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The Business Cycle Implications of Reciprocity in Labor Relations

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Abstract

We develop a reciprocity-based model of wage determination and incorporate it into a modern dynamic general equilibrium framework. We estimate the model and find that, among potential determinants of wages, rent-sharing (between workers and firms) and wage entitlement (based on wages earned in the past) are important to fit the dynamic responses of output, wages and inflation to various exogenous shocks. Aggregate employment conditions (measuring workers' outside option), on the other hand, are found to play only a negligible role for wage setting. These results are broadly consistent with micro-studies on reciprocity in labor relations but contrast with traditional efficiency wage models which emphasize aggregate labor market variables as the main determinant of wage setting.

Keywords: Efficiency Wages, Reciprocity, Estimated DSGE Models

JEL classification: E24, E31, E32, E52, J50

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1. Introduction

Dynamic stochastic general equilibrium (DSGE) models postulating nominal price and wage contracts replicate surprisingly well key business cycle properties. They are, for that reason, increasingly used for monetary policy analysis. Recent studies documenting the performance of these models include Christiano, Eichenbaum and Evans (2005, CEE henceforth), Altig, Christiano, Eichenbaum and Lindé (2004, ACEL henceforth) and Smets and Wouters (2007). These studies uniformly find that nominal wage contracts are crucial for model performance and conclude that a deeper understanding of the contours and implications of wage rigidity needs to be developed.

Standard nominal wage contract models deliver wage rigidity through a reduced-form process imposing that a fraction of workers is prevented from re-optimizing their wage demands in response to new information. By contrast, the present paper proposes a model of wage determination based on reciprocity in labor relations. In line with efficiency wage theory, effort per hour worked in our model is unobservable and thus cannot be contracted upon. The central hypothesis is that workers may derive a psychological benefit from reciprocating a generous wage offer by the firm with harder work, even though providing effort per se is costly and there are no explicit incentives for doing so. Firms are aware of the workers' reciprocity motive and set wages so as to elicit a profit maximizing level of effort. In equilibrium, this leads to a form of conditional wage rigidity that is distinct from the unconditional rigidity in standard wage contract models.

Section 2 reviews the related literature. Section 3 describes the model. Inspired by Rabin's (1993) introduction of fairness into game theory and building on our previous adaptation of this concept for macroeconomics (Danthine and Kurmann, 2007), we explicitly model the psychological benefit derived from reciprocity as the product of the worker's gift to the firm in terms of effort and the firm's gift to the worker in terms of remuneration. The latter is measured as the difference between the utility resulting from the actual wage offer

and the utility obtained under a reference compensation level. Building on micro evidence about reciprocity in labor relations, we let this reference compensation level depend on three potential factors: the worker's outside option described by external labor market conditions; firm-internal labor productivity representing *rent-sharing* considerations; and past wages capturing the notion of *wage entitlement* on the part of workers.

Section 4 analyzes the theoretical implications of the model. Section 5 evaluates the business cycle implications of the model in a modern DSGE framework featuring sticky prices, habit persistence in consumption, variable capital utilization and investment adjustment cost. We estimate the different structural parameters by minimizing the distance between the model-based impulse responses and their empirical counterparts computed from a vector autoregression (VAR) with respect to a neutral technology shock, an investment-specific technology shock and a monetary policy shock. The estimation attributes substantial importance to wage entitlement while also giving significant weight to rent-sharing in the determination of the reference wage. By contrast, external labor market conditions are estimated to matter only marginally. These results are largely consistent with micro evidence on reciprocity in labor relations. Overall, the estimated model fits the empirical VAR dynamics surprisingly well. In particular, the presence of rent-sharing allows the model to *simultaneously* replicate the sluggish response of inflation after a monetary policy shock *and* the sharp drop in inflation on impact of a neutral technology shock. This is an interesting difference to models with nominal wage contracts, which typically fail to generate these distinct conditional responses of inflation that are a robust feature of U.S. data.¹

Section 6 concludes.

¹For economy of space, we defer an in-depth comparison with the nominal wage contracts model to a web-appendix, available at <http://www.er.uqam.ca/nobel/r16374>. The appendix also provides a detailed derivation of the reciprocity model and assesses the robustness of the results along various dimensions.

2. Related Literature

The reciprocity hypothesis receives strong support from a large number of survey studies bearing on labor relations (e.g., Kahneman, Knetsch and Thaler, 1986; or Bewley, 1999) as well as from laboratory experiments in behavioral economics (e.g., Fehr and Falk, 1999).² Both strands of literature also document that firms often refrain from offering explicit rewards for effort because such mechanisms are costly and may negatively affect work morale.

Reciprocity in labor relations was introduced into macroeconomics by Akerlof (1982). As in more conventional efficiency wage formulations such as Salop's (1979) labor turnover theory or Shapiro and Stiglitz' (1984) shirking model, the reference compensation level in Akerlof's (1982) model depends entirely on the worker's expected earnings outside of the firm. Rent-sharing and wage entitlement features are not present.

This focus on firm-external wage references contrasts strongly with the available micro evidence. Bewley (2002), for example, concludes that *"...employees usually have little notion of a fair or market value for their services and quickly come to believe that they are entitled to their existing wage, no matter how high it may be..."* (page 7).³ At the same time, workers also seem to care about firm-internal reference points, a concept that Kahneman, Knetsch and Thaler (1986) associate with the notion of dual entitlement; i.e. firms are entitled to a reference profit while workers are entitled to a reference salary. This receives strong support from numerous survey and experimental studies (e.g. Fehr, Gächter and Kirchsteiger, 1997).

Danthine and Donaldson (1990) are the first to incorporate reciprocity in labor relations into a modern DSGE context. They find that when the worker's reference compensation level depends only on firm-external labor market conditions as in Akerlof (1982), the model fails to improve the ability of DSGE models to replicate business cycle facts. Collard and De la Croix (2000) and Danthine and Kurmann (2004) subsequently show that including the

²See Fehr and Gächter (1999) and Bewley (2002) for an extensive discussion of the empirical evidence.

³The importance of workers' past wages as a reference point is stressed in studies by Levine (1993), Campbell and Kamlani (1997) or Bewley (1999).

workers' past wage in their wage reference generates substantial real rigidity and improves the empirical performance of DSGE models. Danthine and Kurmann (2007), in turn, introduce rent-sharing but stop short of analyzing the implications in a full-blown DSGE framework.

In the present paper, we allow for both wage entitlement and rent-sharing in an explicit model of reciprocity and evaluate the implications in a medium-scale DSGE framework. To our knowledge, Rotemberg (2008) is the only other study that explicitly introduces non-pecuniary considerations in labor relations into a DSGE framework. His model is quite different, however, providing an alternative perspective to the present attempt.⁴

Our paper also relates to recent studies by Hall (2005) and Shimer (2005) among many others who assess the empirical performance of DSGE models with search frictions in the labor market. They conclude that the standard search model where wages are determined by Nash bargaining fails to generate quantitatively important responses to exogenous technology shocks. By contrast, the labor search model becomes more successful if wages are constrained to be a function of past wages. The wage entitlement dimension of our reciprocity-based model offers a rationale for this dependence on past wages.

3. The Model

The economy is populated by five types of agents: households, intermediate goods producers, final goods retailers, a financial intermediary and a monetary authority. Aside from the reciprocity-based mechanism for wage setting, the economy is very similar to the homogenous capital model in ACEL (2004). In line with efficiency wage theory, we assume that effort per unit of labor is an input to production but that it cannot be directly observed. In contrast to labor hours, effort is therefore not contractible. Producers understand, how-

⁴An interesting alternative is Alexopoulos (2004) who considers a shirking model where instead of dismissal, detected shirkers face monetary punishment. The resulting model implies that equilibrium wages depend positively on consumption and negatively on employment. This negative dependence on employment has similar effects on wage setting than rent-sharing in our model and is shown to generate some wage rigidity. However, the results in Alexopoulos (2004) depend crucially on the degree of consumption insurance that workers receive.

ever, that while workers dislike effort *per se*, they derive utility from reciprocating a generous wage offer with a commensurate effort level even in the absence of monitoring.

