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# A Non-Walrasian Labor Market and the European Business Cycle

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## Abstract

This paper investigates to what extent a New Keynesian, monetary model with the addition of a microfounded, non-Walrasian labor market based on union bargaining is able to replicate key aspects of the business cycle. The presence of a representative union offers an explanation for two features of the cycle. First, it generates an endogenous mechanism which produces persistent responses of the economy to both supply and demand shocks. Second, labor unionization causes a lower elasticity of marginal costs to output. This leads to lower inflation volatility. The model can replicate the negative correlation between productivity shocks and employment in the data. Model simulations show the superiority of the unionized framework in reproducing European business cycle statistics relative to a model with a competitive labor market.

*JEL:* E24, E31, E32.

*Key Words:* Trade Unions, Business Cycle, Inflation, Persistence.

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# 1 Introduction

High unemployment rates have been a feature of the euro area countries for the last two decades, despite the concern of the European Commission and national governments. Figure 1 compares unemployment rates in the euro area countries and in the United States. Although the timing of fluctuations for these economies is similar, amplitude and unemployment persistence have been considerably larger for the euro area.

High unions density and coverage rates are striking features of the European labor market. Unionization is substantially more pervasive if compared with the American counterpart, as shown in Table 1. From these measures, we can infer a higher level of union power in Europe relative to the United States during the last two decades.

These facts suggest that a perfectly competitive labor market may not be the appropriate theoretical framework for the euro area, where countries are generally characterized by imperfections in the labor market and rigidities in the economy. In this paper, I incorporate equilibrium unemployment through union bargaining in an otherwise standard New Keynesian monetary model. I then use the model to study the consequences of union bargaining on the business cycle.

The theoretical set up I introduce is characterized by an innovative New Keynesian monetary model which encompasses departures from perfect competition in both labor and product markets. The structure of the labor market is non-Walrasian: Wages are set by the bargaining process between firms and trade unions somewhere above the market-clearing level. This generates unemployment as some individual workers are unable to sell as much labor services as they wish to supply, given the established wages. Goods markets are imperfectly competitive due to the presence of monopolistically competitive, intermediate goods-producing firms. The monetary authority conducts monetary policy through interest rate setting in the form of a Taylor-type rule. Finally, I explicitly incorporate real and nominal rigidities, in the form of capital and price adjustment costs.

The set up improves upon the previous literature in the following manners. First, Hall (2000) stresses that variables' persistence in the aftermath of shocks is a critical property of the data that standard neoclassical models fail to reproduce. He suggests that the inclusion of non-Walrasian features may improve the replication of this feature of the business cycle. Along these lines, Maffezzoli (2001) shows that a real business cycle model with a

monopoly union has a comparative advantage over the Rogerson and Wright (1988) indivisible labor model in the replication of Italian business cycle statistics. Nonetheless, his model cannot embed monetary policy shocks and is not able to generate appropriate persistence in reaction to supply shocks. Alexopoulos (2004) develops a shirking efficiency wage model which improves the replication of labor markets statistics but again fails to deliver an appropriate degree of persistence. Dotsey and King (2001), building upon Chari, Kehoe, and McGrattan (2000), point out that standard sticky price models are not able to account for the persistent response of output to demand shocks and they allow for a number of “supply side” features to improve the performance of a standard sticky price model. In this paper, the introduction of labor market bargaining into a standard sticky price model creates an endogenous mechanism based on lower wage volatility that independently introduces persistence in response to both supply and demand shocks.

Second, Bernanke and Gertler (1995), Christiano, Eichenbaum, and Evans (1997), and Bernanke and Mihov (1998) offer evidence that inflation varies only moderately in response to monetary policy shocks. Standard New Keynesian sticky price models are not capable of capturing this feature of the business cycle. In this set up a unionized labor market generates lower elasticity of marginal costs with respect to output, and this translates into moderate price adjustments. This increases the level of price stickiness to changes in aggregate demand and diminishes inflation volatility.

Third, recent contributions as Christiano and Eichenbaum (1992), Bernanke and Gertler (1995), Bernanke and Mihov (1998), Shea (1998), Basu, Fernald and Kimball (2002), Galí (1999), and Francis and Ramey (2003) point out a negative correlation between productivity shocks and employment. In line with these studies, both the union and the baseline sticky price models of this paper are able to reproduce this feature due to the delayed reaction of prices and production to technology shocks.

Numerical simulations show that the presence of a non-Walrasian labor market improves the ability of a standard sticky price model to replicate the European business cycle relative to the standard model without monopoly unions. Attention is focused on the comparison between models and European statistics for the variables’ standard deviations, relative volatilities with respect to output, and correlations with output. Stochastic simulations illustrate a higher persistence of the variables for the monopoly union model.

Recent literature has employed New Keynesian, sticky price models to study business cycles’ dynamics and shocks’ propagation. The majority of

contributions assume a Walrasian labor market and just few exceptions consider the case of equilibrium unemployment in the economy. Alexopoulos (2002) introduces equilibrium unemployment through imperfectly observed efforts into a standard monetary model and finds that this improves the replication of labor markets' fluctuations. The search and matching approach to labor market equilibrium, first developed by Pissarides (1990) and Mortensen and Pissarides (1994), provides a framework used by Trigari (2004) and Walsh (2003) to model a non-Walrasian labor market in a monetary economy. They find that this setting makes progresses over demand shocks propagation. My approach differs from those along two critical dimensions. First, it employs a different labor market structure: those papers draw their conclusions on the basis of efficiency wages or on the idea that workers and firms look for a convenient match that cannot always be realized. In contrast, this paper relies on union bargaining as the source of unemployment creation. Second, I account for both demand and supply disturbances while previous research focuses mainly on demand disturbances. Such an enriched environment permits an extensive and more realistic testing ground for the model's properties.

The remainder of the paper is organized as follows: Section 2 sets up the model, Section 3 describes the calibration, Section 4 carries out numerical simulations and discusses the results, and, finally, Section 5 concludes.

## **2 Economic Environment**

### **2.1 Overview**

The model is constructed along the lines of those used by Daveri and Maffezzoli (2000), Ireland (2000), King and Rebelo (2000), and Maffezzoli (2001). The distinguishing feature of my modelling strategy is the contemporaneous presence of a non-Walrasian labor market generated by union bargaining, and imperfectly competitive goods markets in a monetary economy with real and nominal rigidities.

