediate good firms face Calvo (1983) type restrictions in price setting. In the beginning of period t, only a fraction $1 - \omega_p$ of intermediate good firms is able to re-optimize the price of its variety. Intermediate good firms that cannot re-optimize simply index their prices to lagged inflation π_{t-1}. This specification yields following log-linearized New Keynesian Phillips Curve:

$$\hat{\pi}_t = \frac{1}{1+\beta}\hat{\pi}_{t-1} + E_t\left[\frac{\beta}{1+\beta}\hat{\pi}_{t+1}\right] + \frac{(1-\omega_p)(1-\beta\omega_p)}{\omega_p(1+\beta)}\hat{\lambda}_{y,t}. \tag{27}$$

2.5 Employment relations

2.5.1 Hiring Firms

Labor services are provided by specialized hiring firms (Christoffel & Kuester 2008). There is a continuum of *potential* hiring firms on the unit interval. Each hiring firm can hire at most one worker j. Hiring firms with filled positions N_{t-1} produce labor services according to a decreasing returns to scale technology $H(h_{j,t}) = h_{j,t}^{\sigma_h}$, with $\sigma_h < 1$. Hence, the units of aggregate labor services L_t produced in period t are given by:

$$L_t = N_{t-1} H(\tilde{h}_t) = \int_0^{N_{t-1}} h_{j,t}^{\sigma_h} dj = \int_0^1 L_{i,t} di \tag{28}$$

The hiring firm j rents the amount $H(h_{j,t})$ of labor services to intermediate good firms at rate W_t on a competitive market. The worker receives the real wage rate $w_{j,t}$ per hour worked $h_{j,t}$.

If the match survives exogenous job destruction at the end of period t, the firm and the worker may re-negotiate the real wage rate with probability $(1-\omega_w)$ in period $t+1$. Otherwise, the real wage rate remains constant. Hence, the value of a filled position to the hiring firm reads as:

$$\mathcal{J}_t(w_{j,t}) = W_t H(h_{j,t}) - w_{j,t}h_{j,t} + (1-\rho)\beta E_t \left[\left(\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \right) (\omega_w \mathcal{J}_{t+1}(w_{j,t}) + (1-\omega_w)\mathcal{J}_{t+1}(w^*_{t+1})) \right]. \tag{29}$$

Hiring firms with unfilled positions may decide whether or not to open a vacancy. Posting a vacancy entails a cost κ per period. Therefore, the hiring firm can expect to gain the value of a filled position $\mathcal{J}_{t+1}$ with probability $q(\theta_t)$ in the next period. With probability $1-q(\theta_t)$ the vacancy remains unfilled. Upon matching, the firm-worker pair j will be able to bargain over the real wage rate w^*_{t+1} with probability $(1-\omega_w)$. If the hiring firm and the worker are unable to bargain, they will adopt the average real wage rate of the previous period, i.e. w_t. Thus, the value of an unfilled vacancy $\mathcal{V}_t$ is given as:

$$\mathcal{V}_t = -\kappa + \beta E_t \left[\left(\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \right) \left(q(\theta_t) \left\{ \omega_w \mathcal{J}_{t+1}(w_t) + (1-\omega_w)\mathcal{J}_{t+1}(w^*_{t+1}) \right\} + [1-q(\theta_t)]\mathcal{V}_{t+1} \right) \right]. \tag{30}$$

Free entry into the matching market ensures that the hiring firm's outside option, i.e. the value of an unfilled vacancy, is zero in each period: $\mathcal{V}_t = 0 \ \forall \ t$. Hence, the non-arbitrage condition for vacancy creation is given by:

$$\frac{\kappa}{q(\theta_t)} = \beta E_t \left[\left(\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \right) \left[\omega_w \mathcal{J}_{t+1}(w_t) + (1-\omega_w)\mathcal{J}_{t+1}(w^*_{t+1}) \right] \right]. \tag{31}$$

2.5.2 Right-to-Manage Wage Bargaining

Right-to-manage wage bargaining (Trigari 2006), in contrast, presumes following sequential setting: First, both parties agree on a real wage rate w_t according to the Nash rule. Second, the hiring firm may choose the number of hours per worker $h_{j,t}$ unilaterally. Thus, the hiring firm sets hours per worker in order to maximize $\mathcal{J}_t$:

$$w_{j,t} = \sigma_h W_t \frac{H(h_{j,t})}{h_{j,t}} \tag{32}$$

$$\Leftrightarrow h_t(w_{j,t}) = \left(\sigma_h \frac{W_t}{w_{j,t}} \right)^{1/(1-\sigma_h)} \tag{33}$$

The first order condition (32) states that hiring firms set hours per worker such that the real wage rate equals the marginal product per hour worked. Provided that σ_h is close to one, this implies that movements in the average real wage rate w_t translate almost one-to-one into changes in the competitive price of labor services W_t and, thus, into real marginal costs $\lambda_{y,t}$. This feature of the right-to-manage bargaining model is referred to as the "wage channel".

Furthermore, equation (33) points out that hours per worker under right-to-manage are a function of the real wage rate. During the wage bargaining, both parties internalize the impact of the real wage rate on the number of hours per worker. Hence, the maximization of the Nash product yields following sharing rule:

$$\eta \left(\frac{\partial \left(\mathcal{W}_t(w_{j,t})/\lambda_{c,t} \right)}{\partial w_{j,t}} \right) \Bigg|^* \mathcal{J}_t^* = (1-\eta) \left(-\frac{\partial \mathcal{J}_t(w_{j,t})}{\partial w_{j,t}} \right) \Bigg|^* \left(\mathcal{W}_t^* / \lambda_{c,t} \right), \tag{34}$$

where $0 < \eta < 1$ denotes the relative ("nominal") bargaining power of the household. The net marginal benefit of an increase in the real wage rate to the worker, and the loss to the hiring firm, respectively, are given as:[8]

$$\begin{aligned}
\delta_t^W &= \left(\frac{\partial \left(\mathcal{W}_t(w_{j,t})/\lambda_{c,t} \right)}{\partial w_{j,t}} \right) \Bigg|^* w_t^* \\
&= \frac{w_t^* h_t^*}{1-\sigma_h} \left[\frac{1}{w_t^*} \left(\psi_f \frac{(h_t^*)^{\sigma_f}}{\lambda_{c,t}} \right) - \sigma_h \right] + (1-\rho)\beta\omega_w E_t \Bigg[\left(\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \right) \left(\frac{w_{t+1}^*}{w_t^*} \right)^{(1+\sigma_f)/(1-\sigma_h)} \\
&\quad w_{t+1}^* \sum_{k=1}^{\infty} \frac{1}{1-\sigma_h} \left(\sigma_h \frac{W_{t+k}}{w_{j,t+k}} \right)^{1/(1-\sigma_h)} \left(\frac{1}{w_{j,t+k}} \right) \left(\frac{\psi_f}{\lambda_{c,t}} \right) \left(\sigma_h \frac{W_{t+k}}{w_{j,t+k}} \right)^{\psi_f/(1-\sigma_h)} \Bigg] \\
&\quad -(1-\rho)\beta\omega_w E_t \left[\left(\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \right) \left(\frac{w_{t+1}^*}{w_t^*} \right)^{\sigma_h/(1-\sigma_h)} w_{t+1}^* \sum_{k=1}^{\infty} \frac{\sigma_h}{1-\sigma_h} \left(\sigma_h \frac{W_{t+k}}{w_{j,t+k}} \right)^{1/(1-\sigma_h)} \right] \qquad (35) \\
\delta_t^F &= \left(-\frac{\partial J_t(w_{i,t})}{\partial w_{i,t}} \right) \Bigg|^* w_t^* \\
&= w_t^* h_t^* + (1-\rho)\beta\omega_w E_t \left[\left(\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \right) \left(\frac{w_{t+1}^*}{w_t^*} \right)^{\sigma_h/(1-\sigma_h)} \right]. \qquad (36)
\end{aligned}$$

Thus, using equations (18), (25), (28), (29), and (34) the steady-state wage equation can be written as:

$$wh = \eta^* \left[\lambda_y (1-\alpha) \frac{Y}{n} + \kappa\theta \right] + (1-\eta^*) \left[b + \frac{\psi_f}{\lambda_c} \frac{h^{1+\sigma_f}}{1+\sigma_f} \right], \tag{37}$$

where the effective bargaining weight η_t^* is a time-dependent variable:

$$\eta_t^* = \frac{\eta \delta_t^W}{\eta \delta_t^W + (1-\eta)\delta_t^F}. \tag{38}$$

[8]We have multiplied both expressions with the re-negotiated real wage rate w_t^*.