3.1. Households

There is a $[0, 1]$ continuum of identical individuals spread across a $[0, 1]$ continuum of identical households. In each household, some of the individuals are working while others are unemployed. An individual's momentary utility is given by

$$\log(C_t - bC_{t-1}) + \log(1 - L_t) - L_t \left[\frac{1}{2}e_t^2 - \mathfrak{R}(e_t, \cdot) \right],$$

where C_t stands for current consumption, C_{t-1} is the previous period's consumption, $b \geq 0$ is the habit parameter, 1 is total hours available per individual, L_t is the fraction of hours worked, and e_t is the effort level per hour worked. The term $\mathfrak{R}(e_t, \cdot)$ admits that workers derive utility from reciprocal behavior towards their employer.⁵ The optimality condition guiding this decision is

$$e_t = \mathfrak{R}_e(e_t, \cdot). \tag{1}$$

We call this equation the *Effort Condition* (EC). As long as $\mathfrak{R}_e(e_t, \cdot) > 0$, workers are willing to reward a wage offer perceived as generous with positive effort even though no direct material gain derives from such action.⁶

Following Rogerson (1988) and Hansen (1985), labor is assumed to be indivisible in the sense that individuals would like to supply L_t^* but that they have to choose between working a fixed shift $H > L_t^*$ or not working at all. In such a situation, the household can make its members better off by providing a lottery whereby a fraction N_t of individuals work

⁵The function $\mathfrak{R}(e_t, \cdot)$ potentially depends on many more variables than effort, among them the firm's wage. The atomistic representative worker is assumed to take these additional variables as exogenous.

⁶Rabin (1993) also entertains the possibility, but we do not follow his lead on this score, that a perverse equilibrium may arise whereby the worker's punishment of an unfair wage offer in terms of lower than normal effort provides the worker with extra utility.

a fraction H hours while the remaining $1 - N_t$ individuals remain unemployed. In view of avoiding heterogeneity, we assume that households make all investment decisions and redistribute income net of investment to their members. For the type of separable preferences assumed here, efficient risk sharing implies an identical level of consumption for employed and unemployed individuals alike. The representative household's stand-in preferences are thus given by

$$\mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log(C_t - bC_{t-1}) + N_t \left[\log(1 - H) - \frac{1}{2}e_t^2 + \mathfrak{R}(e_t, \cdot) \right] \right\},$$

where \mathbf{E}_0 is the expectations operation given information at time 0.

The optimal decision problem is split into two subperiods. Households come into the first subperiod with physical capital stock K_t , real money holdings M_t/P_t and a perfectly diversified portfolio of claims to firms. After the realization of the technology shocks (described below), households decide on their participation to the lottery N_t and collect labor income $W_t N_t$, capital income $R_t^K K_t$ and dividends from firms D_t . Households then allocate resources between investment in new capital I_t and consumption C_t . In the second subperiod, the money growth shock $\mu_t = \bar{M}_t/\bar{M}_{t-1}$ realizes and households receive a transfer $(\mu_{M_t} - 1)\bar{M}_t/P_t$ from the monetary authority. Households then decide on their real cash holdings Q_t and deposit the remainder $M_t/P_t - Q_t + (\mu_t - 1)M_t^a/P_t$ with a financial intermediary at gross nominal rate R_t . Real money holdings in the beginning of next period are therefore

$$\frac{M_{t+1}}{P_t} = R_t \left[\frac{M_t}{P_t} - Q_t + (\mu_{M_t} - 1) \frac{\bar{M}_t}{P_t} \right] + Q_t + W_t N_t + R_t^K K_t + D_t - [1 + \eta(v_t)] C_t - I_t. \quad (2)$$

Cash demand in this economy is positive because cash facilitates consumption transactions. Specifically, let velocity of the household's cash balances be defined as $v_t \equiv C_t/Q_t$. The larger velocity, the lower the transaction costs $\eta(v_t)$ on consumption; i.e. $\eta' < 0$ and $\eta'' > 0$.

The capital stock evolves according to

$$K_{t+1} = [1 - \delta(u_t)]K_t + V_t F(I_t, I_{t-1}), \quad (3)$$

where $F(I_t, I_{t-1}) = (1 - S(I_t/I_{t-1}))I_t$ embodies investment adjustment cost with S satisfying $S(\Delta I) = S'(\Delta I) = 0$ in steady state and $S'' \geq 0$; and V_t denotes an exogenous investment-specific technology shock. As in Fisher (2006), the growth rate $\mu_{V,t} \equiv V_t/V_{t-1}$ of this shock is governed by $\hat{\mu}_{V,t} = \rho_{\mu_V} \hat{\mu}_{V,t-1} + \varepsilon_{\mu_V,t}$, where $\hat{\mu}_{V,t} = (\mu_{V,t} - \mu_V)/\mu_V$ is defined as the percentage deviation from steady state μ_V and $\varepsilon_{\mu_V,t}$ is an i.i.d. innovation with mean zero and variance $\sigma_{\varepsilon_{\mu_V}}^2$. Following King and Rebelo (2000), the depreciation rate $\delta(u_t)$ is an increasing convex function of capital utilization u_t by firms. By no arbitrage, it must be true that $V_t R_t^K = \mu_{V,t} R_t P_{t-1}/P_t - 1 + \delta(u_t)$.

3.2. Reciprocity

We follow the approach of Rabin (1993) as adapted to a modern macroeconomic setting by Danthine and Kurmann (2007) and define $\mathfrak{R}(e_t, \cdot)$ as the product of the respective 'gifts' of an employed individual (i.e. the representative worker) and the firm

$$\mathfrak{R}(e_t, \cdot) = d(e_t, \cdot)g(W_t, \cdot).$$

The factors $d(e_t, \cdot)$ and $g(W_t, \cdot)$ are both concave and denote, respectively, the gift of the representative worker in terms of effort towards the firm and the gift of the firm in terms of the wage towards the worker. Hence, when workers perceive a wage offer as generous (i.e., $g(W_t, \cdot) > 0$), their utility increases if they reciprocate the gift with higher effort (i.e., $d(e_t, \cdot) > 0$). The representative agent assumption of the indivisible labor framework implies that for this calculation, workers do not take into account the impact of their own effort on the firm's output and thus on the gift of the firm; i.e., $g_e(W_t, \cdot) = 0$ in the eyes of the representative worker.

In defining $d(e_t, \cdot)$ and $g(W_t, \cdot)$, we follow Rabin one more step and measure the gifts as the deviation of effort and wages, respectively, from some reference or norm levels. Given our specification of preferences, the norm effort level for the worker is quite naturally $e_n = 0$. We thus specify the worker's gift as

$$d(e_t, \cdot) = e_t^\alpha, \tag{4}$$

with $0 < \alpha < 1$. This specification considerably simplifies the ensuing analysis. At the same time, we note that the dynamics of the log-linearized model would not be affected if we multiplied the right-hand side by a constant or allowed for a more general functional form.⁷

The definition of the wage reference in the specification of the firm's gift is more critical because, as we will see, this affects the optimal wage policy of the firm. As discussed in Section 2, various hypotheses have been entertained on this point. Our strategy is to adopt an encompassing specification with the goal of letting the data speak. We define

$$\begin{aligned} g(W_t, \cdot) = & \log[(1 - \tau_t)W_t] - \varphi_1 \log[(1 - \tau_t)\psi_t Y_t/n_t] \\ & - \varphi_2 \log[(1 - \tau_t)\bar{W}_t \bar{n}_t] - \varphi_3 \log[(1 - \tau_t)[s\bar{W}_{t-1} + (1 - s)W_{t-1}]], \end{aligned} \tag{5}$$

The first term, $\log[(1 - \tau_t)W_t]$, is the consumption utility that the worker attributes to the firm's actual wage offer. The variable τ_t in this expression denotes the state-contingent tax rate that the household applies to the revenue of workers so as to implement optimal risk sharing across household members. The remaining terms in $g(W_t, \cdot)$ define a weighted sum of utility levels that would obtain for various reference compensation points. In particular, the term $\log[(1 - \tau_t)\psi_t Y_t/N_t]$ describes the utility obtained if the firm distributed its entire revenue to its workers and thus proxies for the firm's ability to pay. The term $\log[(1 - \tau_t)\bar{W}_t \bar{n}_t]$ measures the worker's expected utility from leaving the firm and work elsewhere. Finally, the term $\log[(1 - \tau_t)[s\bar{W}_{t-1} + (1 - s)W_{t-1}]]$ captures the utility level obtained if the salary

⁷The appendix provides more details on robustness along this dimension. In earlier versions of the paper, we experimented with a specification that featured non-zero norm effort but found that this had little effect on the dynamics of the model.

were to stay at last period's level. For $s = 1$ we are in the so-called 'social-norm' case where the worker considers the past aggregate wage level as the reference. For $s = 0$ we are in the 'personal-norm' case where the worker consider her own past wage within the firm as the relevant reference. We do not impose either of these two extreme cases and instead estimate s from the data.