This framework differs from previous contributions in the following respects. First, Daveri and Maffezzoli (2000) and Maffezzoli (2001) develop a non-Walrasian labor market in a real business cycle framework. I extend the analysis to an imperfectly competitive goods market in a monetary economy and make use of price and capital rigidities to deliver reliable monetary policy evaluation.

Second, as noted above, the literature on non-Walrasian labor market implemented through union bargaining never explicitly considered the action of the monetary authority. Here, monetary authority is explicitly accounted for through a Taylor-type rule for monetary policy.

As noted above, this model mainly differs from the typical dynamic stochastic general equilibrium (hereafter, DSGE) model by the presence of equilibrium unemployment caused by the bargaining power of the union over the wage. To explain the existence of the union, the difference in the supply of labor and capital for the household needs to be considered. In fact, for each period, while capital can be sold to a large number of firms, labor is indivisible and can be provided to only one firm. Households realize the possibility of extracting some producer surplus by joining trade unions that negotiate wages at the firm level while representing their members. The objective of these institutions is to maximize the average labor income of members regardless of capital income. Once a representative union sets the wage rate—higher than the competitive wage—the representative firm chooses the level of employment which maximizes its profit. As a result, some members of the union remain unemployed and are entitled to receive a subsidy from the government. To prevent quits by unemployed members, unions redistribute wages of employed people among all members. In this way, as in Pencavel (1986), unions act to completely insure markets so that the simplifying assumption of homogeneous agents is preserved over time.

The model describes the behavior of a representative household, a representative finished goods-producing firm, a continuum of intermediate goods-producing firms indexed by  $i \in [0, 1]$ , a representative trade union indexed by  $j \in [0, 1]$ , and a monetary authority.

This economy is populated by a continuum of ex-ante identical, infinitely lived worker-households with names in the closed interval  $[0, 1]$ . During each period,  $t = 0, 1, 2, \dots$ , the representative household purchases output from the representative finished goods-producing firm and supplies capital and labor to the intermediate goods-producing firms in imperfectly competitive markets. It purchases riskless bonds and uses money provided by the government and profits by the firms. The household faces adjustment costs related to investment in physical capital.

For each period, each intermediate goods-producing firm produces a distinct, perishable intermediate good indexed by  $i \in [0, 1]$ ; for convenience firm  $i$  produces good  $i$ . In addition, the representative intermediate goods-producing firm faces a cost of adjusting its nominal price, as in Rotemberg

(1992). This cost of price adjustment allows the monetary authority to influence the behavior of real variables in the short-run.

Each representative union indexed by  $j \in [0, 1]$  unilaterally maximizes its objective function during each period  $t = 0, 1, 2, \dots$  taking as given the labor demand function as determined by the representative goods-producing firm.

The government is the authority in charge of distributing the monetary aggregate to the agents during each period  $t = 0, 1, 2, \dots$ . It also provides the household with lump-sum transfers, and riskless bonds.

Finally, the monetary authority establishes the nominal interest rate in response to output and inflation deviations from their steady state levels and accounting for monetary policy inertia.

## 2.2 The Representative Household

A comparison between the Walrasian and the non-Walrasian model is possible if the dynamics of the labor market takes place on the extensive margin. In the usual DSGE framework, each member of the household chooses between working a fixed number of hours and not working at all. The choice set is not convex, but it may be convexified by introducing employment lotteries. For this reason, I employ a modified version of the Rogerson and Wright (1988) indivisible labor model. As it is described in King and Rebelo (2000), by entering a lottery a household member can choose to work a fraction of  $n$  days and to remain unemployed for the remaining  $1 - n$  days. With the assumption of perfect risk sharing, it can be shown that the stand-in representative household maximizes an expected utility function of the form<sup>1</sup>

$$E \sum_{t=0}^{\infty} \beta^t u(C_t, n_t, \frac{M_t}{P_t}) = E \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{1-\mu} [C_t^{1-\mu} v(n_t)^{1-\mu} - 1] + \kappa_m \log \frac{M_t}{P_t} \right\}, \quad (1)$$

where  $v(n_t) = \left[ n_t v_e^{\frac{1-\mu}{\mu}} + (1 - n_t) v_u^{\frac{1-\mu}{\mu}} \right]^{\frac{\mu}{1-\mu}}$ , and  $0 < \beta < 1$ . Variables  $v_e$  and  $v_u$  represent the utility of leisure for the employed and unemployed representative household respectively. Consumption and real money holdings are represented by  $C_t$  and  $M_t/P_t$  respectively. The coefficient  $n_t$  is the probability for the representative household of being employed, whereas  $1 - n_t$  is her

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<sup>1</sup>See Appendix for further details.

probability of being unemployed during each period  $t = 0, 1, 2, \dots$ . Note that aggregating individuals into a representative household permits to interpret  $n_t$  as the employment rate. In this set up the Walrasian setting shares two key features with the union model: first, an infinitely elastic labor supply for any given shadow value of installed physical capital (and the marginal utility of consumption) and, second, unemployment can be positive in equilibrium due to the lottery uncertainty.

The representative household enters period  $t$  with bonds  $B_{t-1}$  and money  $M_{t-1}$ . At the beginning of the period, the household receives a lump-sum nominal transfer  $T_t$  from the monetary authority and nominal profits  $F_t$  from each intermediate goods-producing firm. The household supplies  $n_t$  units of labor to the representative union at the wage rate  $W_t$ , and  $K_t$  units of capital at the rental rate  $Q_t$  to each intermediate goods-producing firm  $i \in [0, 1]$  during period  $t$ . While unemployed, the household receives a reservation wage  $\bar{W}_t$  in the form of lump-sum transfers from the government which incorporates unemployment subsidies and her value of leisure. Then, her bonds mature, providing  $B_{t-1}$  additional units of money. The household uses part of this additional money to purchase  $B_t$  new bonds at nominal cost  $B_t/r_t$ , where  $r_t$  represents the gross nominal interest rate between  $t$  and  $t + 1$ . The household may also use his income for consumption,  $C_t$ , or investment,  $I_t$ .