2.6 Government and Monetary Authority

The government finances unemployment benefits b, issues bonds B_t that pay a nominal interest rate R_t in period $t+1$, and consumes a constant share of output $G_t = gY_t$. Any seigniorage revenue is rebated to the households. Each period, the budget balance is maintained by imposing a lump-sum tax T_t:

$$T_t + (M/P)_t + B_t = bU_{t-1} + \frac{(M/P)_{t-1}}{\pi_t} + B_{t-1}\frac{R_{t-1}}{\pi_t} + G_t. \tag{39}$$

Monetary policy obeys a generalized Taylor (1993) rule:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R_t}\right)^{\phi_r} \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y}\right)^{(1-\phi_r)} \exp\left(\epsilon_t^r\right), \tag{40}$$

where ϵ_t^r is a serially uncorrelated, mean zero stochastic process and $\phi_\pi > 1$. Accordingly, the monetary authority sets the short-term nominal interest rate depending on the lagged nominal interest rate R_{t-1}, current inflation π_t, and the current level of economic activity Y_t (Clarida et al. 2000).

2.7 Market Clearing

The model economy is closed by the resource constraint. It postulates that output is divided into private consumption, investment, government consumption, vacancy posting costs, and capital utilization costs.

$$Y_t = C_t + I_t + G_t + \kappa V_t + a\left(x_t\right)\bar{k}_{t-1}. \tag{41}$$

3 Model Evaluation

3.1 Calibration US

We analyze the cyclical behavior of the log-linearized model economy around the non-stochastic steady state. The parameters are chosen to be largely consistent with those standard in the literature. The time period of the model corresponds to one quarter.

Preferences The discount factor β is chosen to match an annual real interest rate of 4 percent (Kydland & Prescott 1982). Following Christiano et al. (2005), we assume logarithmic preferences in consumption ($\sigma_c = 1$), together with external habit formation ($\psi_c = 0.65$). In addition, we borrow their estimates for the interest semi-elasticity of money demand (0.96, implying $\sigma_q = 6.3$) and the elasticity of substitution between differentiated intermediate goods ($\xi_p = 6$). The latter value implies that the average mark-up

$((1/\lambda_y)-1)$ is equal to 20%. For the intertemporal elasticity of labor supply $(1/\sigma_f)$ we target a value that lies within the range [0.3 – 0.7] estimated by MaCurdy (1983).

Production and the Capital Market The monthly depreciation rate δ is set to match an annual rate of 10% (Kydland & Prescott 1982). In addition, we adopt following two parameters from Christiano et al. (2005): First, we set $\alpha = 0.36$ which corresponds to a steady state labor share slightly below 64%.[9] Second, the scaling parameter of the investment adjustment cost function ($\chi_s = 2$) is chosen such that the elasticity of investment with respect to a one percent temporary increase in the current price of installed capital is equal to 0.4. Our chosen value for the elasticity of capital utilization with respect to the rental rate of capital $(\chi_b/\chi_a) = 1$ is close to the estimate by Smets & Wouters (2007).

Matching and the Labor Market Following Shimer (2005), we target an average unemployment rate $U = 5.7\%$ and a steady state job finding rate $q(\theta)\theta = 83.4\%$. This requires setting the job destruction rate ρ equal to 5% (Davis & Haltiwanger 1990). Moreover, we assume that unemployment benefits $b = rep_b\, W$ as well as the steady state leisure gain from unemployment

$$\frac{\psi_f}{\lambda_{c,t}} \frac{h_t^{1+\sigma_f}}{1+\sigma_f} = rep_h\, W = rep_h\, \lambda_y (1-\alpha)(Y/N), \tag{42}$$

can be quantified as percentage of the competitive price of labor services W. This allows us to derive an expression which we can solve for the steady state (un)employment rate in closed form. Therefore, we plug the vacancy filling rate (31), the steady state job flow condition (3), and the wage equation (37) into the job creation condition (31):

$$\frac{N}{1-N} = \frac{[(1-\eta^*)(1-\alpha)(1-(rep_b+rep_h))\lambda_y Y] - [(\kappa V/\beta\rho)(1-\beta(1-\rho))]}{\eta^* \kappa V} \tag{43}$$

We parameterize equation (43) as follows: *Effective* bargaining power is assumed to be symmetrically distributed, i.e. $\eta^* = 0.5$ (Svejnar 1986). Unemployment benefits $rep_b = 0.36$ are calibrated using OECD (2006, p. 60) data on the net replacement rate. Average vacancy posting costs are set to the standard value of $\kappa V = 1\%$ (Hamermesh & Pfann 1996, p. 1278). Output Y is normalized to unity. Given these values, we have to set $rep_h = 28.5\%$ in order to replicate an average unemployment rate $U = 5.7\%$. Thus, the total replacement ratio is equal to $rep_b + rep_h = 64.5\%$. Our calibration implies that the semi-elasticity of unemployment with respect to the replacement rate is equal to 3. This value lies within the range of estimates by Costain & Reiter (2008).[10]

[9] In labor search models the labor share is slightly lower than the production elasticity of labor.

[10] As a further robustness check, we reduce unemployment benefits by 10 percentage points. This implies that the steady state unemployment rate falls by 1.3 percentage points, which is in line with the results of Bassanini & Duval (2006).

The matching elasticity of vacancies ($\mu = 0.5$) does not affect the steady state of the model economy, but its cyclical behavior. We set $\mu = 0.5$, which is within the interval $[0.3, 0.5]$ proposed by Petrongolo & Pissarides (2001). Moreover, our choice ($\mu = \eta^*$) satisfies the Hosios (1990) condition. Finally, we set the steady state vacancy filling rate $q(\theta)$ to 0.7 (van Ours & Ridder 1992).[11]

Right-to-Manage Bargaining Given that average working time h is normalized to unity (Trigari 2006), we can derive an expression for labor efficiency σ_h, using the competitive price of labor services (25), the value of a job to the firm (29), the firm's first order condition for hours per worker (32), and the job creation condition (31):

$$\sigma_h = 0.9775 = 1 - \frac{(\kappa V/\rho\beta)(1-\beta(1-\rho))}{\lambda_y(1-\alpha)H(h)}. \tag{44}$$

This value is close to constant returns to scale (Christoffel & Kuester 2008). We then assume that worker's "nominal" and effective bargaining power are equal in the steady state, i.e. $\eta = \eta^* = 0.5$. This implies that, in the steady state, the net marginal benefit of an increase in the real wage rate to the worker (δ^W) equals the net marginal loss to the hiring firm (δ^F). According to equations (35) and (36), this condition holds if the real wage rate w equals the marginal rate of substitution. This requires setting $\sigma_h = 2.43$, a value that is consistent with the results of MaCurdy (1983).

Government and Monetary Policy We calibrate the share of governmental consumption in total output g to 18% (Smets & Wouters 2007), which implies an average consumption share (C/Y) of about 56%. The ratio of nominal output $P\,Y$ to the monetary aggregate M, i.e. the velocity of money, is set to 0.36 (Christiano et al. 2005). The values chosen for the generalized Taylor rule ($\phi_r = 0.8, \phi_\pi = 2.0, \phi_y = 0.3$) are taken from Gertler et al. (2008).

Price and Wage Rigidities We adopt the Calvo (1983) price ($\omega_p = 0.60$) and wage ($\omega_w = 0.65$) rigidity parameters estimated by Christiano et al. (2005).

Stochastic Processes We calibrate the law of motion for the technology shock using the conventional values ($\rho^z = 0.95, \iota^z = 0.007$) suggested by Cooley & Prescott (1995). The standard deviation of the monetary policy shock ($\iota^m = 0.002$) is taken from Walsh (2005).

[11] As demonstrated by Shimer (2005), the model allows for the normalization of the vacancy filling rate. Nevertheless, we choose a meaningful value.

3.2 Calibration France

Our analysis focuses on the impact of staggered prices, staggered wages, and the size of labor market flows. Hence, in order to facilitate comparability with the US model economy, we only alter the respective parameters (Table 2). Following Álvarez et al. (2006), we set the degree of price rigidity $\omega_p^F = 0.75$. The parameter governing the degree of wage rigidity ($\omega_w^F = 0.83$) is chosen in accordance with du Caju et al. (2008). Furthermore, we target the average French unemployment rate between 1978:2007, i.e. $U^F = 9.0\%$ (OECD 2008*b*). Given that the French job finding rate exhibits almost no duration dependence (Hobijn & Şahin 2009, Elsby et al. 2009), we approximate the steady-state job finding rate ($q^F(\theta^F)\theta^F = 21.3\%$) by the average fraction of workers unemployed for less than three months (OECD 2008*a*). These values imply an average job separation rate equal to $\rho^F = 2.36\%$.[12] The amount of French unemployment benefits is calibrated to $rep_b^F = 0.57$ (OECD 2006). We then set the leisure gain from unemployment $rep_l^F = 0.188$ in order to match the average French unemployment rate (Equation 43). Finally, we choose $\sigma_f^F = 4.19$, such that $\eta^* = \eta$ holds. The implied value of labor efficiency ($\sigma_h^F = 0.9723$, Equation 44) remains almost unchanged.