3.3. Firms

3.3.1. Intermediate goods producers

Intermediate goods producers sell their product in a perfectly competitive market to retailers at relative price ψ_t . The representative firm produces with technology

$$Y_t = (A_t e_t n_t)^\alpha (u_t K_t)^{1-\alpha} \quad (6)$$

where A_t denotes an exogenous neutral technology shock. The growth rate $\mu_{A,t} \equiv A_t/A_{t-1}$ evolves according to $\hat{\mu}_{A,t} = \rho_{\mu_A} \hat{\mu}_{A,t-1} + \varepsilon_{\mu_A,t}$, where $\hat{\mu}_{A,t}$ is the percentage deviation from steady state μ_A and $\varepsilon_{\mu_A,t}$ is an i.i.d. innovation with mean zero and variance $\sigma_{\varepsilon_{\mu_A}}^2$.

Effort e_t cannot be observed directly by the firm. However, firms understand that workers provide effort according to (1). Furthermore, the firm knows that households let their members participate in the labor market only if the wage exceeds the total marginal disutility from working. The intermediate goods firm therefore chooses real wages W_t , labor n_t , capital K_t and utilization u_t to maximize

$$E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t+j} [\psi_{t+j} Y_{t+j} - R_{t+j} W_{t+j} n_{t+j} - R_{t+j}^K K_{t+j}] \quad (7)$$

subject to the household's participation constraint, the effort condition (1) and technology (6). The firm's problem is dynamic because the wage set today may influence effort tomorrow through the existence of the firm's past wage W_{t-1} in the effort condition (1). Since households are the ultimate owners, firms discount future cash flows by $\beta^j \Lambda_{t+j}$, where Λ_{t+j}

denotes the marginal utility of consumption in $t + j$. The wage bill in $t + j$ is multiplied by R_{t+j} because we assume, as in CEE (2005) and ACEL (2004), that firms need to borrow the wage bill from a financial intermediary (see below).

3.3.2. Retailers

There is a continuum of retailers $z \in [0, 1]$ each paying a per-period fixed cost ϕX_t , where $X_t \equiv A_t V_t^{\frac{1-\alpha}{\alpha}}$ is proportional to trend output and ensures that there is a stationary profit-to-output ratio. Production occurs through linear transformation of intermediate goods Y_t into differentiated final good $Y_t(z)$. As noted above, these intermediate goods are traded in a competitive market at relative price ψ_t ; i.e. ψ_t is the real marginal cost of final goods.

Households value the differentiated final goods according to a Dixit-Stiglitz aggregator

$$Y_t^f = \left[\int_0^1 Y_t(z)^{(\theta_p-1)/\theta_p} dz \right]^{\theta_p/(\theta_p-1)}, \quad (8)$$

where Y_t^f is the total demand; and $\theta_p > 1$ denotes the elasticity of substitution. The demand for good $Y_t(z)$ can be derived as

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\theta_p} Y_t^f, \quad (9)$$

where $P_t(z)$ is the price of final good z , which is set according to a variant of the partial adjustment process proposed by Calvo (1983). In every period, a fraction κ_p of intermediate goods firms are deprived of the opportunity to reoptimize their price. They instead update their price according to

$$P_t(z) = \pi_{t-1}^{\omega_p} \pi^{1-\omega_p} P_{t-1}(z), \quad (10)$$

where $\pi_{t-1} \equiv P_{t-1}/P_{t-2}$ denotes last period's aggregate inflation, and π denotes trend inflation. The probability κ_p is constant through time and independent of firms' individual pricing history. The case $\omega_p = 1$ corresponds to ACEL's (2004) specification for which there is full indexation to past inflation.

3.3.3. Financial intermediary

As mentioned above, intermediate good producers cover their wage bill $W_t n_t$ by borrowing from a financial intermediary. The financial intermediary funds these loans from household deposits $M_t/P_t - Q_t + (\mu_t - 1)\bar{M}_t/P_t$. At the end of the period, firms pay back $R_t \bar{W}_t \bar{n}_t$ to the intermediary which then returns $R_t[M_t/P_t - Q_t + (\mu_t - 1)\bar{M}_t/P_t]$ to households.

3.4. Monetary policy

We assume that the central bank follows a money growth rule of the form

$$\hat{\mu}_{M,t} = \hat{\mu}_{M^*,t} + \phi_A \hat{\mu}_{A,t} + \phi_V \frac{1 - \alpha}{\alpha} \hat{\mu}_{V,t}, \quad (11)$$

with $\hat{\mu}_{M^*,t} = \rho_{\mu_M} \hat{\mu}_{M^*,t-1} + \varepsilon_{\mu_M,t}$, where $\varepsilon_{\mu_M,t}$ is an i.i.d. shock with mean zero and variance $\sigma_{\varepsilon_{\mu_M}}^2$; and ϕ_A, ϕ_V allow for accommodation of the two technology shocks.

3.5. Aggregation and general equilibrium

Since all intermediate producers are identical, we have $W_t = \bar{W}_t$ and $\bar{n}_t = n_t$. Furthermore, $M_t = \bar{M}_t$ in equilibrium. Loan market clearing thus implies

$$W_t N_t = \mu_t M_t - Q_t. \quad (12)$$

As shown in Yun (1996), constant returns to scale technology and competitive input markets imply that all price setters operate on the same aggregate real marginal cost schedule, independent of their price level. The same is true here for retailers. As a result, the aggregate price dynamics is fully summarized by the price level of reoptimizing firms and the average price charged by non-optimizing firms, which is simply last period's aggregate price times the indexing factor $\pi_{t-1}^\omega \pi^{1-\omega}$. This allows us to derive the national income accounting equation⁸

$$Y_t = [1 + \eta(v_t)]C_t + I_t + \phi X_t. \quad (13)$$

⁸In this equation, we ignore the relative price defined in Yun (1996) that links intermediate goods production Y_t to final goods usage Y_t^f . For our loglinearized evaluation of the model, this is of no consequence.

In our analysis, we are also interested in economy-wide profits by firms, defined as

$$profits_t = Y_t - R_t W_t n_t - \phi X_t. \quad (14)$$

The general equilibrium dynamics of our model results from the various optimality conditions and constraints described in this section. The quantitative results discussed in Section 5 arise from log-linearizing the different equations around the non-stochastic steady states of the appropriately normalized variables and then solving for the rational expectations equilibrium with the numerical algorithm developed by King and Watson (1998).