By investing  $I_t$  units of the finished good during each period  $t$ , the representative household increases the capital stock over time according to

$$K_{t+1} = (1 - \delta)K_t + I_t - \frac{\phi_k}{2} \left( \frac{K_{t+1}}{\gamma_{t+1}K_t} - 1 \right)^2 K_t, \quad (2)$$

where  $1 < \delta < 0$  is the depreciation rate, the parameter  $\phi_k \geq 0$  represents the magnitude of capital adjustment costs, and  $\gamma_{t+1}$  is the gross steady state growth rate of the capital stock at  $t + 1$ . For all  $t = 0, 1, 2, \dots$ , fraction of aggregate employment and capital supplied by the representative household must satisfy

$$n_t = \int_0^1 n_t(i) di,$$

$$K_t = \int_0^1 K_t(i) di,$$

and total profits received by each household are

$$F_t = \int_0^1 F_t(i) di$$

during each period  $t = 0, 1, 2, \dots$ . The household carries  $M_t$  units of money,  $B_t$  bonds, and  $K_{t+1}$  units of capital into period  $t + 1$ , subject to the budget constraint

$$C_t + I_t + \frac{B_t}{r_t P_t} + \frac{M_t}{P_t} = \frac{B_{t-1}}{P_t} + \frac{n_t W_t}{P_t} + \frac{F_t}{P_t} + \frac{T_t}{P_t} + \frac{Q_t K_t}{P_t} + \frac{M_{t-1}}{P_t} + (1 - n_t) \frac{\bar{W}_t}{P_t} \quad (3)$$

for all  $t = 0, 1, 2, \dots$

Thus the household chooses  $\{C_t, n_t, K_{t+1}, I_t, B_t, M_t\}_{t=0}^\infty$  to maximize its utility subject to the budget constraint (3) for all  $t = 0, 1, 2, \dots$ . Letting  $m_t = M_t/P_t$  denote real balances,  $\pi_t = P_t/P_{t-1}$  the inflation rate, and  $\Lambda_t$  the non-negative Lagrange multiplier on the budget constraint (3), the first order conditions for this problem are

$$C_t^{-\mu} v(n_t)^{1-\mu} = \Lambda_t, \quad (4)$$

$$\frac{\mu}{1-\mu} \left( C_t^{1-\mu} v(n_t)^{\frac{-(1-\mu)^2}{\mu}} \right) = \frac{\Lambda_t}{P_t} (W_t - \bar{W}_t), \quad (5)$$

$$\begin{aligned} & \Lambda_t \left[ 1 + \phi_k \left( \frac{K_{t+1}}{\gamma_{t+1} K_t} - 1 \right) \frac{1}{\gamma_{t+1}} \right] \\ = & \beta E_t \Lambda_{t+1} \left[ (1 - \delta) + \frac{Q_{t+1}}{P_{t+1}} - \frac{\phi_k}{2} \left( \frac{K_{t+2}}{\gamma_{t+2} K_{t+1}} - 1 \right)^2 + \phi_k \left( \frac{K_{t+2}}{\gamma_{t+2} K_{t+1}} - 1 \right) \frac{K_{t+2}}{\gamma_{t+2} K_{t+1}} \right] \end{aligned} \quad (6)$$

$$\beta r_t E_t \frac{\Lambda_{t+1}}{\pi_{t+1}} = \Lambda_t, \quad (7)$$

$$\frac{\kappa_m}{m_t} + \beta E_t \frac{\Lambda_{t+1}}{\pi_{t+1}} = \Lambda_t, \quad (8)$$

with the transversality condition

$$\lim_{\tau \rightarrow \infty} \beta^{t+\tau} K_{t+\tau+1} \Lambda_{t+\tau+1} = 0, \quad (9)$$

and equation (2) with equality for all  $t = 0, 1, 2, \dots$ . Equations (4)-(9) together with the household budget constraint (3) and the evolution of capital stock (2) provide the necessary and sufficient conditions to solve the household problem.

According to equation (4), the Lagrange multiplier must equal the household's marginal utility of consumption. According to equation (5), the marginal disutility of working equals the marginal utility of consumption multiplied by the real wage differential from working and being unemployed. This equation represents the labor supply equation in the Walrasian setting of the model. For the non-Walrasian setting, it is replaced by the equation from the union bargaining process described below. Equations (6)-(8), are standard Euler equations and describe the optimal path for capital, bonds and money holdings respectively.<sup>2</sup>

### 2.3 The Representative Finished Goods-Producing Firm

During each period  $t = 0, 1, 2, \dots$ , the representative finished goods-producing firm uses  $Y_t(i)$  units of each intermediate good  $i \in [0, 1]$ , purchased at nominal price  $P_t(i)$ , to produce  $Y_t$  units of the finished product at constant returns to scale technology

$$\left[ \int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}} \geq Y_t,$$

where  $\theta > 1$ . Hence, the finished goods-producing firm chooses  $Y_t(i)$  for all  $i \in [0, 1]$  to maximize its profits

$$P_t \left[ \int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}} - \int_0^1 P_t Y_t(i) di,$$

for all  $t = 0, 1, 2, \dots$ . the first order conditions for this problem are

$$Y_t(i) = \left[ \frac{P_t(i)}{P_t} \right]^{-\theta} Y_t$$

for all  $i \in [0, 1]$  and  $t = 0, 1, 2, \dots$

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<sup>2</sup>Note that in the presence of an interest rate rule, which is assumed below, the money demand equation simply determines the nominal level of money balances. For this reason, it can be safely ignored in the computation of the equilibrium.

Competition drives the finished goods-producing firm's profit to zero at the equilibrium. This zero profit condition implies that

$$P_t = \left[ \int_0^1 P_t(i)^{1-\theta} di \right]^{\frac{1}{1-\theta}}$$

for all  $t = 0, 1, 2, \dots$

## 2.4 The Representative Intermediate Goods-Producing Firm

During each period  $t = 0, 1, 2, \dots$ , the representative intermediate goods-producing firm hires  $n_t$  units of labor and  $K_t(i)$  units of capital from the representative household in order to produce  $Y_t(i)$  units of intermediate good  $i$  according to the constant return to scale technology

$$Y_t(i) = a_t \{ \alpha K_t(i)^\eta + [n_t(i)H_t]^\eta \}^{\frac{1}{\eta}} \quad (10)$$

where  $\eta < 1$ , and  $\alpha > 0$ . The aggregate technology shock,  $a_t$ , follows the autoregressive process

$$\ln(a_t) = \rho_a \ln(a_{t-1}) + \varepsilon_{at}$$

where  $\rho_a < 1$ . The zero-mean, serially uncorrelated innovation  $\varepsilon_{at}$  is normally distributed with standard deviation  $\sigma_a$ . The aggregate per-capita human capital stock  $H_t$  makes the production function labor augmented. The accumulation of human capital stock develops following the rule

$$H_{t+1} = H_t + \varphi n_t H_t,$$

in this way, the human capital accumulation evolves at the rate  $\gamma_t = 1 + \varphi n_t$ . This expression captures the positive externality of a higher level of aggregate per-capita human capital stock. Barro and Sala-i-Martin (1995, p. 42) show that a CES production function generates endogenous growth if the elasticity of substitution between labor and capital is greater than one. This is not the case of this set up.