3.3 Inspecting the Mechanism of Staggered Wage Contracts

This section examines the dynamic behavior of a New Keynesian business cycle model with right-to-manage wage bargaining. Our computations are performed using Dynare 4.0.2 (Juillard 1996). Table (1) presents the impulse responses of the US model economy to an innovation in monetary policy, given different values of the real wage rigidity parameter ($\omega_w = \{0.00, 0.01, 0.65, 0.83\}$). Table (2) repeats the same exercise for a neutral technology shock. The graphs depict the evolution of the impulse responses over 32 quarters.

Impulse Responses to an Innovation in Monetary Policy The impulse responses reveal that staggered wage contracts are an effective means to reduce the elasticity of the *average* real wage rate. Even if there is only a very small share of matches that are unable to re-negotiate ($\omega_w = 0.01$), we observe a significant difference in the dynamic behavior of the real wage rate compared to the fully flexible wage regime ($\omega_w = 0.00$). If we increase the wage rigidity parameter until it equals the value estimated for the US economy ($\omega_w = 0.60$), the elasticity of the real wage rate decreases further. However, the value estimated for France ($\omega_w = 0.83$) generates almost the same impulse response as the US value.

Since labor efficiency σ_h is close to unity, the impulse responses of the average real wage rate w_t and of the competitive price of labor services W_t match each other almost exactly.

[12] Our values are almost identical to the ones of Sigrist (2009), who estimates an average job finding rate equal to 20.1% and an average job separation rate equal to 2.4% for France on a quarterly basis.

Moreover, Equation (26) shows that the competitive price of labor services feeds directly into the determination of real marginal costs $\lambda_{y,t}$. Hence, any rigidity in the average real wage rate is transmitted via the competitive price of labor services into the dynamic time path of real marginal costs. This implies that real wage rigidity under right-to-manage wage bargaining is able to reduce the elasticity of real marginal costs. The New Keynesian Phillips Curve entails that these sluggish dynamics translate into persistent movements of inflation. The direct link between real wage rigidity and inflation persistence established by the right-to-manage bargaining model is known as the "wage channel" (Trigari 2006).

Furthermore, we note that the model is not only capable to generate persistent responses in inflation, but also in output and total labor input. The so-called wage channel established by the right-to-manage bargaining approach increases not only the persistence of inflation, but dampens also the response of the real interest rate. In the case of variable capital utilization, this implies that the input of capital services responds more sluggishly. Consequently, given that matching frictions induce a lagged response in total labor input, we note that the response of aggregate output reaches its minimum not impact, but just in the second period after an innovation in monetary policy.

The mechanism behind staggered right-to-manage wage bargaining can be described as follows. Firm j is able to set unilaterally the profit maximizing number of hour per worker $h_{j,t}$, given the spread between the real wage $w_{j,t}$ paid in match j and the competitive price of labor services W_t (Equation 33). Recall that the impulse responses of the average real wage rate w_t and of the competitive price of labor services W_t match each other almost exactly. Hiring firms that are unable to re-negotiate, however, may be forced to pay a real wage rate $w_{j,t}$ that is quite different from the competitive price of labor services. Hence, given that labor efficiency σ_h is close to unity, these firms tend to adjust the number of hours per worker drastically.[13]

Following three impulse response functions illustrate the consequences of right-to-manage wage bargaining: (i) the number of hours per worker associated with the *average* real wage rate w_t,[14] (ii) the number of hours per worker associated with the *re-negotiated* real wage rate w_t^*, and (iii) the number of hours per worker associated with the *lagged* average real wage rate w_{t-1}. In the case of fully flexible real wages, the average real wage rate and the re-negotiated real wage rate are identical, and so are the corresponding impulse responses of hours per worker. Yet, even if there is only a very small share of firms that is unable to re-negotiate ($\omega_w = 0.01$), we note that these firms find it optimal to adjust the number of hours per worker to a large extent. In response to an innovation in monetary policy, the impulse response of hours per worker associated with the lagged

[13]This is a distinct feature of the right-to-manage bargaining model with staggered wage contracts. Only if the number of hours per worker depends on the real wage rate, a dispersion of hours per worker can emerge.

[14]In our first order approximation, the number of hours per worker associated with the average real wage rate is equal to the average number of hours per worker (Schmitt-Grohe & Uribe 2004).

average real wage rate $h(w_{t-1})$ plummets on impact by more than 60% and then shoots up sharply, peaking at approximately 40% above its steady-state value after 3 quarters. Given that the average number of hours per worker $h(w_t)$ remains almost unchanged, large movements in $h(w_{t-1})$ imply a significant change in the adjustment pattern of hours per worker associated with the re-negotiated real wage rate $h(w_t^*)$. In the case of fully flexible wages, the impulse response of $h(w_t^*)$ shows a negative spike on impact and a fast convergence to its steady-state value. But if only 1% of the wage contracts is not re-negotiated in every period, the impulse response shows a clear hump-shape and a considerably slower speed of convergence.

We emphasize this issue, since the impulse response of the number of hours per worker associated with the re-negotiated real wage rate $h(w_t^*)$ is of great importance for the dynamics of the whole model economy. In particular, the movements in $h(w_t^*)$ determine the sign of the response of the effective bargaining weight η_t^*. This implies that movements in $h(w_t^*)$ feed back into the re-negotiated real wage rate w_t^*. If wages are fully flexible, an innovation in monetary policy induces a fall in the effective bargaining weight of the household which accounts for approximately 2/3rd of the reduction in the re-negotiated real wage rate w_t^*. With increasing real wage rigidity, instead, the bargaining weight of the household *raises* on impact by 3% and, hence, stabilizes the re-negotiated real wage rate. This explains why the impulse response of the re-negotiated real wage w_t^* rate matches the impulse response of the average real wage rate w_t almost exactly.

Impulse Responses to a Neutral Technology Shock This section analyzes the effects of a neutral technology shock on the dynamic behavior of the model economy. Consistent with the results of Ravn & Simonelli (2008), Figure (2) shows that the impact response of employment is positive, and then continues to rise until it reaches a maximum after about 6 quarters.[15] Real wage rigidity clearly amplifies the response of the employment level. Hours per worker, on the other hand, show a negative impact response. In the following periods, however, the average number of hours per worker rises dramatically and peaks after about 6 quarters. Comparing the elasticities of the employment level and hours per worker, we note that firms adjust employment primarily through the intensive margin. This prediction is not consistent with the data (see below). For this reason, we observe that the responses of total labor input and hours per worker are very similar. Total labor input remains below its steady-state value in the first few quarters after a neutral technology shock. As soon as prices adjust, intermediate good firms expand output and tend to demand more labor services from the hiring firms. Hence, total labor input follows a hump-shaped pattern. This implies that output and total labor input are positively correlated at the business cycle frequencies in response to a neutral technology

[15]In our model, $N_t = 1 - U_t$ holds (see Footnote 3). Hence, the responses of employment and unemployment are symmetric.

shock ($\rho_{X,Y}$=0.95, see Table 3). Furthermore, the expansion in aggregate output induces the monetary authority to raise the nominal interest rate. Thus, we observe a pronounced U-shape in the impulse response of inflation.

Staggered wage contracts reduce the elasticity of the real wage in the same way as in response to monetary policy shocks. But, in contrast to the last section, real wage rigidity now increases the amplitude of the fluctuations in the average number of hours per worker. As a result, the elasticity of average labor costs $w_t h_t$ rises, the more rigid is the real wage rate. This surprising outcome is due to the fact that hiring firms that are unable to re-negotiate tend to increase the number of hours per worker $h_{j,t}$ enormously. Hiring firms that are able to re-negotiate, instead, even decrease the number of hours per worker h_t^* slightly.