4. Model implications

4.1. Labor market

The labor market in our model is determined by the intermediate producers' decisions for employment and the wage rate that maximize the present value of profits subject to the EC in (1).⁹ Given the Cobb-Douglas specification of production in (6), the necessary first-order conditions are

$$R_t W_t = \alpha \psi_t \frac{Y_t}{n_t} \left[1 + \frac{\partial e_t}{\partial n_t} \frac{n_t}{e_t} \right] \quad (15)$$

$$R_t n_t = \alpha \psi_t \frac{Y_t}{e_t} \frac{\partial e_t}{\partial W_t} + E_t \left[\frac{\beta \Lambda_{t+1}}{\Lambda_t} \alpha \psi_{t+1} \frac{Y_{t+1}}{e_{t+1}} \frac{\partial e_{t+1}}{\partial W_t} \right]. \quad (16)$$

The first condition is labor demand. The elasticity $\frac{\partial e_t}{\partial n_t} \frac{n_t}{e_t} \geq 0$ takes into account an unusual margin: higher employment through its negative effect on labor productivity may increase the firm's gift and therefore workers' effort. At a given wage, this leads firms to overhire relative to a more standard labor market case.

The second condition describes how wages are set to elicit optimal effort. The left-hand side is the cost of increasing the wage rate. The first term on the right-hand side shows the

⁹Firms also need to satisfy the household's participation constraint. We implicitly set the indivisible labor constant H such that this constraint is always satisfied.

current benefit from doing so whereas the second term measures the negative effect of a wage increase on future effort. We can use labor demand to rewrite this second condition as

$$1 = \varepsilon(e_t, W_t) - \varepsilon(e_t, n_t) + \beta E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \frac{\psi_{t+1}}{\psi_t} \frac{Y_{t+1}}{Y_t} \varepsilon(e_{t+1}, W_t) \right], \quad (17)$$

where $\varepsilon(e_t, W_t) = \frac{\partial e_t}{\partial W_t} \frac{W_t}{e_t}$ is the elasticity of effort with respect to wages and so forth for the other elasticities. We label this equation the *Modified Solow Condition* (MSC). For $\varepsilon(e_t, n_t) = 0$ and $\varepsilon(e_{t+1}, W_t) = 0$, the MSC reduces to Solow's (1979) original condition, which says that at the optimal wage rate, the marginal cost of an effective unit of work equals its average cost. For $\varepsilon(e_t, n_t) > 0$, Solow's condition no longer applies because a marginal wage increase has an additional positive effect on labor productivity. This in turn decreases the firm's gift and thus effort. Likewise, for $\varepsilon(e_{t+1}, W_t) < 0$, the firm has to take into account that a higher wage today makes it more difficult to elicit effort next period.

To make these trade-offs explicit, we introduce our specification of the worker's gift (Equation (4)) and the firm's gift (Equation (5)). The EC in (1) becomes

$$\begin{aligned} \log(W_t) = & \frac{e_t^{2-\alpha}}{\alpha} + \varphi_1 \log(\psi_t Y_t / n_t) + \varphi_2 \log(\bar{W}_t \bar{n}_t) + \varphi_3 \log(s \bar{W}_{t-1} + (1-s)W_{t-1}) \\ & - \alpha(1 - \varphi_1 - \varphi_2 - \varphi_3) \log(1 - \tau_t), \end{aligned} \quad (18)$$

where we have isolated the state-contingent tax part for convenience. This equation indicates the wage that the firm needs to pay in order to elicit effort level e_t as optimally determined by the MSC. The EC and MSC together thus replace the labor supply schedule of standard competitive models of the labor market. For $\varphi_1 > 0$, the optimal wage increases with the firm's revenue per worker, a notion that we associate with *rent-sharing*. For $\varphi_2 > 0$, the optimal wage increases with the aggregate wage and employment level, two measures that capture *external labor market conditions*. For $\varphi_3 > 0$, the optimal wage depends positively on past real wages, a notion that we call *wage entitlement*.

The wage setting equation (18) implies important parameter restrictions for an environment with stochastic growth in which effort and the labor share $W_t N_t / Y_t$ are stationary (see

appendix for proof).¹⁰

Proposition 1 *Stationarity of effort and the labor share along the balanced growth path requires $\varphi_1 + \varphi_2 + \varphi_3 = 1$.*

We can also apply the gift definitions in (4) and (5) to the MSC in (17) to derive an expression for optimal effort

$$\frac{2-\alpha}{\alpha}e_t^{2-\alpha} = 1 - \varphi_1 + \beta E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \frac{\psi_{t+1}}{\psi_t} \frac{Y_{t+1}}{Y_t} \frac{-(1-s)\varphi_3 \left[\frac{2-\alpha}{\alpha} e_t^{2-\alpha} + \alpha\varphi_1 \right]}{\frac{2-\alpha}{\alpha} e_{t+1}^{2-\alpha} + \alpha\varphi_1} \right]. \quad (19)$$

The expression makes clear that the firm's effort decision is generally a complicated forward-looking problem. However, there are two exceptions.

Proposition 2 *For $s = 1$ (the pure social norm case) or $\varphi_3 = 0$ (no wage entitlement), firms find it optimal to elicit a constant effort level.*

Proof: For $s = 1$ or $\varphi_3 = 0$, the MSC in (19) reduces to $e^* = \alpha(1 - \varphi_1)/(2 - \alpha)^{1/(2-\alpha)}$.

4.2. Business cycle implications of rent-sharing and wage entitlement

To get a sense of the business cycle implications of rent-sharing and wage entitlement, we loglinearize the model and abstract from physical capital. Ignoring constants, aggregate production (6) and wage setting (18) become

$$\begin{aligned} \hat{y}_t &= \alpha(\hat{a}_t + \hat{e}_t + \hat{n}_t) \\ (1 - \varphi_2)\hat{w}_t &= \frac{2-\alpha}{\alpha}e^{2-\alpha}\hat{e}_t + \varphi_1(\hat{y}_t - \hat{n}_t) + \varphi_2\hat{n}_t + \varphi_3\hat{w}_{t-1} \end{aligned}$$

Hatted lower-case variables denote percentage deviations from the respective steady states of the appropriately normalized aggregates.¹¹

¹⁰The proposition implies that state-dependent household taxes drop out of all the equations.

¹¹To simplify the analysis, we treat the neutral productivity shock A_t as a stationary variable. None of the results change if we treat the neutral productivity shock as a non-stationary variables (as is the case in the empirical analysis).

We focus on the social norm case $s = 1$ for which optimal effort is constant; i.e. $\hat{e}_t = 0$. In so doing we anticipate our estimates in Section 5, which imply that effort varies little or not at all over the business cycle. Combining the first two equations and imposing $\varphi_1 + \varphi_2 + \varphi_3 = 1$ from Proposition 1, we obtain

$$\hat{w}_t = \frac{\alpha\varphi_1}{\varphi_1 + \varphi_3}\hat{a}_t + \frac{1 - (2 - \alpha)\varphi_1 - \varphi_3}{\varphi_1 + \varphi_3}\hat{n}_t + \frac{\varphi_3}{\varphi_1 + \varphi_3}\hat{w}_{t-1}. \quad (20)$$

Despite its partial equilibrium character (\hat{w}_t depends on both \hat{n}_t and \hat{w}_{t-1} , which are endogenous), this equation reveals interesting properties about the effects of rent-sharing and wage entitlement. The more workers' effort depends on rent-sharing (i.e. the larger φ_1), the stronger is the direct impact of technology shocks on wages, and the smaller (or more negative) is the wage response to fluctuations in hours worked. Rent-sharing thus has an ambiguous general equilibrium influence on the response of wages to a technology shock. If the equilibrium response of hours worked is large, rent-sharing reduces the wage response. If, instead, hours worked react little or even negatively, rent-sharing increases the wage response to a technology shock. Figure 1a illustrates these effects by contrasting a labor market with rent sharing (solid wage setting curve) with a labor market without rent sharing (dotted wage setting curve). Suppose that before the technology shock, both economies are in the same equilibrium (point E). If, as depicted, the labor demand curve shifts out relatively little in response to a technology change $\hat{a}_t > 0$, then the real wage adjusts more in the rent-sharing economy (point E' vs. point E''). By contrast, rent-sharing unambiguously lowers the reaction of wages to monetary policy shocks (because $\hat{a}_t = 0$ in this case). In fact, if φ_1 is sufficiently large such that $1 - (2 - \alpha)\varphi_1 - \varphi_3 < 0$, wages and employment move in opposite directions. Figure 1b depicts such a situation.