Since the intermediate goods are not perfect substitutes in the production of the final goods, the intermediate goods-producing firm faces an imperfectly competitive market. During each period  $t = 0, 1, 2, \dots$  it sets the nominal price  $P_t(i)$  for its output, subject to satisfying the representative

finished goods-producing firm's demand. The intermediate goods-producing firm faces a quadratic adjustment cost of adjusting nominal prices, measured in terms of the finished goods and given by

$$\frac{\phi_p}{2} \left[ \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right]^2 Y_t,$$

where  $\phi_p > 0$  is the degree of adjustment cost and  $\pi$  is the steady state inflation rate.

The problem for the firm is to choose  $\{P_t(i), n_t(i), K_t(i)\}_{t=0}^{\infty}$  to maximize its total market value given by

$$E \sum_{t=0}^{\infty} \beta^t \Lambda_t \left[ \frac{F_t(i)}{P_t} \right],$$

where  $\beta^t \Lambda_t / P_t$  measures the marginal utility value to the representative household of an additional dollar in profits received during period  $t$  and where

$$\frac{F_t(i)}{P_t} = \left[ \frac{P_t(i)}{P_t} \right]^{1-\theta} Y_t - \frac{n_t(i)W_t}{P_t} - \frac{K_t(i)Q_t}{P_t} - \frac{\phi_p}{2} \left[ \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right] \frac{Y_t}{P_t}$$

for all  $t = 0, 1, 2, \dots$ . Letting  $\Xi_t$  the Lagrange multiplier on (10), the first order conditions for this problem are

$$\begin{aligned} 0 = & (1 - \theta)\Lambda_t \left[ \frac{P_t(i)}{P_t} \right]^{-\theta} \left( \frac{Y_t}{P_t} \right) + \theta \Xi_t \left[ \frac{P_t(i)}{P_t} \right]^{-(1+\theta)} \left( \frac{Y_t}{P_t} \right) \\ & - \phi_p \Lambda_t \left[ \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right] \left[ \frac{Y_t}{\pi P_{t-1}(i)} \right] + \beta \phi_p E_t \left\{ \Lambda_{t+1} \left[ \frac{P_{t+1}(i)}{\pi P_t(i)} - 1 \right] \left[ \frac{P_{t+1}(i)Y_{t+1}}{\pi P_t(i)^2} \right] \right\}, \end{aligned} \quad (11)$$

$$\frac{\Lambda_t}{P_t} W_t = \Xi_t a_t \{ \alpha K_t(i)^\eta + [n_t(i)H_t]^\eta \}^{\frac{1}{\eta}-1} [n_t(i)]^{\eta-1} H_t^\eta, \quad (12)$$

$$\frac{\Lambda_t}{P_t} Q_t = \Xi_t a_t \{ \alpha K_t(i)^\eta + [n_t(i)H_t]^\eta \}^{\frac{1}{\eta}-1} \alpha K_t(i)^{\eta-1}, \quad (13)$$

for all  $t = 0, 1, 2, \dots$ . These first order conditions are in line with the standard findings of the literature. In particular, (12) and (13) show that firm maximizes its profits when marginal cost of labor and capital equates marginal

revenues of these factors. Equation (11) highlights that the firm sets prices as a mark up on marginal cost, accounting for price adjustment costs. This equation relates the price level with the real variables of the economy. Note that log-linearizing equation (11) produces a New Keynesian forward looking Phillips Curve.

## 2.5 The Representative Trade Union

In the economy there are decentralized trade unions, named on  $j \in [0, 1]$ , and each intermediate goods-producing firm negotiates with a single union which is too small to influence the outcome of the market. Each household can supply its labor to only one firm and is a price taker in the capital market. By organizing in trade unions, the households can extract some producer surplus.

The representative union negotiates the wage rate on behalf of its members. The bargaining process is modelled as a static Stackelberg game in which the representative union (leader) chooses the wage rate and the representative intermediate goods-producing firm (follower) decides how much labor to employ given the established wage rate. This modelling strategy belongs to the same family of the commonly used “right to manage” models introduced by Nickell (1982). In the latter the employment decisions are unilateral decisions of management so that the wage setting can be established through the bargaining process between unions and firms. The choice of this formulation may be justified by transaction costs, and it also fits with the empirical observation that firms set labor demand unilaterally.

Due to the lack of consensus about a union’s utility function, as noted by Farber (1986), I assume, as in Maffezzoli (2001), that the representative union maximizes the average members’ wage bill in the form of the following objective function

$$n_t(i)W_t(j) + (1 - n_t(i))\bar{W}_t(j)$$

where  $\bar{W}_t$  is the unions’ reservation wage, taking the conditional labor demand of the intermediate goods-producing representative firm, and the representative household reservation wage as given. For the sake of simplicity, the union reservation wage  $\{\bar{W}_t\}_{t=0}^{\infty}$  is assumed to be exogenous in the form of a lump-sum transfer from the government.

As in Maffezzoli (2001), the representative union maximizes the real discounted labor income of its members

$$E \sum_{t=0}^{\infty} \frac{\beta^t}{P^t} [n_t(i)W_t(j) + (1 - n_t(i))\bar{W}_t(j)]$$

with respect to the wage rate  $\{W(j)\}_{t=0}^{\infty}$ , subject to the conditional labor demand (12). The first order conditions for this problem are

$$\left(\frac{a_t n_t(i) H_t}{Y_t}\right)^\eta \left[ (1 - \eta) \left(\frac{a_t n_t(i) H_t}{Y_t}\right)^\eta + \eta \right] = \frac{\Lambda_t n_t(i)}{\Xi_t Y_t} \bar{W}_t(j). \quad (14)$$

This non-linear equation defines the wage setting rule for the economy after the union bargaining process has been carried out. Unlike the representative household labor supply (5), this equation accounts for optimal supply side decisions in the labor market. Equation (14) together with the labor demand (12) determines the equilibrium wage. Negotiations lead to a higher wage than in the case of perfect market competition so that the labor market exhibits equilibrium unemployment. Note that a novel feature of equation (14) is the presence of both household and firm Lagrange multipliers.