In order to study the consequences of right-to-manage wage bargaining for the dynamics of the labor market, we recall that the incentive of a potential hiring firm to open a new vacancy is provided by the discounted flow of expected profits. Moreover, as shown by Christoffel & Kuester (2008), right-to-manage bargaining entails that the profit flow of a hiring firm $\Pi_{j,n}$ is proportional to its labor costs $w_{j,t}h_{j,t}$:

$$\Pi_{j,n}(t) = W_t H(h_{j,t}) - w_{j,t}h_{j,t} = ((1-\sigma_h)/\sigma_h)w_{j,t}h_{j,t} \tag{45}$$

In other words, the model predicts that (un)employment fluctuates stronger, the more volatile are labor costs. For this reason, the introduction of real wage rigidity amplifies the volatility of the labor market variables. It does so, however, not because labor costs are more rigid, but because labor costs are more volatile.

In addition to that, we note that real wage rigidity raises the elasticity of output by a large extent. The increase in the elasticity of aggregate output is mainly driven by adjustments in the average number of hours per worker. Since firms are able to adjust the number of hours per worker unilaterally, they do so extensively. This explains why right-to-manage bargaining model with staggered wage contracts is able to increase the *absolute* volatility of the labor market, but not the *relative* movements of unemployment with respect to aggregate output (see also Table 3). Hence, our model cannot replicate the stylized the stylized business cycle fact that most of the variation in total labor input is due to movements into and out of employment rather than to adjustments in the average number of hours per worker (see Section 3.4).

This finding clearly contradicts previous work by Shimer (2004) and Hall (2005), which suggests that real wage rigidity establishes an important amplification mechanism for the labor market. The opposing implications are driven by differences in the underlying bargaining process. Under Nash bargaining, as assumed by Shimer (2004) and Hall (2005), the real wage rate w_t splits the mutual surplus, while hours per worker h_t are set independently of the actual real wage rate in order to maximize the mutual surplus. Maximization of the mutual surplus requires that the marginal product of labor is equal to the marginal rate of substitution (Cheron & Langot 2004). This has three important implications. First, as shown by Trigari (2006), the marginal rate of substitution is the main determinant of the dynamics of real marginal costs — and not the real wage rate. Second, the profit flow of hiring firms is not proportional to labor costs. Consequently, models with Nash bargaining and real wage rigidity (Krause & Lubik 2007) do not exhibit a "wage channel", but are capable to amplify the relative volatility of the labor market. Third, the real wage rate is *not* allocative for hours per worker. Hence, the effective bargaining weight is constant and unable to absorb any shocks.

3.4 A Transatlantic Perspective

This section examines the impact of country-specific frictions on the dynamic behavior of the model economy. In particular, we focus on differences in the price rigidity parameter, the wage rigidity parameter, and in the degree of matching frictions in the labor market. In particular, we account for the fact that European transition rates between employment and unemployment are considerably lower. The higher value of the average unemployment rate is mainly due to a more generous replacement ratio. We then evaluate the model calibrated to the US (Section 3.1) against the model calibrated to the French economy (Section 3.2). In order to disentangle the effects of these frictions, we additionally evaluate two counter-factual model economies: (*i*) the model calibrated to France, but with prices flexible as in the US and (*ii*) the model calibrated to France, but with prices *and* wages flexible as in the US. The latter model exhibits the same Calvo type rigidity parameters as the US model economy, but differs in the calibration of the labor market.

Impulse Responses to an Innovation in Monetary Policy Table (3) shows that the degree of price rigidity plays a dominant role in the determination of aggregate inflation. If prices change more frequently, the impulse response function is considerably more elastic and immediate. The more flexible response of US prices entails that aggregate output falls by less and converges much faster to its steady state value. Quite surprisingly, the higher degree of real wage rigidity in France has no significant impact on the responses of inflation and output. Furthermore, we observe that the impulse response of the French unemployment rate exhibits a clear hump-shape. In the US model economy, on the contrary, the unemployment rate spikes on impact and then converges quickly to its steady state value. This pattern is mainly explained by the smaller value of the job separation rate which delays labor market turnover.

In summary, the model indicates that the transmission of an innovation in monetary policy to the economy is mainly determined by the degree of price rigidity. The degree of real wage rigidity, in contrast, seems to be less important.[16]. In addition, we find out that central banks concerned about the stabilization of employment should closely monitor the transition rates between the different labor market states.

Impulse Responses to a Neutral Technology Shock When the two model economies are hit by a neutral technology shock (Table 4), we observe more interdependencies between the three frictions considered. On the one hand, the larger degree of price rigidity raises the amplitude of output and inflation. On the other hand, the larger degree of real wage rigidity dampens the amplitude and delays the speed of convergence. In total, the amplitude of both impulse responses remains almost constant, but convergence is slower under the French calibration. Again, the labor market calibration affects primarily the response of the unemployment rate. First, we note that the percentage impact response of the French unemployment rate is only about 1/4 of the US value. Second, in the same way as above, greater price rigidity increases the amplitude of the unemployment rate, while a large degree of real wage rigidity dampens the fluctuations. As a result, the joint impact of the two Calvo type rigidities raises the persistence of the unemployment rate, but leave its amplitude virtually unchanged.

Discussion of the Second Moments Table (3) illustrates the unconditional second moments of the US economy, the French economy, and the conditional model generated data. As is well known, US labor market fluctuations are very volatile and persistent. The US unemployment rate is about 7 times as volatile as output, vacancies even more. This stylized fact has attracted much attention in the recent literature.[17] Total labor input is about as volatile as output. Most of its variability seems to be due to variations in the stock of employment rather than the average number of hours per worker, confirming the findings of Cooley & Prescott (1995). The wage bill per worker is significantly less volatile than output. Besides, we observe that consumption is somewhat less volatile than output, while investment fluctuates more. Inflation exhibits significantly less cyclical variability than output, is counter-cyclical, and very persistent.

Quite surprisingly, we notice that the unconditional moments of the French economy are fairly similar. The most interesting differences are the following. The volatility of French output is only about 2/3 of the US value. This implies that the absolute volatility of aggregate variables like unemployment, vacancies, investment or consumption is significantly lower than in the US, although the relative volatilities are very close to each

[16]Section (3.3) sheds some light upon this surprising result. The presence of real wage rigidity is relevant for the transmission of monetary policy. However, the medium US value and the high French value generate almost the same results

[17]Shimer (2005) stimulated a considerable discussion on how to match the high volatility found in the data. The most prominent examples include staggered Nash bargaining (Gertler & Trigari 2009) and an alternative calibration procedure (Hagedorn & Manovskii 2008).

other. In addition, we note that, in France, co-movement between output and all variables considered is weaker. In particular, the wage bill per worker and its components are essentially acyclical. Nevertheless, the wage bill per worker exhibits a considerable degree of cyclical volatility.

The model presented is not designed to match these facts. The model was rather developed to replicate the qualitative pattern of the impulse response functions. Nevertheless, the model is capable to replicate a positive correlation between output and total labor input at the business cycle frequencies to a neutral technology shock (Ravn & Simonelli 2008). Apart from that, the simulated data clearly point out along which lines the fit of the model is yet to be improved. Neither the neutral technology shock, nor the monetary policy shock is able to explain the large cyclical volatility in the unemployment rate. On the other hand, the model generates excess volatility in the number of hours per worker. This implies that most of the volatility in total labor input is induced along the intensive margin. At least for the US, this is in contrast to the data. The paper by Christoffel & Kuester (2008) shows that the introduction of a per-period fixed costs in the production of labor services (representing, for instance, health insurance contributions) may help to increase the elasticity of the extensive margin. Another shortcoming of the staggered right-to-manage wage bargaining model is that even modest Calvo type rigidities in wage bargaining entail almost constant real wage rates over the business cycle.

4 Conclusion

This paper develops a New Keynesian business cycle model akin to Christiano et al. (2005) and Smets & Wouters (2003) with staggered right-to-manage wage bargaining (Trigari 2006). We assume that, upon matching, firm-worker pairs first bargain over the real wage rate which is subject to staggered wage contracts. In the second step, hiring firms may choose the number of hours per worker unilaterally. This setting implies that the real wage rate is allocative for the number of hours per worker. Consequently, any rigidity in the real wage rate is transmitted via the New Keynesian Phillips Curve into persistent movements of inflation. This feature of the right-to-manage wage bargaining is referred to as the “wage channel”.

The key result of our paper is that a reasonably calibrated version of the model is able to generate persistent responses in output, inflation, and total labor input to both technology and monetary policy shocks. New Keynesian models with Nash bargaining (e.g. Walsh 2005), in contrast, are not able to generate hump-shaped responses to monetary policy shocks once capital accumulation is introduced (Heer & Maussner 2010). Staggered right-to-manage wage bargaining, however, increases not only the persistence of inflation, but also of the real interest rate. Since we assume variable capital utilization, this leads to a hump-shaped decline in the input of capital services. In addition to that, matching frictions induce a sluggish response in total labor input. Consequently, we observe that the response of aggregate output reaches its minimum not impact, but just in the second period after an innovation in monetary policy.