Now consider wage entitlement. Equation (20) indicates that the more past wages influence workers' effort and thus the firm's wage decision (i.e. the larger φ_3), the smaller are the effects of movements in technology and employment and the larger is the persistence of wage movements. If φ_3 is sufficiently large such that $1 - (2 - \alpha)\varphi_1 - \varphi_3 < 0$, wages and

employment move inversely.

Through wages, rent-sharing and wage entitlement can have a profound impact on real marginal cost, which in loglinearized terms equals

$$\hat{\psi}_t = \alpha(\hat{R}_t + \hat{w}_t) - \alpha\hat{a}_t.$$

The smaller the wage response (a fortiori if it is negative), the more negative is the reaction of real marginal cost to a technology shock. In response to a monetary policy shock, marginal cost may also fall for two reasons. First, a monetary policy shock is typically associated with a fall in the interest rate; i.e. $\hat{R}_t < 0$. Second, if rent-sharing and wage entitlement are sufficiently strong, wages fall on impact as well.

This real marginal cost dynamics has interesting implications for inflation and profits. For inflation, our pricing restrictions imply a loglinearized equation of the form

$$\hat{\pi}_t = \theta_b \hat{\pi}_{t-1} + \theta_f E_t \hat{\pi}_{t+1} + \gamma \hat{\psi}_t,$$

with $\theta_b = \frac{\omega_p}{1+\beta\omega_p}$, $\theta_f = \frac{\beta}{1+\beta\omega_p}$ and $\gamma = \frac{(1-\kappa_p)(1-\beta\kappa_p)}{\kappa_p(1+\beta\omega_p)}$. Following the literature, we refer to this equation as the New Keynesian Phillips curve (NKPC). Let $\delta_1 \leq 1$ ($\delta_2 \geq 1$) denote the stable (unstable) root of this equation, then the NKPC can be expressed as

$$\hat{\pi}_t = \delta_1 \hat{\pi}_{t-1} + \left(\frac{\gamma}{\theta_f \delta_2} \right) \sum_{j=0}^{\infty} \left(\frac{1}{\delta_2} \right)^j E_t \hat{\psi}_{t+j}.$$

As long as the backward-looking component of inflation is unimportant (i.e. ω_p and thus δ_1 is small), inflation is predominantly driven by changes in present and future expected real marginal costs (the more so the larger γ). In such a case, inflation drops after a technology shock if real marginal cost falls on impact and remains persistently low thereafter. Concurrently, inflation reacts in a smooth, hump-shaped pattern to a monetary policy shock if real

marginal cost exhibits a delayed increase. For profits, in turn, we can express (14) as

$$\widehat{profits}_t = \frac{1/\psi - \tilde{\alpha}}{1 - \tilde{\alpha}} \hat{y}_t - \frac{\tilde{\alpha}}{1 - \tilde{\alpha}} \hat{\psi}_t$$

with $\tilde{\alpha} \equiv \alpha/(1 - (1 - \alpha)\varphi_1)$. Rent-sharing and wage entitlement affect profits in two different ways. First, the smaller (or more negative) the reaction of marginal cost to a shock, the stronger the profit response. Second, the larger φ_1 (i.e., the stronger the rent-sharing motive), the larger $\tilde{\alpha}$ and thus the more sensitive are profits to output and real marginal cost.

Finally, consider the case of variable effort (i.e. $s < 1$). In this case, the MSC in (17) implies the following loglinearized dynamics for optimal effort

$$\hat{e}_t = -\Omega \sum_{i=0}^{\infty} \left(\frac{(1-s)\varphi_3\beta}{1 - (1-\alpha)\varphi_1} \right)^i \left[(E_t \hat{\lambda}_{t+i} - \hat{\lambda}_t) + (E_t \hat{\psi}_{t+i} - \hat{\psi}_t) + (E_t \hat{y}_{t+i} - \hat{y}_t) \right],$$

where $\Omega \equiv \frac{1 - (1-\alpha)\varphi_1 - (1-s)\varphi_3\beta}{(2-\alpha)(1-\varphi_1 - (1-s)\varphi_3\beta)} > 0$. The firm finds it optimal to elicit a lower effort level today if (i) future profits are expected to be valued higher by shareholders ($E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t > 0$); (ii) the price of intermediate goods is expected to increase ($E_t \hat{\psi}_{t+1} - \hat{\psi}_t > 0$); (iii) future production is expected to increase ($E_t \hat{y}_{t+1} - \hat{y}_t > 0$). As we will see in the last part of the paper, all three of these factors are typically positive after expansionary shocks and thus, effort will react countercyclically. But since this reaction remains small relative to the response of other macro aggregates, variable effort has only a small impact on the fit of the model.

5. Empirical evaluation

5.1. Estimation approach

We proceed with a quantitative evaluation of the full DSGE model described in Section 3. We estimate the structural parameters by minimizing the distance between a set of impulse

responses functions (IRFs) implied by the model and their empirical counterparts from an identified VAR. We adopt this limited information approach rather than a full-information likelihood-based estimator for two reasons. First, our focus is on the dynamics of prominent macro variables in response to specific shocks that have clear empirical counterparts in the VAR literature. Second, we want to compare our results with recent studies by CEE (2005) and ACEL (2004) who employ the same estimation approach to analyze the performance of very similar DSGE models with nominal wage rigidities.

The specification of our VAR follows closely the one adopted by ACEL (2004). We use an updated sample spanning the period from 1959:2 to 2008:2 of their 10-dimensional data vector containing stationary combinations of different macro aggregates. We add to this the ratio of corporate profits to GDP as an eleventh variable.¹²

The shock identification is taken directly from ACEL (2004). They identify a monetary policy shock, a neutral technology shock and an investment-specific technology shock based on the following restrictions developed in previous work by Shapiro and Watson (1988), Christiano, Eichenbaum and Evans (1998) and Fisher (2006):

- The monetary policy shock is identified as an innovation to the federal funds rate that may only have a contemporaneous effect on velocity and real profits.
- The neutral technology shock and the investment-specific technology shock are the only innovations that may have a permanent effect on labor productivity.
- The investment-specific technology shock is the only innovation that may have a permanent effect on the relative price of investment goods.

Since our model satisfies all of these timing and long-run properties of the shock processes,

¹²The variables used in the VAR are: (1) the change in the relative price of investment; (2) labor productivity growth; (3) GDP deflator inflation; (4) capacity utilization; (5) hours; (6) labor income share; (7) the consumption-output ratio; (8) the investment-output ratio; (9) the federal funds rate; (10) the velocity of MZM transaction balances; and (11) the profit-output ratio. The investment price data is an updated sample of the series computed in DiCecio (2009). The other series are described in the appendix.

we directly compare the IRFs of our model with the empirical VAR responses. Denote by $\hat{\Psi}$ the vector of IRFs over a time period of 20 quarters for each of the three shocks obtained from the identified VAR. Likewise, denote by $\Psi(\zeta)$ the same vector of IRFs implied by our model, where ζ contains all the structural parameters of the model. Then, the estimator of some parameter subset $\zeta^* \subseteq \zeta$ is the solution to

$$\hat{\zeta}^* = \arg \min_{\zeta^*} \left[\hat{\Psi} - \Psi(\zeta) \right]' \Omega^{-1} \left[\hat{\Psi} - \Psi(\zeta) \right],$$

where Ω is a diagonal matrix with the sample variances of $\hat{\Psi}$ along the diagonal.¹³

5.2. Structural VAR evidence

Figure 2 displays the IRFs of the five key variables output, average hours, real wages, inflation and real profits to a one standard deviation change in each of the three identified shocks. The thin solid lines are the point estimates from the VAR, with the surrounding grey areas representing the 95% confidence intervals.¹⁴ The circled lines pertain to the IRFs from the estimated model and are discussed afterwards.

For the monetary policy shock, we identify the following stylized facts: (i) output, hours and real profits respond with a significant hump that peaks four to five quarters after the shock; (ii) the real wage rate increases slightly, yet insignificantly; (iii) inflation drops on impact, although insignificantly, and then exhibits a delayed positive hump-shape.