## 2.6 The Monetary Authority

The monetary authority conducts monetary policy through changes of the nominal interest rate  $r_t$  in response to deviations of lagged output  $Y_{t-1}$ , lagged inflation  $\pi_{t-1}$ , from their steady state levels  $y$  and  $\pi$  following the Taylor-type rule

$$\ln\left(\frac{r_t}{r}\right) = \rho_r \ln\left(\frac{r_{t-1}}{r}\right) + (1 - \rho_r) \left[ \rho_y \ln\left(\frac{Y_{t-1}}{Y}\right) + \rho_\pi \ln\left(\frac{\pi_{t-1}}{\pi}\right) \right] + \varepsilon_{rt} \quad (15)$$

where  $r$  is the steady state value of the nominal interest rate,  $r_{t-1}$  is the lagged nominal interest rate, and  $\varepsilon_{rt}$  is a normally distributed serially uncorrelated innovation with zero mean and standard deviation  $\sigma_r$ . As advocated by Carlstrom and Fuerst (2000), I employ lagged values for output and inflation because it is consistent with the information set of the monetary authority at time  $t$ , and it guarantees determinacy.

Parameter  $\rho_R$  expresses the degree of interest rate smoothing. If  $\rho_\pi$  is larger than one the monetary authority policy is to stabilize inflation; the same holds for output if  $\rho_y$  is larger than zero. As pointed out in Clarida et al. (1998), this modelling strategy for the monetary authority incorporates consistent monetary policy actions for the United States as well as European countries.

## 2.7 Symmetric Equilibria

The unionized and non-unionized equilibria differ in the way in which the labor supply is derived. In the absence of the representative union, labor supply comes from the household maximization process for  $\{n_t\}_{t=0}^\infty$ . Instead, in the presence of a representative union the labor supply depends upon the wage rate  $\{W_t(j)\}_{t=0}^\infty$  which is from the bargaining between the union and the firm. Common to the two settings is the following:

In a symmetric dynamic equilibrium all intermediate goods-producing firms and trade unions make identical decisions, so that  $n_t(i) = n_t$ ,  $y_t(i) = y_t$ ,  $P_t(i) = P_t$ ,  $F_t(i) = F_t$ ,  $W_t(j) = W_t$ , and  $\overline{W}_t(j) = \overline{W}_t$  for all  $i \in [0, 1]$ ,  $j \in [0, 1]$ , and  $t = 0, 1, 2, \dots$ . The equilibrium is defined as a sequence of functions for relative prices  $\{W_t, Q_t, r_t, P_t\}_{t=0}^\infty$ , an infinite dimensional allocation for the firm  $\{K_t^d, n_t^d, Y_t\}_{t=0}^\infty$ , an infinite dimensional allocation for the household  $\{C_t, I_t, K_t^s, B_t, M_t\}_{t=0}^\infty$ , a sequence of human capital stock  $\{H_t\}_{t=0}^\infty$ , and a sequence of government policy  $\{B_t, M_t\}_{t=0}^\infty$  such that:

- the allocation  $\{K_t^d, n_t^d, Y_t, P_t, F_t\}_{t=0}^\infty$  solves the firm problem,
- the allocation  $\{C_t, I_t, K_{t+1}^s, B_t, M_t\}_{t=0}^\infty$  solves the representative household problem,
- market clearing on all markets  $K_t^d = K_t^s$ ,  $n_t^d = n_t^s$ ,  $Y_t = C_t + I_t + \frac{\phi_P}{2} \left( \frac{P_t(i)}{P_{t-1}(i)} - \pi \right)^2 Y_t$ , and the human capital accumulation holds,
- the market clearing conditions  $T_t = M_t - M_{t-1} - (1 - n_t)\overline{W}_t$  and  $B_t = B_{t-1} = 0$  must hold for all  $t = 0, 1, 2, \dots$
- monetary policy rule holds for all  $t = 0, 1, 2, \dots$

The system is approximated by log-linearizing its equations around the stationary steady state. In this way, I attain a linear dynamic system which describes the path of the endogenous variables' relative deviations from their steady state value accounting for exogenous shocks in the economy. This

latter method is referred as the state-space approach and the Klein (2000) technique, which builds upon the seminal paper by Blanchard and Kahn (1980), allows writing the system of linearized difference equations as

$$\mathbf{s}_t = \mathbf{\Psi}\mathbf{s}_{t-1} + \mathbf{\Omega}\boldsymbol{\varepsilon}_t,$$

and

$$\mathbf{f}_t = \mathbf{U}\mathbf{s}_t.$$

The vector  $\mathbf{s}_t$  contains the model state variables which includes the current values of the capital stock  $k_t = K_t/H_t$ , the lagged interest rate  $r_{t-1}$ , the lagged values of output  $y_{t-1} = Y_{t-1}/H_{t-1}$ , lagged inflation  $\pi_{t-1}$ , the lagged values of firms' profit  $f_{t-1} = F_{t-1}/P_{t-1}H_{t-1}$ . The vector  $\mathbf{f}_t$  includes the model flow variables which are current consumption  $c_t = C_t/H_t$ , employment rate  $n_t$ , the multipliers  $\lambda_t = \Lambda_t H_t^\mu$ , and  $\xi_t = \Xi_t H_t^\mu$ , investments  $i_t = I_t/H_t$ , the human capital accumulation  $\gamma_t = H_{t+1}/H_t$ , and the real factor prices  $w_t = W_t/P_t H_t$ , and  $q_t = Q_t/P_t$ . Finally, the vector  $\boldsymbol{\varepsilon}_t$  contains the innovation shocks  $\{\varepsilon_{at}, \varepsilon_{rt}\}$  which are assumed to be serially and mutually uncorrelated.<sup>3</sup> With this formulation, the elements of the matrices  $\mathbf{\Psi}$ ,  $\mathbf{\Omega}$ , and  $\mathbf{U}$  all depend upon parameters expressing private agents' tastes and technologies and parameters of the monetary authority rule.

### 3 Model Calibration

The variables of the model are calibrated using data from the euro area and structural parameters are in line with other studies as Smets and Wouters (2003), Galí, Gertler, and Lopez-Salido (2002) which apply DSGE models to the European economy. I calibrate the model on quarterly frequencies and the value for each parameter is reported below.

The model accounts for a trend in the variables through human capital accumulation which captures the labor augment technological progress expressed by the term  $g = 1 + \varphi n$ . This setup implies that the variables grow at the gross rate of human capital accumulation along a balanced growth path.

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<sup>3</sup>More formally, the covariance matrix of the innovation shocks can be expressed as  $E(\boldsymbol{\varepsilon}_t, \boldsymbol{\varepsilon}_t') = \begin{bmatrix} \sigma_A^2 & 0 \\ 0 & \sigma_R^2 \end{bmatrix}$ .