In response to a neutral technology shock, our model replicates a hump-shaped response of output and a U-shaped response of inflation. Turning to the labor market, we note that unemployment shows a negative impact response and then continues to decrease sluggishly. Hours per worker, instead, exhibit a negative impact response, but then rise for about 2 years before eventually falling. Hence, consistent with the findings of Ravn & Simonelli (2008), we observe a positive correlation between output and total labor input at the business cycle frequencies in response to a neutral technology shock.

Furthermore, we compare the model's dynamic behavior when calibrated to the US and to a European economy. We find that the degree of price rigidity explains most of the differences in response to a monetary policy shock. Differences in the degree of wage rigidity, instead, alter the dynamics of the model economy only by little. When the economy is hit by a neutral technology shock, both price and wage rigidities turn out to be important. Apart from that, our results indicate that matching frictions matter primarily for the dynamics of the labor market.

On the other hand, neither the neutral technology shock, nor the monetary policy shock is able to explain the large cyclical volatility in the unemployment rate. This implies that most of the volatility in total labor input is induced along the intensive margin. At least for the US, this is in contrast to the data. The paper by Christoffel & Kuester (2008) shows that the introduction of a per-period fixed costs in the production of labor services (representing, for instance, health insurance contributions) may help to increase the elasticity of the extensive margin. Another shortcoming of the staggered right-to-manage wage bargaining model is that even modest Calvo type rigidities in wage bargaining entail almost constant real wage rates over the business cycle.

It would be interesting to extend our analysis along two dimensions. First, we have only investigated the impact of two structural shocks so far. Therefore, it seems to be a natural choice to extend our analysis to a variety of other shocks. In particular, the literature suggests examining the impact of investment-specific technology shock, government spending shocks, or shock to the matching technology. The second step in our research program will be to estimate the present model along the lines described by Smets & Wouters (2007).

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A Tables

Parameter	Description	Value	Source
		Preferences	
β	discount factor	0.99	Kydland & Prescott (1982)
σ_c	relative risk aversion	1	Christiano et al. (2005)
ψ_c	habit formation	0.65	Christiano et al. (2005)
σ_q	money demand elasticity	6.3	Christiano et al. (2005)
ξ_p	elasticity of substitution	6	Christiano et al. (2005)
σ_f	hours supply elasticity	2.43	MaCurdy (1983)
	Production and the Capital Market		
α	capital elasticity	0.36	Christiano et al. (2005)
χ_s	investment adjustment cost	2	Christiano et al. (2005)
χ_b/χ_a	utilization elasticity	1	Smets & Wouters (2007)
δ	depreciation rate	0.025	Kydland & Prescott (1982)
	Matching and the Labor Market		
U	unemployment rate	0.057	Shimer (2005)
$q(\theta)\theta$	job finding rate	0.828	Shimer (2005)
ρ	job destruction rate	0.05	Davis & Haltiwanger (1990)
η^*	effective bargaining power	0.5	Svejnar (1986)
rep_b	unemployment benefits	0.36	OECD (2006)
κV	vacancy posting costs	0.01	Hamermesh & Pfann (1996)
rep_h	leisure gain from U	0.285	Costain & Reiter (2008)
μ	matching elasticity of U	0.5	Petrongolo & Pissarides (2001)
$q(\theta)$	vacancy filling rate	0.7	van Ours & Ridder (1992)
	Right-to-Manage Bargaining		
σ_h	labor efficiency	0.9775	Christoffel & Kuester (2008)
h	hours per worker	1	Trigari (2006)
η	"nominal" bargaining power	0.5	Nash (1953)
	Government and Monetary Policy		
g	governmental consumption	0.18	Smets & Wouters (2007)
$(PY)/M$	velocity of money	0.36	Christiano et al. (2005)
ϕ_r	autoregressive parameter	0.8	Gertler et al. (2008)
ϕ_π	Taylor principle parameter	2.0	Gertler et al. (2008)
ϕ_y	output gap parameter	0.3	Gertler et al. (2008)
	Price and Wage Rigidity		
ω_p	price rigidity	0.60	Christiano et al. (2005)
ω_w	wage rigidity	0.65	Christiano et al. (2005)
	Stochastic Processes		
ρ^z	technology shock persistence	0.95	Cooley & Prescott (1995)
ι^z	technology shock sd	0.007	Cooley & Prescott (1995)
ι^m	monetary policy shock sd	0.002	Gertler et al. (2008)

Table 1: The parameterized US model economy

Parameter	Description	Value	Source
ω_p^F	price rigidity	0.75	Álvarez et al. (2006)
ω_w^F	wage rigidity	0.83	du Caju et al. (2008)
U^F	unemployment rate	0.091	OECD (2008*b*)
$q^F(\theta^F)\theta^F$	job finding rate	0.212	OECD (2008*a*)
ρ^F	job destruction rate	0.021	OECD (2008*a*,*b*)
rep_b^F	unemployment benefits	0.57	OECD (2006)
rep_h^F	leisure gain from U	0.188	implied
σ_f^F	hours supply elasticity	4.19	implied
σ_h^F	labor efficiency	0.9723	implied

Table 2: Parameters specific to the French model economy

		Y	π	U	N	$N \times l$	l	w	$w \times l$	V	I	C
US Data	σ_X/σ_Y	(0.015)	0.59	7.32	0.80	0.96	0.26	0.50	0.54	9.03	2.88	0.82
	$\rho_{X,Y}$	1.00	-0.64	-0.86	0.81	0.87	0.70	0.20	0.52	0.89	0.94	0.85
	$\rho_{X_t,X_{t+1}}$	0.86	0.93	0.89	0.93	0.93	0.93	0.82	0.84	0.90	0.90	0.86
US Technology Shock	σ_X/σ_Y	(0.03)	0.37	0.68	0.04	1.03	0.99	0.13	1.08	0.90	2.14	0.34
	$\rho_{X,Y}$	1.00	-0.64	-0.91	0.91	0.95	0.94	0.67	0.95	0.71	0.99	0.98
	$\rho_{X_t,X_{t+1}}$	0.94	0.86	0.92	0.92	0.87	0.87	0.97	0.93	0.89	0.95	0.93
US Monetary Policy Shock	σ_X/σ_Y	(0.003)	0.29	1.50	0.09	1.24	1.18	0.03	1.18	3.06	1.74	0.41
	$\rho_{X,Y}$	1.00	0.79	-0.89	0.89	1.00	1.00	0.75	1.00	0.54	0.99	0.99
	$\rho_{X_t,X_{t+1}}$	0.74	0.87	0.53	0.53	0.74	0.73	0.84	0.73	0.13	0.78	0.72
French Data	σ_X/σ_Y	(0.009)	0.98	6.19	0.58	0.72	0.56	0.84	0.65	8.18	3.01	0.90
	$\rho_{X,Y}$	1.00	-0.49	-0.70	0.77	0.67	0.06	-0.08	-0.05	0.31	0.87	0.71
	$\rho_{X_t,X_{t+1}}$	0.87	0.90	0.90	0.95	0.93	0.91	0.83	0.77	0.77	0.90	0.73
France Technology Shock	σ_X/σ_Y	(0.02)	0.33	0.38	0.04	1.23	1.20	0.07	1.24	1.06	2.04	0.36
	$\rho_{X,Y}$	1.00	-0.64	-0.99	0.99	0.92	0.92	0.72	0.93	0.67	0.99	0.95
	$\rho_{X_t,X_{t+1}}$	0.95	0.92	0.96	0.96	0.87	0.86	0.97	0.87	0.92	0.96	0.95
France Monetary Policy Shock	σ_X/σ_Y	(0.004)	0.12	0.52	0.00	1.24	1.21	0.00	1.21	2.76	1.79	0.38
	$\rho_{X,Y}$	1.00	0.80	-0.96	0.96	1.00	1.00	0.56	1.00	0.66	0.99	0.99
	$\rho_{X_t,X_{t+1}}$	0.79	0.91	0.83	0.83	0.79	0.79	0.88	0.79	0.43	0.83	0.76

Table 3: Simulated Second Moments. For each variable, we report the relative standard deviation with respect to output σ_X/σ_Y, the co-movement with output $\rho_{X,Y}$, and the first order autocorrelation $\rho_{X_t,X_{t+1}}$. The percentage standard deviation of output is given in brackets. All data (1970:1-2008:4) are taken from the OECD databases "Economic Outlook" and "Main Economic Indicators". The time series of French vacancies starts only in 1989:1. All time series are logged and de-trended with a Hodrick & Prescott (1997) filter 1600.