For the neutral technology shock, the following observations stand out: (i) output jumps on impact and then gradually increases to its new permanent level; (ii) hours react little on impact before displaying a hump-shaped response back to their initial value; (iii) the real wage rate hardly reacts on impact and then increases slowly to its new permanent level; (iv) inflation drops sharply on impact before slowly returning towards the initial rate. While the

¹³Jorda and Kozicki (2005) extend this estimation method with an efficient weighting matrix that allows for statistical testing.

¹⁴The confidence intervals were computed by bootstrap simulation. See ACEL (2004) for details.

reaction of hours to the technology shock is a topic of much controversy, the sharp drop in inflation and the sluggish reaction of real wages are robust features of VAR studies.¹⁵

For the investment-specific technology shock, finally, we find that (i) output, hours and real profits jump on impact; (ii) inflation reacts positively but insignificantly; and (iii) the real wage rate falls on impact before sluggishly increasing to its new permanent level.

In sum, the striking observation from these VAR results is the small and sluggish response of real wages, irrespective of the type of shock, and the very distinct reaction of inflation with respect to monetary and neutral technology shocks.

5.3. Estimation results

We partition the parameters of our model into two groups. The first group consists of model parameters that we calibrate such as to match salient long-run characteristics of the data. Table 1 reports the calibrations. The first four values imply a labor share close to 0.7 as reported by Gollin (2002); an average annualized real interest rate of 3 percent; an average markup for final goods producers of 11% in line with Basu and Fernald (1997); and an annual depreciation rate of 10 percent. The values for the three growth rates μ_V , μ_A and μ_M are set such as to match the sample averages for the decrease in the price of investment relative to the GDP deflator (1.68% annually), the growth rate of real GDP (1.81% annually), and the growth rate of our money aggregate (6.98% annually). Finally, steady state velocity v equals the average value of C/Q over the sample; the value of η is set such that the average transaction cost for consumption goods is 2.5% of GDP, which equals the value added in the finance, insurance and real estate sector (see Christiano, Motto and Rostagno, 2003); and the fixed cost parameter is set such that economy-wide net profits are zero as suggested by Basu and Fernald (1994) or Rotemberg and Woodford (1995). The calibration for all parameters but α and θ_p is as in ACEL (2004).

The second group of parameters is estimated and consists of structural model parameters

¹⁵The appendix reviews this VAR literature as well as other empirical evidence.

$\varphi_1, \varphi_3, s, \gamma, \omega_p, b, \sigma_u, S'', \epsilon$ as well as the parameters governing the dynamics of the exogenous shock processes. As shown in Proposition 1, balanced growth imposes $1 = \varphi_1 + \varphi_2 + \varphi_3$. We thus estimate only φ_1 and φ_3 . For pricing, there is a direct mapping (given ω_p) between the NKPC slope parameter γ and the probability of price reoptimization $1 - \kappa_p$. This mapping depends on the existence of firm-specific capital and non-convexities in demand (see for example Eichenbaum and Fischer, 2007). While we do not model these features, they could be easily introduced. We thus estimate γ directly and attach less importance to the value for κ_p that this estimate implies. The last three structural model parameters are, respectively, the curvature of the investment adjustment cost function S'' ; the elasticity of the slope of the capital depreciation rate with respect to utilization $\sigma_u \equiv \delta''(u)u/\delta'(u)$; and the interest semi-elasticity of money demand ϵ as defined in ACEL (2004). Together with the other parameters, they determine the dynamics of the loglinearized system.¹⁶

We estimate the different parameters to match the following IRFs computed from the VAR: output, money growth, inflation, the Fed Funds rate, capacity utilization, hours worked, real wages, consumption, investment, velocity, the relative price of investment and real profits. The first column of Table 2 reports the point estimates and the associated standard errors (in parenthesis).¹⁷ Both the coefficient for rent sharing of $\hat{\varphi}_1 = 0.27$ and the coefficient on wage entitlement of $\hat{\varphi}_3 = 0.68$ are sizable and precisely estimated. The two estimates together imply $\hat{\varphi}_2 = 1 - \hat{\varphi}_1 - \hat{\varphi}_3 = 0.05$. Hence, external employment conditions are estimated to play only a minor role for wage setting, which accords well with the survey studies on reciprocity discussed in Section 2.

The estimate of $\hat{s} = 1$ indicates that the data favors a purely social norm version of wage entitlement where workers care about past aggregate wages rather than the firm-internal past wage.¹⁸ In response, firms do not internalize the effect of current wages on future effort

¹⁶For $S'' = 0$, adjustment cost are zero around the steady state. For $\sigma_u = 0$, capital utilization is proportional to the rental rate whereas for $\sigma_u \rightarrow \infty$ utilization is constant.

¹⁷Standard errors are inferred from the empirical weighting matrix via the delta method. See ACEL (2004).

¹⁸Since this parameter is estimated to be at its upper bound, it would not be meaningful to report standard

and adopt a compensation policy that keeps effort constant at all times (see Proposition 2). Since workers remain on average in the same job for several quarters, this estimate of s may not seem so plausible. In the robustness section at the end of the paper, we therefore reestimate the model with s calibrated to a value in line with job flows data.

Turning to pricing, we estimate a coefficient on real marginal cost in the NKPC of $\hat{\gamma} = 0.27$ and a weight for lagged inflation indexation of $\hat{\omega}_p = 0$. The estimate of $\hat{\gamma} = 0.27$ implies an average price rigidity of only 2.5 quarters, which is close to the micro-estimates of price rigidity by Bils and Klenow (2004) and others even though our model does not feature firm-specific capital or non-convexities in demand. This estimate is much higher than the corresponding value reported in other single-equation and full-information DSGE estimations.¹⁹ We reconsider this issue in the robustness section. The estimate of $\hat{\omega}_p = 0$ implies $\theta_b = 0$ which means that inflation is a purely forward-looking process. This is somewhat lower than reported in other estimations, which report values of θ_b around 0.25, and contrasts with CEE (2005) and ACEL (2004) who fix $\omega_p = 1$, which implies $\theta_b \approx 0.5$.

The estimates of the other parameters are close to those reported in ACEL (2004) with three notable exceptions. First, capital utilization is estimated to be considerably less costly in our model; second, the estimated standard deviation of the neutral technology growth innovation is almost three times smaller in our model; and third, monetary policy in our model is estimated not to accommodate neutral technology growth (i.e. $\hat{\phi}_{\mu_A} = 0$). The last two differences suggest that our reciprocity model generates larger internal amplification with respect to neutral technology shocks than a similar model with nominal wage contracts. We confirm this conjecture in the appendix.

errors for it. We thus fix it when computing standard errors for the other parameters. We adopt the same approach throughout the paper for any parameter that is estimated at one of its bounds.

¹⁹See Gali and Gertler (1999) and Kurmann (2007) among many others for single-equation estimates; or Smets and Wouters (2007) for full-information DSGE estimates.

5.4. *Empirical performance*

We evaluate the performance of the estimated model by comparing the fit of the model-generated IRFs with the empirical counterparts from the VAR. Reconsider Figure 2, which plots the IRFs of output, hours, inflation, real wages and real profits.²⁰ The model is successful in generating the hump-shaped response of output and hours with respect to all three shocks. The model also performs remarkably well with respect to inflation. In particular, the estimated model is capable of simultaneously generating the delayed, hump-shaped response of inflation after a monetary policy shock and the sharp drop of inflation on impact of the neutral technology shock. However, the model cannot match the small positive response of inflation to the investment-specific shock.

The key to understanding these very different responses of inflation is the forward-looking nature of the NKPC, which implies that inflation depends on the expected path of future marginal cost. In response to the monetary policy shock, marginal cost drops on impact and becomes slightly positive only after 8 quarters (shown in the appendix). As a result, inflation falls slightly on impact (thus rationalizing the price puzzle observed in the data) before increasing in a persistent, hump-shaped pattern. With respect to a neutral technology shock, marginal cost responds negatively and reverts only slowly to steady state. Inflation thus drops sharply on impact and remains below trend for more than 10 quarters. A similar fall in marginal cost explains why inflation drops after an investment-specific shock.