Based on the fact that the annual growth rate for the euro area countries is approximately 2.26 percent, I set the parameter  $g$  equal to 1.0056.

I compute the steady state values for inflation,  $\pi$ , using the OECD *Economic Outlook* data set for countries composing the euro area. I set the value for steady state gross inflation equal to 1.04 on an annual basis so that we can use a calibration value of 1.01.

As noted, some structural parameters are borrowed from values commonly used in the literature. I take the calibrated value for the technology shock from Smets and Wouters (2003), who estimate a DSGE model for the euro area using Bayesian techniques. Hence, I set serial correlation and standard deviation for technology shock,  $\rho_A$  and  $\sigma_A$ , equal to 0.8674 and 0.0056 respectively. The value for the variance of the policy shock is in line with Clarida et al. (1998), who estimate a similar specification for this shock with the generalized method of moments. Its standard deviation,  $\sigma_\varepsilon$ , equals 0.0018.

I choose parameters for the employment rate,  $n$ , growth rate,  $\gamma$ , investment share of output,  $i/y$ , and capital share of output,  $k/y$ , in order to match with the euro area data. I assign the following values:  $n = 61\%$ ,  $\gamma = 0.48\%$ ,  $i/y = 21\%$ , and  $k/y = 12.73$ . These values imply a technological parameter,  $\alpha$ , equals to 1.15, a depreciation rate,  $\delta$ , of 0.02, and a scale parameter,  $\varphi$ , of 0.0082. I set the parameter  $\theta$ , which measures the degree of market power owned by the representative goods-producing firm, equal to 6 following Rotemberg and Woodford (1992). Since the steady state value of  $\theta$  determines the mark-up of prices over marginal costs, this value implies a mark-up of 20% which is reasonable for the European economy. I set the discount factor,  $\beta$ , equal to 0.99, which implies an annual steady state real interest rate of 4% for the euro area as in Smets and Wouters (2003). I set the elasticity of intertemporal substitution,  $\mu$ , equal to 2 as it is King and Rebelo (2000). I set the substitution parameter,  $\eta$ , equal to -0.43 as it was estimated for the European economy in Pissarides (1998). It implies an elasticity of substitution between physical and human capital equal to 0.7, which is a reasonable value for the euro area. On this parameter, I carried out an extensive sensitivity analyses and I established that it does not affect the quality of the results. The value for the reservation wage  $\bar{W}$  is calibrated using equation (14) and matching the value for the employment rate  $n$ .

I set the parameters of the monetary policy rule using Smets and Wouters (2003) and are in line with the studies in Taylor (1999) and Woodford (2001). With this respect, values for the interest rate response to inflation,  $\rho_\pi$ , interest

rate response to output,  $\rho_\pi$ , and the degree of interest rate smoothing,  $\rho_r$ , take values close to the so called Taylor-type rule for monetary policy. In particular, the interest rate response to inflation,  $\rho_\pi$ , is set equal to 1.658, the interest rate response to output,  $\rho_y$ , equals 0.148, and the degree of interest rate smoothing,  $\rho_r$ , is set equal to 0.9. As specified in Carlstrom and Fuerst (2000), this setting assures that the model does not suffer indeterminacy or explosive results.

Due to the novel feature of quadratic adjustment costs that represent rigidities in the economy, exact number for these parameters for the euro area are not available in the literature. For this reason, I follow the prescription of Ireland (2000) who suggest a high level of price and capital adjustment costs. With this in mind, the price adjustment costs parameter,  $\phi_p$ , is set equal to 30, and the parameter representing the capital adjustment costs,  $\phi_k$ , equals 40.

## 4 Findings

This section points out the findings from the model. The analysis compares the union economy model with a baseline sticky price model. Both demand and supply shocks are considered. This section is divided into two parts: first, I analyze the model's prediction and, second, I simulate the model in order to test its ability to capture some Euro area business cycle facts.

### 4.1 Model Predictions

Figures 2 and 3 show the responses of monetary and productivity shocks respectively. For each variable, I plot its response to shocks in the union model (straight line) and the baseline sticky price model (dashed line).

The qualitative response of the variables in the two models is similar for both supply and demand shocks. Therefore, the introduction of a union bargaining process does not affect the nature of the baseline dynamics. However, from a quantitative perspective, the two models differ in some key aspects.

First, a general feature of the union model is its ability to deliver more persistence in the variables after demand or supply shocks hit the economy. In both models a productivity shock causes output, capital, and consumption to rise, and the rental rate of capital, the nominal interest rate, employment, and inflation to fall. These reactions are standard in the literature, except for

employment which will be explained below. For all the variables, the degree of persistence is higher in the union case. When a contractionary monetary shock hits the economy, the nominal interest rate immediately rises, causing real variables and inflation to fall with, again, a higher degree of persistence in the case of an economy with unions.

To understand the generation of persistence, I limit the analysis to the case of monetary shocks but the analysis applies to the case of productivity shocks along the same lines. First, it must be noticed that a monetary shock is a white noise process so that its effect vanishes after one period. Hence, the dynamics of the variables in later periods are entirely independent from the influences of this exogenous shock. For all the impulses, except for the factors' remuneration, the initial jump in the variables is higher for the unionized economy and the degree of persistence is more pronounced. The higher initial change may be explained by the different effect that a shock has on the household's Lagrange multiplier. As already mentioned, the Lagrange multiplier represents both the marginal utility of consumption for the representative household as well as the shadow value of installed physical capital. In this model, as is standard in the literature, both consumption and capital are negatively related to their marginal values. Therefore, an exogenous shock is able to influence both the demand and supply sides of the economy through its effect on the Lagrange multiplier. In fact, since a contractionary monetary policy shock has a higher positive impact on the multiplier in the unionized economy, the change in consumption and capital is more pronounced and this leads to a higher initial change in the other real variables. Once the shock occurs and the variables react, the speed of convergence along the original steady state is lower for the unionized economy. This feature is generated by the lower volatility of wages in the economy with the representative union as shown in Figure 2. The presence of the union generates "real rigidities" in the economy. Lower wage volatility causes employment to adjust slowly along the original balanced growth path and through this channel the speed of convergence of the other real variables decreases. As mentioned, the persistence dynamics are similar for both supply and demand shocks. Initially, variables in the unionized economy respond with a higher magnitude, and then converge more slowly to the original steady state. To sum up, for both shocks, the key features that explain the different reaction and persistence are the effect on the household's Lagrange multiplier and the distinct wage volatility in the aftermath of a shock for the two economies.