B Impulse Response Functions

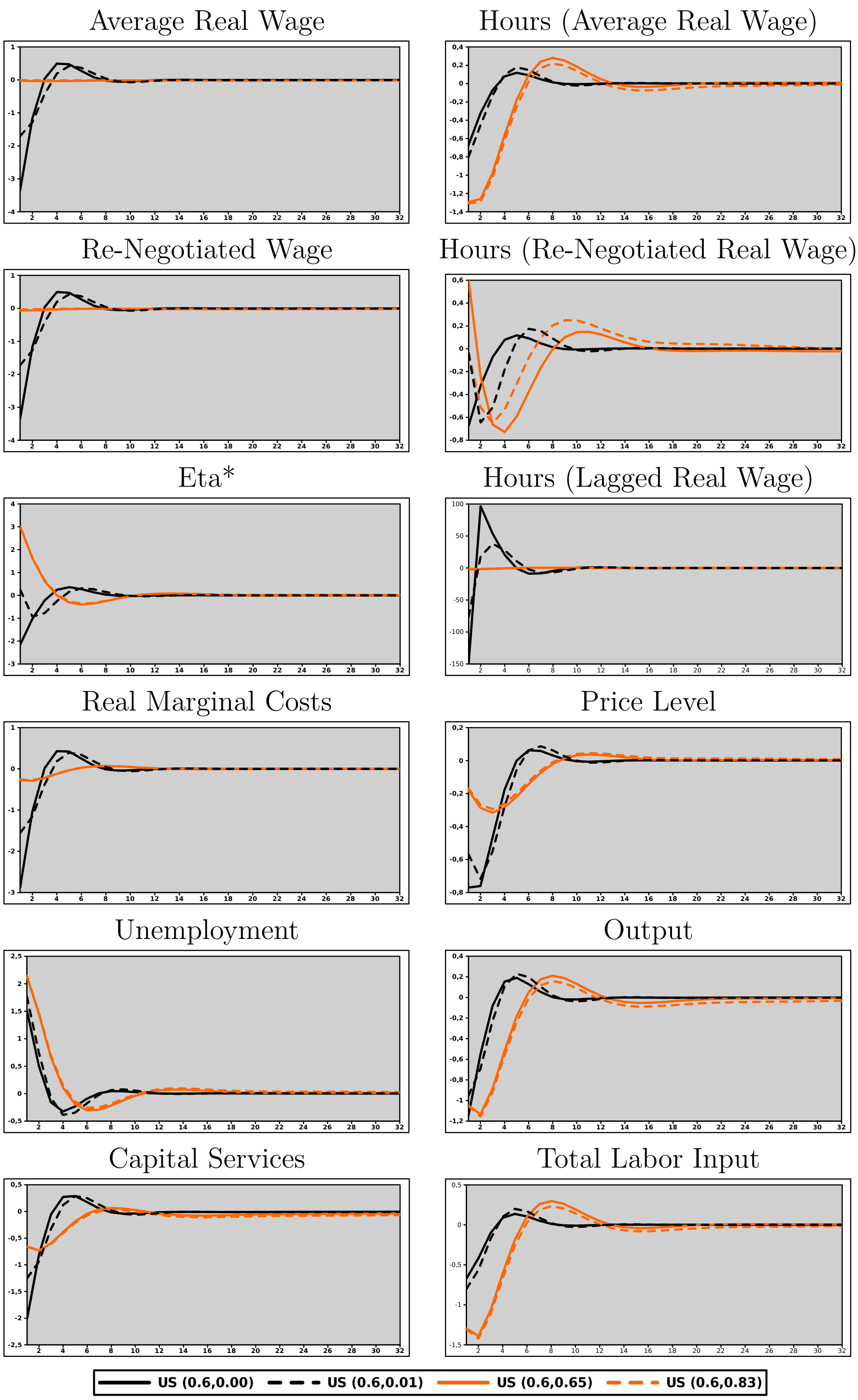

Figure 1: Impulse responses of the US model economy to a monetary policy shock. The black solid line represents the case $\omega_w = 0.00$. The back dashed line represents the case $\omega_w = 0.01$. The orange solid line represents the case $\omega_w = 0.65$. The orange dashed line represents the case $\omega_w = 0.83$. Units on the y-axis are given as percentage deviation from the steady state. Units on the x-axis correspond to quarters.

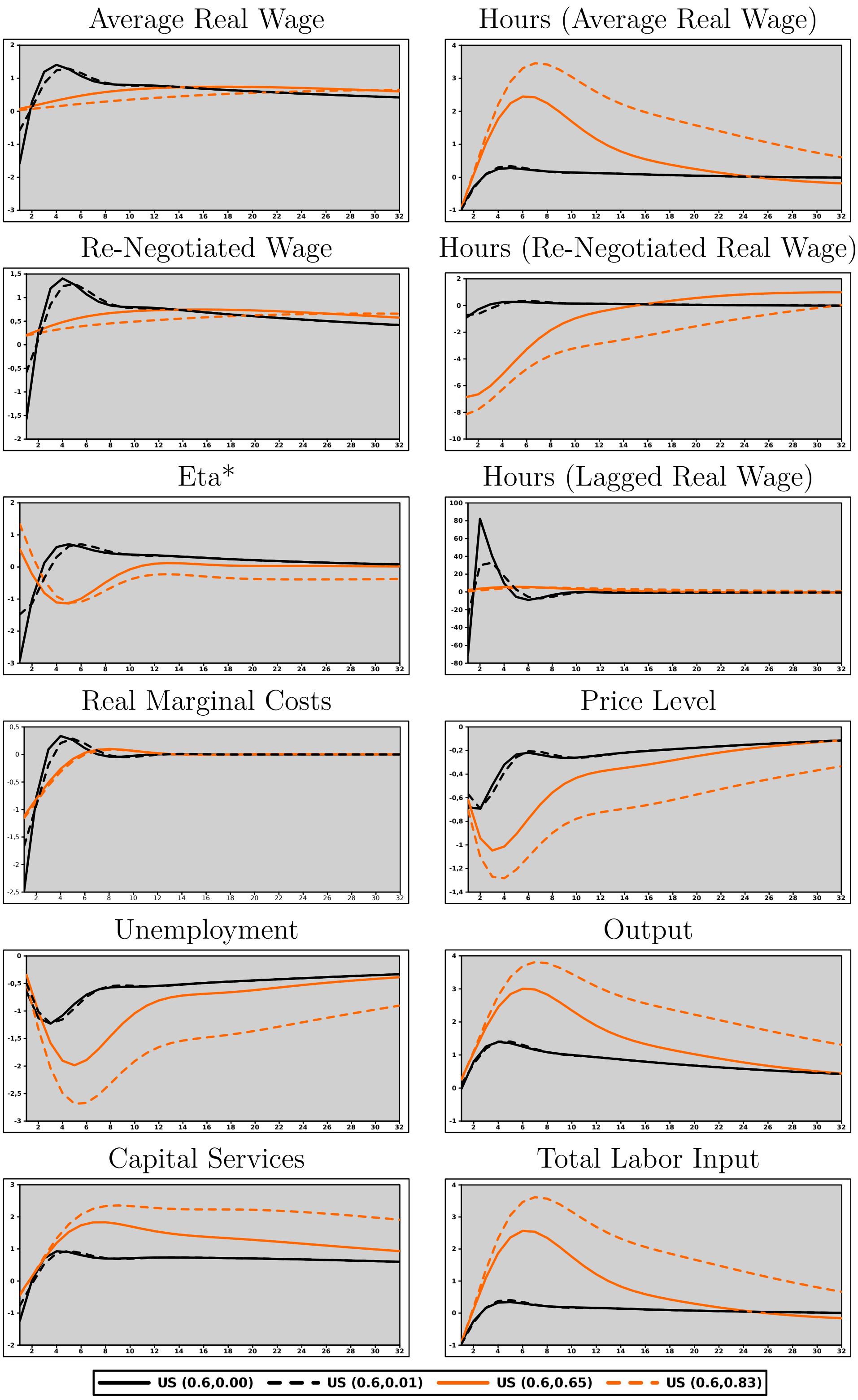

Figure 2: Impulse responses of the US model economy to a neutral technology shock. The black solid line represents the case $\omega_w = 0.00$. The back dashed line represents the case $\omega_w = 0.01$. The orange solid line represents the case $\omega_w = 0.65$. The orange dashed line represents the case $\omega_w = 0.83$. Units on the y-axis are given as percentage deviation from the steady state. Units on the x-axis correspond to quarters.