The negative response of marginal cost to the three shocks is in part due to the direct impact of interest rates and, in case of the neutral technology shock, to total factor productivity. The second important contributor is the sluggish or even inverse dynamics of real wages, due to the presence of both wage entitlement and rent-sharing.²¹ In particular, if

²⁰The appendix reports the IRFs of all variables used in the estimation. Overall, the model matches the dynamics of the different variables well.

²¹The estimated model implies a small negative reaction of real wages on impact of the monetary policy shock whereas in the VAR, the response is slightly positive. It should be noted, however, that the response of real wages to a monetary shock is highly sensitive to the specification and sample period of the VAR. For example, ACEL (2004) report for their 1959:2-2001:4 sample that real wages slightly fall over the first few

external employment conditions were important for worker's evaluation of fairness (i.e. if $\varphi_2 = 1 - \varphi_1 - \varphi_3$ was large), wages would become more volatile and the model would lose the ability to match the inflation response with respect to the different shocks. In addition, if we turned off rent-sharing and increased wage entitlement (so as to keep φ_2 low), the drop in marginal cost in response to a monetary policy shock would be much smaller and inflation would react positively on impact of the shock. Hence, rent-sharing contributes a powerful new mechanism for wage rigidity, especially with respect to non-technology shocks.

Finally, consider real profits. The model generates a positive hump-shaped response with respect to the monetary policy shock. While the magnitude is smaller than the point estimates observed in the data, this positive response is to be considered as a success of the model. In fact, CEE (1997) find that a baseline sticky price model with a Walrasian labor market generates a counterfactual negative response and view this as a key failing of New Keynesian models. The estimated model is also capable of matching the flat response of real profits on impact of the neutral technology shock and the slight jump in real profits after the embodied technology shock. As with inflation, the key to understanding these reactions of real profits is the dynamics of marginal cost and thus wage setting.

5.5. Robustness

We assess the robustness of the model's performance along three dimensions. First, as discussed above, our estimate of $\hat{\gamma} = 0.27$ is high whereas $\hat{\omega}_p = 0$ is low relative to estimates typically reported in the literature. We therefore fix $\gamma = 0.021$ and $\omega_p = 0.228$, which are the values implied by the point estimate reported in Smets and Wouters (2007), and reestimate the other parameters. The second column of Table 2 reports the results. Many of the parameters remain close to the baseline estimates, including the coefficients for rent-sharing and wage entitlement. However, the model now requires substantially larger

quarters after the monetary policy shock, with the other macro aggregates reacting very similarly to those estimated by our VAR. A similar countercyclical response is also present in Edge et al. (2003).

neutral technology shocks and monetary policy provides stronger accommodation for both technology shocks. As we report in the appendix, the model is still capable of matching the amplified, hump-shaped responses of the real aggregates to the different shocks. Furthermore, inflation still reacts sluggishly to the monetary policy shock and drops on impact of the neutral technology shock, although to a lesser extent. This is because inflation is now much less sensitive to marginal cost and because monetary policy accommodates the neutral technology shock.

The second robustness check is with respect to s , the relative importance of social norms in wage entitlement. As we noted above, the estimate of $\hat{s} = 1$ may not be very plausible because workers on average remain in the same job for several quarters and thus, wage entitlement should be at least partially firm-internal (i.e., the personal norm). Information on the proportion of job stayers in the total workforce is provided by the survey of Davis et al. (2006). Based on data from the Longitudinal Employer Household Dynamics (LEHD), these authors report that about 24% of all workers change establishments each quarter.²² We thus set $s = 0.25$ and reestimate the remaining parameters (but keeping $\gamma = 0.021$ and $\omega_p = 0.228$). The resulting estimates are reported in the third column of Table 2. Rent-sharing is now estimated to be zero whereas wage entitlement becomes more important (the implied weight on external employment conditions increases only slightly to $\varphi_2 = 1 - \varphi_1 - \varphi_3 = 0.086$). The other parameters are estimated to be similar to the ones reported above. As we show in the appendix, effort now reacts countercyclically to all three shocks but the relative magnitude of these fluctuations is modest. Consequently, the overall fit of the model remains close to the one obtained for the first robustness exercise. The appendix also explains in detail why rent-sharing disappears in this case. In short, when γ is small, rent-sharing is less powerful in smoothening inflation after a monetary policy shock and the estimation has

²²A quarterly separation rate of 24% is substantially higher than the typical 10% measured in the JOLTS dataset or inferred from CPS unemployment dynamics (e.g. Shimer, 2005). The reason for this discrepancy is that the LEHD data includes all separations of workers, even those who go through very short employment spells (i.e., get hired and leave in the same quarter). For our purpose, this seems like the appropriate measure.

a harder time identifying its importance relative to wage entitlement.²³

The third robustness exercise consists of reestimating the model based on IRFs obtained from a VAR on the shorter 1982-2008 sample. This is motivated by recent evidence suggesting that the conduct of monetary policy has changed and that the relative importance of shocks has decreased substantially starting in the early 1980s. All estimates and IRFs are available in the appendix. There are some quantitative differences in the VAR results. But the model remains capable of matching the dynamics of most macro aggregates. Most importantly, given the above robustness checks, rent-sharing is estimated to have more weight in wage setting than wage entitlement (outside employment conditions remain negligible). This remains true even if we restrict γ and ω_p to the relevant estimates from Smets and Wouters (2007) and fix $s = 0.25$.

6. Conclusion

In this paper, we incorporate a reciprocity-based model of wage determination into a modern DSGE framework. We estimate the structural parameters of the model and assess its ability to generate the distinct dynamics of prominent macroeconomic aggregates in response to various exogenous shocks. Our estimation suggests that workers' past wage level (a factor we associate with a sense of wage entitlement) but also firms' ability to pay (resulting from rent-sharing considerations) are the most important determinants of wage setting. Aggregate labor market conditions – the wage reference typically emphasized in standard efficiency wage formulations – are estimated to be of minor importance. These findings accord well with a large number of survey studies on reciprocity in labor relations and wage setting in general. The reason often given in these studies for the relative unimportance of firm-external labor market conditions is that individuals have only little knowledge of the market

²³For example, we could fix $\varphi_1 = 0.25$ and reestimate the model without greatly deteriorating the fit of the model. Also, if we simply fixed $s = 0.25$ and reestimated all other parameters including γ and ω_p , rent-sharing would remain important.

value of their work and thus resort to alternative reference points. While our model stops short of formalizing this information problem, we find the match between our estimates of the determinants of wage setting and the survey evidence intriguing and suggestive of interesting avenues for future research.

Overall, the estimated reciprocity model performs well when confronted with the empirical VAR dynamics of key variables. In particular, the presence of rent-sharing allows the model to simultaneously replicate the sluggish response of inflation after a monetary policy shock and the sharp drop in inflation on impact of a neutral technology shock. This is an interesting difference to models with nominal wage contracts, which typically fail to generate these distinct conditional responses of inflation.