The inability of sticky price models to replicate the low elasticity of in-

flation to monetary shocks has been debated by several contributions as Bernanke and Gertler (1995), Christiano, Eichenbaum, and Evans (1997), and Bernanke and Mihov (1998). The union model improves the replication over this dimension. In fact, it can generate a decrease in the elasticity of inflation to monetary policy compared with the baseline sticky price model. Responses of real marginal cost to a contractionary monetary policy are shown in Figure 4. A comparison of Figure 2 and Figure 4 shows that the sensitivity of real marginal cost to output is lower for the unionized economy. In fact, in the aftermath of a contractionary monetary policy shock, output falls approximately 2.2% in the baseline economy and 2.5% in the unionized economy; in contrast, the associated variation in real marginal costs is a decline of roughly 8% in the baseline economy and 4% in the unionized economy. The mechanism at work which generates this result is the reduced sensitivity of marginal costs to variations in aggregate output. This implies that the same shock, which changes output to a small extent in both settings, generates a smaller decrease in the level of marginal costs for the unionized economy. This means that smaller variation in real marginal costs leads firms to adjust prices by a smaller extent. This amplifies the sluggishness of the aggregate price level in response to changes in aggregate demand and, therefore, reduces inflation volatility. Quantitatively, the inflation peak is about 1.5% in the union economy and 2.1% in the baseline model. This finding is in line with European empirical evidence such as Fehr and Goette (2004).

Another important feature of this model is its ability to generate a negative correlation between productivity and employment. This feature does not need the union presence; the baseline sticky price model is also able to reproduce it. This fact has been observed empirically by Shea (1998), Basu, Fernald and Kimball (2002), Galì (1999), and Francis and Ramey (2003), and is in stark contrast with the intuitive prediction of neoclassical models. The debate on this topic is far from being closed, as pointed out in Christiano, Eichenbaum, and Vigfusson (2003). In this setup, as in Galì (1999), this feature arises because technology shocks do not have an exhaustive effect on aggregate demand. For this reason each firm does not change the level of output fully in the same period as when the shock is realized. Since productivity increases, the labor input required to produce a certain level of output decreases.

## 4.2 Model Simulations

The series for the variables are taken from Fagan, Henry, and Mestre (2001) and they are drawn from the European Central Bank data base. The data are quarterly from 1980:1 through 1998:4. Output is measured by real GDP, consumption is measured by private consumption, investment is measured by gross investment, employment is measured by standard units of labor, inflation is measured by changes in the GDP deflator, and the interest rate is measured by the short term interest rate. All data, except for the interest rate, are seasonally adjusted. The real variables are expressed in per-capita terms by dividing by the total population between ages of 15 and 64. All variables, except inflation and the interest rate, are transformed into logarithms. All the series are H-P filtered so that only the cyclical component remains.

The state space representation of the model is used to generate realization of the model by simulating a system of difference equations in  $\mathbf{s}_t$  and  $\mathbf{f}_t$  for  $T$  periods by generating a  $(T \times 1)$  dimensional series of Gaussian white noise innovations,  $\boldsymbol{\varepsilon}_t$ , where  $T$  is the number of simulated periods that equals the number of periods in the observed time series of the economy. The simulated statistics are based on a set of 1000 simulations over a 76-quarter horizon, as the size of the sample considered.

Tables 2 through 4 list business cycle statistics for the Euro area macro-economic variables output, consumption, investment, employment, inflation, and interest rates and compare them with the simulated series for the union (U) and baseline sticky price (SP) models. The statistics reproduced are the standard deviation, the relative volatility (the ratio of the standard deviation of each variable and the standard deviation of output), and the correlation coefficient with output.

Table 2 shows the standard deviations for the variables under investigation. A comparison of the union and the baseline models shows that the presence of a representative union produces higher volatility for the real variables, and lower volatility for inflation. The union model is better able to replicate the variance of inflation, the interest rate, output, and consumption. The union model underperforms in the replication of the variance of investment and employment.

Table 3 compares the relative standard deviation of the variables with respect to output so that these statistics can be interpreted as the volatility of the variables. From model's simulations we notice that in the union model

the volatility of the nominal variables is lower and the volatility of the real variables is higher, except for consumption. A comparison with the data shows that the union model matches the European economy better over all. The only mismatch is given by the interest rate for which the actual economy statistic is 0.75, whereas the union and baseline models produce values of 0.34 and 0.38. Nonetheless, it must be noticed that the difference for this variable in the simulated models is small.

Table 4 presents the correlations of the variables with output. As for the previous measure, the volatility of the correlations is lower for the nominal variables although the reverse relation does not hold for all the real variables. A shortcoming of both models is their inability to replicate the correlation of the interest rate with output. As Boivin and Giannoni (2003) point out, this may be due to the time span considered for the monetary policy rule. Nonetheless, the union model generates statistics closer to the ones in the actual economy.

As a further exercise, I explore whether the model simulations produce more persistence in the variables for the union model, as the theoretical analysis suggest. As in Maffezzoli (2001), I compare the correlations of supply and demand shocks with lags and leads of the simulated series for both union and baseline models. Tables 5 and 6 reproduce these statistics for the productivity and policy shocks respectively. For both shocks, the correlation in lead periods is higher in the union model, which suggests that the non-Walrasian setting delivers a higher degree of persistence.

The overall lesson from these results is that the union model is better able than the standard sticky price model to replicate several key aspects of the European business cycle.

## 5 Conclusions

This paper combines equilibrium unemployment generated through a simple union bargaining process into an otherwise standard New Keynesian monetary model. The combination of a non-Walrasian labor market with general equilibrium models has been recently introduced in the New Keynesian literature through efficiency wage and search models, and has been used to study business cycles' dynamics and shocks' propagation. This paper is the first attempt to introduce a union bargaining process to study interactions between both supply and demand shocks and the business cycle in a monetary

sticky price model.

The introduction of union bargaining produces two main results. First, variables' persistence in the aftermath of supply and demand shocks increases. The presence of the representative union in the economy generates real rigidities because of the lower wage volatility relative to a perfect competitive labor market. This feature produces an endogenous mechanism which increases variables' persistence. Second, inflation becomes less volatile. The sensitivity of real marginal costs to output is lower in the unionized economy so that firms adjust prices by a smaller extent compared to the competitive labor market. The model is also able to reproduce the negative correlation between productivity shocks and employment that is observed in the data. Model simulations show the union model is superior to the standard sticky price model in replicating European business cycles.