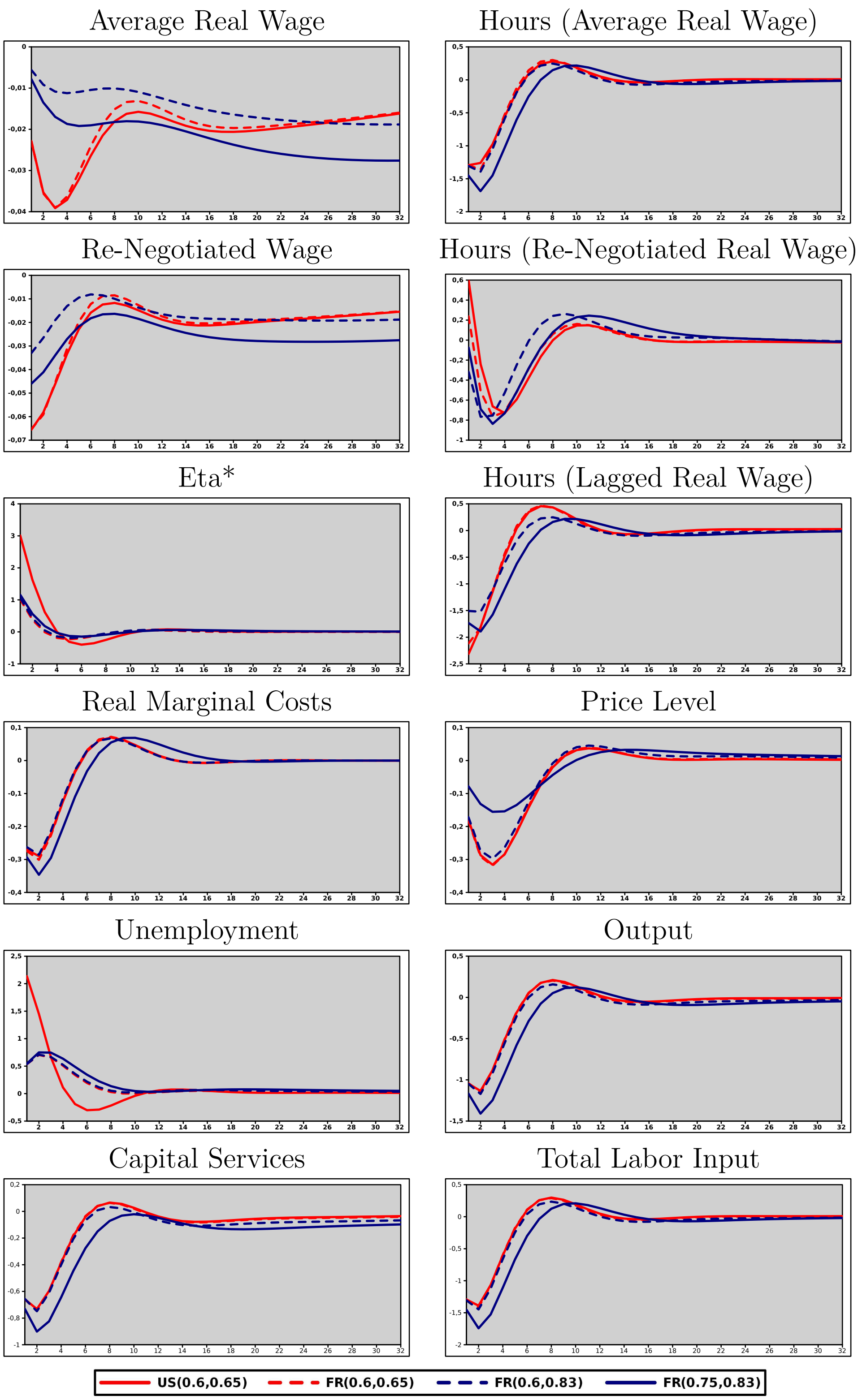

Figure 3: Impulse Responses to a Monetary Policy Shock. The red solid line represents the US model economy. The red dashed line represents the French model economy, but prices *and* wages are as flexible as in the US. The blue dashed line represents the French model economy with prices as flexible as in the US. The blue solid line represents the French model economy. Units on the y-axis are given as percentage deviation from the steady state. Units on the x-axis correspond to quarters.

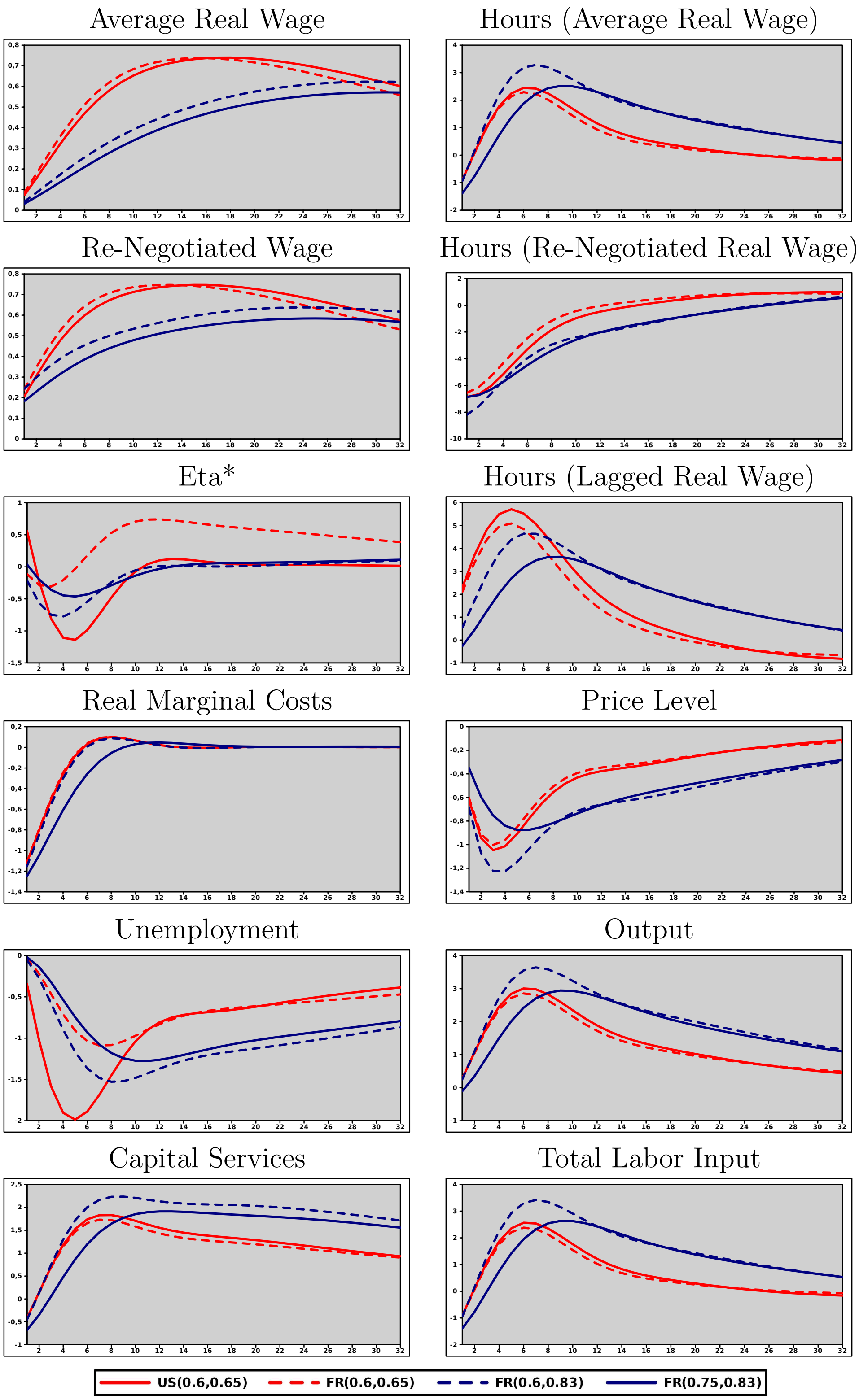

Figure 4: Impulse Responses to a Neutral Technology Shock. The red solid line represents the US model economy. The red dashed line represents the French model economy, but prices *and* wages are as flexible as in the US. The blue dashed line represents the French model economy with prices as flexible as in the US. The blue solid line represents the French model economy. Units on the y-axis are given as percentage deviation from the steady state. Units on the x-axis correspond to quarters.