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Table 1: Calibrated parameters

α	β	θ_p	δ	μ_V	μ_A	μ_M	V	$\eta C/Y$
0.75	0.9942	10	0.025	1.0042	1.00013	1.017	0.45	0.036

Table 2: Estimates for reciprocity model

	Baseline estimates	Estimates with $\gamma = 0.021$ and $\omega_p = 0.228$	Estimates with $s = 0.25$, $\gamma = 0.021$ and $\omega_p = 0.228$
φ_1	0.269 (0.015)	0.225 (0.154)	0.000 (<i>n.a.</i>)
φ_3	0.677 (0.007)	0.713 (0.050)	0.914 (0.000)
s	1.000 (<i>n.a.</i>)	1.000 (<i>n.a.</i>)	0.250 (<i>n.a.</i>)
γ	0.269 (0.004)	0.021 (<i>n.a.</i>)	0.021 (<i>n.a.</i>)
ω_p	0.000 (<i>n.a.</i>)	0.228 (<i>n.a.</i>)	0.228 (<i>n.a.</i>)
b	0.810 (0.001)	0.748 (0.007)	0.724 (0.001)
S''	3.117 (0.021)	3.143 (0.156)	4.604 (0.103)
σ_u	0.581 (0.108)	1.087 (0.334)	1.197 (0.250)
ϵ	0.964 (0.030)	0.798 (0.041)	0.757 (0.047)
ρ_{μ_A}	0.981 (0.001)	0.792 (0.004)	0.763 (0.005)
$\sigma_{\varepsilon_{\mu_A}}$	0.025 (0.018)	0.079 (0.019)	0.086 (0.008)
ρ_{μ_V}	0.296 (0.205)	0.591 (0.033)	0.631 (0.032)
$\sigma_{\varepsilon_{\mu_V}}$	0.202 (0.069)	0.123 (0.014)	0.113 (0.033)
ρ_{μ_M}	0.441 (0.014)	0.556 (0.004)	0.525 (0.047)
$\sigma_{\varepsilon_{\mu_M}}$	0.159 (0.019)	0.155 (0.038)	0.148 (0.035)
ϕ_{μ_A}	0.000 (<i>n.a.</i>)	0.741 (0.014)	0.674 (0.024)
ϕ_{μ_V}	1.172 (0.159)	3.139 (0.033)	3.395 (0.059)
Objective	1097.443	1246.378	1318.379

Standard errors are computed via the delta method from the bootstrapped variance matrix of the IRFs. See ACEL (2004) for details.

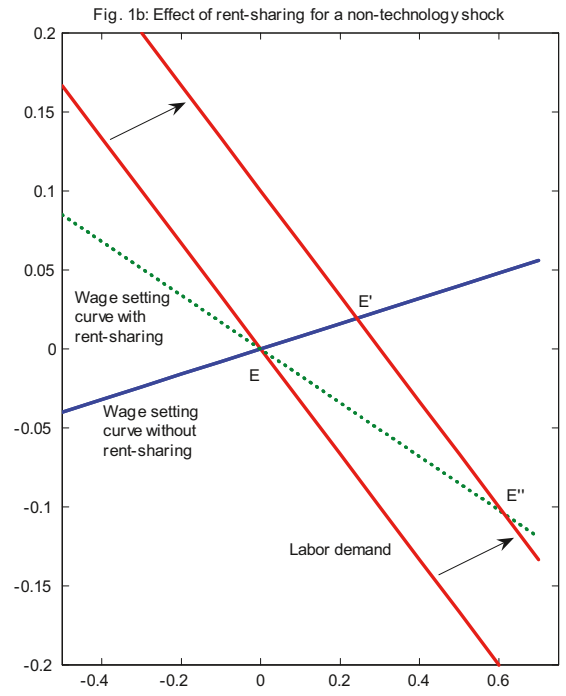
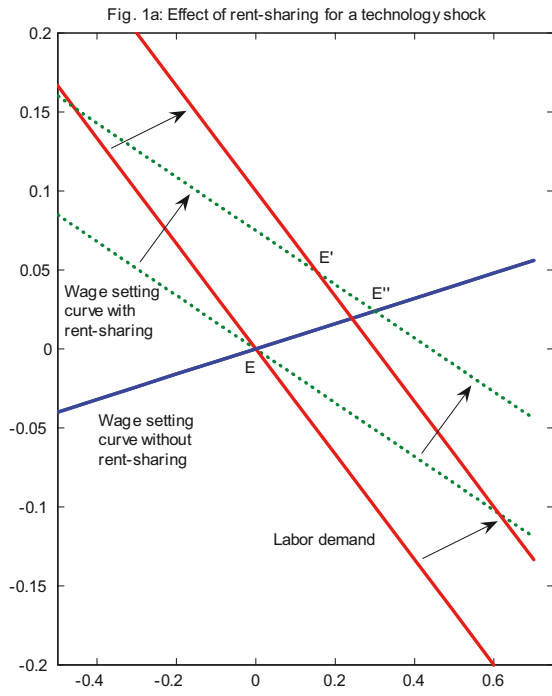


Figure 1: The effects of rent-sharing

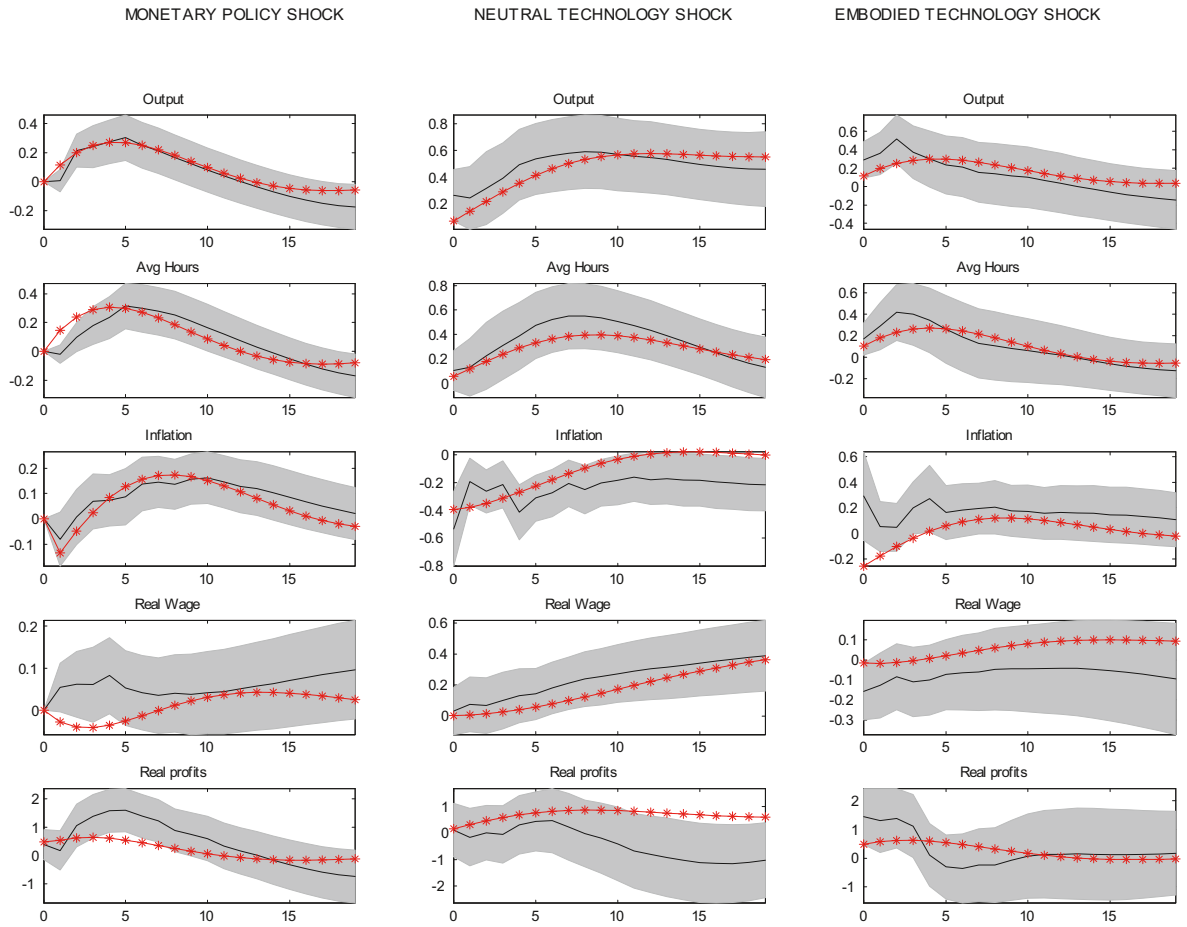


Figure 2: Impulse responses of VAR (solid lines and grey intervals) and estimated reciprocity model (red starred lines)

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