C The Log-Linear Model

$$\hat{M}_t = -\mu(N/U)\hat{N}_{t-1} + (1-\mu)\hat{V}_t \qquad \text{ad (1)}$$

$$\hat{q}_t = \hat{M}_t - \hat{V}_t \qquad \text{ad (2)}$$

$$N\hat{N}_t = (1-\rho)N\hat{N}_{t-1} + M\hat{M}_t \qquad \text{ad (3)}$$

$$\hat{w}_t = \omega_w \hat{w}_t^* + (1-\omega_w)\hat{w}_{t-1} \qquad \text{ad (4)}$$

$$K\hat{\hat{K}}_t = (1-\delta)K\hat{\hat{K}}_{t-1} + I\hat{I}_t \qquad \text{ad (8)}$$

$$\hat{\lambda}_{c,t} = [\sigma_c/((1-\psi_c)(1-\beta\psi_c))]\left[\psi\hat{C}_{t-1} - \left(1+\beta\psi_c^2\right)\hat{C}_t + \psi_c\beta E_t\left\{\hat{C}_{t+1}\right\}\right] \qquad \text{ad (12)}$$

$$r\hat{r}_t = \chi_a \hat{x}_t \qquad \text{ad (13)}$$

$$\hat{\lambda}_{c,t} = \hat{R}_t + E_t\left\{\hat{\lambda}_{c,t+1} - \pi_{t+1}\right\} \qquad \text{ad (14)}$$

$$\hat{I}_t = \left[\left(\hat{\lambda}_{k,t} - \hat{\lambda}_{c,t})/\chi_s\right) + \hat{I}_{t-1} + \beta E_t\left\{\hat{I}_{t+1}\right\}\right] \Big/ \left(1+\beta\right) \qquad \text{ad (16)}$$

$$\hat{Q}_t = \hat{\lambda}_{k,t} - \hat{\lambda}_{c,t} \qquad \text{ad (17)}$$

$$\hat{Q}_t = E_t\left\{\hat{\lambda}_{c,t+1} - \hat{\lambda}_{c,t} + \beta(1-\delta)\hat{Q}_{t+1} + \beta r\hat{r}_{t+1}\right\} \qquad \text{ad (17)}$$

$$\begin{aligned}\mathcal{W}\hat{\mathcal{W}}_t^* = {} & \frac{wh}{1-\sigma_h}\left(\hat{W}_t - \sigma_h\hat{w}_t^*\right) - \frac{\psi_f h^{1+\sigma_f}}{(1-\sigma_h)\lambda_c}\left(\hat{W}_t - \hat{w}_t^*\right) + \frac{\psi_f h^{1+\sigma_f}}{(1+\sigma_f)\lambda_c}\hat{\lambda}_{c,t} \qquad \text{ad (18)} \\ & + \frac{\beta(1-\rho)\omega_w}{1-\beta(1-\rho)\omega_w}\left(\frac{\sigma_h wh}{1-\sigma_h} - \frac{\psi_f h^{1+\sigma_f}}{\lambda_c(1-\sigma_h)}\right)E_t\left\{\hat{w}_{t+1}^* - \hat{w}_t^*\right\} \\ & - \frac{\beta q(\theta)\theta\omega_w}{1-\beta(1-\rho)\omega_w}\left(\frac{\sigma_h wh}{1-\sigma_h} - \frac{\psi_f h^{1+\sigma_f}}{\lambda_c(1-\sigma_h)}\right)E_t\left\{\hat{w}_{t+1}^* - \hat{w}_t\right\} \\ & + (1-\rho-q(\theta)\theta)\beta\mathcal{W}E_t\left\{\hat{\lambda}_{c,t+1} - \hat{\lambda}_{c,t} + \hat{\mathcal{W}}_{t+1}^*\right\} - \beta\mathcal{W}q(\theta)\theta\left(\hat{M}_t + (N/U)\hat{N}_{t-1}\right)\end{aligned}$$

$$\hat{Y}_t = \hat{\epsilon}_t^z + \alpha\hat{\hat{K}}_{t-1} + \alpha\hat{x}_t + (1-\alpha)\hat{N}_{t-1} + (1-\alpha)\sigma_h\hat{h}_t \qquad \text{ad (22)}$$

$$\hat{\epsilon}_t^z = \rho^z\hat{\epsilon}_{t-1}^z + \hat{\iota}_t^z \qquad \text{ad (23)}$$

$$\hat{r}_t = \hat{\lambda}_{y,t} + \hat{Y}_t - \hat{\hat{K}}_{t-1} - \hat{x}_t \qquad \text{ad (24)}$$

$$\hat{W}_t = \hat{\lambda}_{y,t} + \hat{Y}_t - \hat{N}_{t-1} - \sigma_h\hat{h}_t \qquad \text{ad (25)}$$

$$\hat{\pi}_t = \left(\hat{\pi}_{t-1} + \beta E_t\left\{\hat{\pi}_{t+1}\right\} + [((1-\beta\omega_p)(1-\omega_p))/\omega_p]\hat{\lambda}_{y,t}\right) \Big/ \left(1+\beta\right) \qquad \text{ad (27)}$$

$$\begin{aligned}\mathcal{J}\hat{\mathcal{J}}_t^* = {} & \frac{wh}{\sigma_h}\left(\hat{W}_t - \sigma_h\hat{w}_t^*\right) \qquad \text{ad (29)} \\ & + \frac{wh\beta(1-\rho)\omega_w}{1-\beta(1-\rho)\omega_w}E_t\left\{\hat{w}_{t+1}^* - \hat{w}_t^*\right\} + \beta(1-\rho)\mathcal{J}E_t\left\{\hat{\lambda}_{c,t+1} - \hat{\lambda}_{c,t} + \hat{\mathcal{J}}_{t+1}^*\right\}\end{aligned}$$

$$-\frac{\kappa}{q}\hat{q}_t = \left[\frac{wh\beta\omega_w}{1-\beta(1-\rho)\omega_w}\right]E_t\left\{\hat{w}_{t+1}^* - \hat{w}_t\right\} + \beta\mathcal{J}E_t\left\{\hat{\lambda}_{c,t+1} - \hat{\lambda}_{c,t} + \hat{\mathcal{J}}_{t+1}^*\right\} \qquad \text{ad (31)}$$

$$\hat{w}_t = \hat{W}_t - (1-\sigma_h)\hat{h}_t \qquad \text{ad (32)}$$

$$\hat{\mathcal{J}}_t^* = \hat{\mathcal{W}}_t^* + \hat{\delta}_t^F - \hat{\delta}_t^W \qquad \text{ad (34)}$$

$$\delta^W \hat{\delta}_t^W = -\frac{wh\sigma_h}{(1-\sigma_h)^2}\left(\hat{W}_t - \sigma_h \hat{w}_t^*\right) + \frac{(1+\sigma_f)\psi_f h^{1+\sigma_f}}{(1-\sigma_h)^2\lambda_c}\left(\hat{W}_t - \hat{w}_t^*\right) - \frac{\psi_f h^{1+\sigma_f}}{(1-\sigma_h)\lambda_c}\hat{\lambda}_{c,t} \quad \text{ad (35)}$$

$$+ \beta(1-\rho)\omega_w \delta^W E_t\left\{\left(\frac{(1+\sigma_f)}{(1-\sigma_h)^2}\frac{\psi_f h^{\sigma_f}}{\lambda w} - \left(\frac{\sigma_h}{1-\sigma_h}\right)^2\right)\left(\hat{w}_{t+1}^* - \hat{w}_t^*\right)\right\}$$

$$+ \beta(1-\rho)\omega_w \delta^W E_t\left\{\hat{\delta}_{t+1}^W + \hat{\lambda}_{c,t+1} - \hat{\lambda}_{c,t}\right\}$$

$$\delta^F \hat{\delta}_t^F = \frac{wh}{1-\sigma_h}\left(\hat{W}_t - \sigma_h \hat{w}_t^*\right) \quad \text{ad (36)}$$

$$+ \beta(1-\rho)\omega_w \delta^F E_t\left\{\frac{\sigma_h}{1-\sigma_h}\left(\hat{w}_{t+1}^* - \hat{w}_t^*\right) + \hat{\delta}_{t+1}^F + \hat{\lambda}_{c,t+1} - \hat{\lambda}_{c,t}\right\}$$

$$\hat{R}_t = \phi_r \hat{R}_{t-1} + (1-\phi_r)\phi_\pi \hat{\pi}_t + (1-\phi_r)\phi_y \hat{Y}_t + \hat{\epsilon}_t^r \quad \text{ad (40)}$$

$$\hat{\epsilon}_t^r = \rho^r \hat{\epsilon}_{t-1}^r + \hat{\iota}_t^r \quad \text{ad (40)}$$

$$Y\hat{Y}_t = I\hat{I}_t + C\hat{C}_t + \kappa V\hat{V}_t + G\hat{Y}_t + K\chi_b \hat{x}_t \quad \text{ad (41)}$$