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## 6 Appendix

This Appendix shows how to derive the representative household's utility function as it appears in equation (1). King, Plosser, and Rebelo (1988) show that a utility function in consumption and leisure can be expressed as

$$U_t = \frac{1}{1-\mu} [C_t v(n_t)]^{1-\mu} - 1, \quad (\text{A.1})$$

where the function  $v(n_t)$  satisfies at some regularity conditions.<sup>4</sup> The marginal utility of consumption of (A.1) can be expressed as

$$U_1(C_t, n_t, \frac{M_t}{P_t}) = C_t^{-\mu} v(n_t)^{1-\mu}.$$

Assuming perfect risk sharing, the marginal utility of consumption for employed ( $e$ ) and unemployed ( $u$ ) members of the household is the same. Therefore, the following holds

$$C_{et}^{-\mu} v_e(n_t)^{1-\mu} = C_{ut}^{-\mu} v_u(n_t)^{1-\mu} \quad (\text{A.2})$$

The average consumption for the representative household can be written as

$$C_t = n_t C_{et} + (1 - n_t) C_{ut}. \quad (\text{A.3})$$

Using equation (A.2), expression (A.3) can be written as

$$C_{et} = \frac{C_t}{n_t + (1 - n_t) \frac{v_u(n_t)}{v_e(n_t)}}. \quad (\text{A.4})$$

The utility for the representative household can be written as

$$\begin{aligned} & n_t U(C_{et}, n_t, \frac{M_t}{P_t}) + (1 - n_t) U(C_{ut}, 1 - n_t, \frac{M_t}{P_t}) \\ &= [C_{et} v_e(n_t)]^{1-\mu} \left\{ n_t + (1 - n_t) \left[ \frac{C_{ut} v_u(n_t)}{C_{et} v_e(n_t)} \right] \right\} + \kappa_m \frac{M_t}{P_t}. \end{aligned} \quad (\text{A.5})$$

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<sup>4</sup>Namely, from King, Plosser, and Rebelo (1988),  $v(n)$  is twice continuously differentiable and, since  $\mu > 1$ ,  $v(n)$  is decreasing and convex. In addition, to assure the overall concavity of  $U$ ,  $-\mu v(n) v_{nn}(n) > (1 - 2\mu) [v_n(n)]^2$ .

Equations (A.2) and (A.4) into (A.5) yield

$$U(C_t, n_t, \frac{M_t}{P_t}) = v_e(n_t)^{1-\mu} C_t^{1-\mu} \left\{ n_t + (1 - n_t) \left[ \frac{C_{ut}v_u(n_t)}{C_{et}v_e(n_t)} \right]^{\frac{1-\mu}{\mu}} \right\}^\mu + \kappa_m \frac{M_t}{P_t}$$

which is equivalent to equation (1) in the paper once the irrelevant term  $v_e(n_t)^{1-\mu}$  is dropped and the function is rescaled for the constant -1.

**Table 1. Union Density and Bargaining Coverage Rates**

Country	Union Density			Bargaining Coverage		
	1980	1990	1994	1980	1990	1994
United States	22	16	16	26	18	18
Euro Area	49.7	42.9	44.3	82.6	81.3	82.3

Source: OECD, Employment Outlook (1997) and computations from the author.

**Table 2. Standard Deviation**

Variable	EU-11	Union	Sticky Price
Output	1.31	1.28	1.05
Consumption	1.15	0.80	0.65
Investment	2.76	3.61	3.06
Employment	1.16	1.84	1.53
Inflation	0.56	0.84	0.97
Interest Rate	0.98	0.43	0.40

Notes: Observed (EU-11) and simulated (from union and sticky price models) standard deviations. The observed statistics are based on seasonally adjusted quarterly data from Fagan, Henry, and Mestre (2001) from 1980:1 to 1998:4. The real variables are expressed in per-capita terms by dividing by the total population, age between 15 and 64. Variables, except inflation, and interest rate, are transformed in logarithms. All the series are H-P filtered so that only the cyclical component remains. The simulated business cycle statistics are based on 1000 simulations over 76 quarter horizon and are H-P filtered for comparison purposes. Simulated figures are averages across simulations.

**Table 3. Relative Standard Deviation**

<b>Variable</b>	<b>EU-11</b>	<b>Union</b>	<b>Sticky Price</b>
Output	1.00	1.00	1.00
Consumption	0.88	0.63	0.62
Investment	2.11	2.84	2.92
Employment	0.55	1.45	1.48
Inflation	0.43	0.67	0.94
Interest Rate	0.75	0.34	0.38

Notes: Observed (EU-11) and simulated (from union and sticky price models) relative standard deviations respect to output. For further information, see notes to Table 2.

**Table 4. Correlation with Output**

<b>Variable</b>	<b>EU-11</b>	<b>Union</b>	<b>Sticky Price</b>
Output	1.00	1.00	1.00
Consumption	0.91	0.89	0.88
Investment	0.85	0.93	0.93
Employment	0.92	0.74	0.61
Inflation	0.26	0.31	0.52
Interest Rate	0.17	-0.44	-0.36

Notes: Observed (EU-11) and simulated (from union and sticky price models) correlation with output. For further information, see notes to Table 2.

Table 5. Correlations of Simulated Series with Supply Shocks

	Output		Consumption		Investment		Employment		Inflation		Inter.Rate	
	U	SP	U	SP	U	SP	U	SP	U	SP	U	SP
t+3	0.30	0.23	0.26	0.22	0.28	0.20	0.24	0.13	0.11	0.10	-0.33	-0.26
t+2	0.42	0.37	0.44	0.41	0.34	0.28	0.22	0.09	0.00	0.04	-0.32	-0.28
t+1	0.53	0.50	0.65	0.64	0.34	0.31	0.12	-0.02	-0.22	-0.09	-0.16	-0.16
t	0.54	0.56	0.85	0.88	0.20	0.22	-0.16	-0.30	-0.62	-0.40	-0.06	-0.07
t-1	0.29	0.32	0.48	0.52	0.08	0.11	-0.15	-0.22	-0.41	-0.28	0.02	0.00
t-2	0.10	0.14	0.21	0.26	0.00	0.03	-0.13	-0.15	-0.25	-0.18	0.07	0.04
t-3	-0.02	0.02	0.02	0.07	-0.06	-0.03	-0.12	-0.10	-0.13	-0.10	0.10	0.06

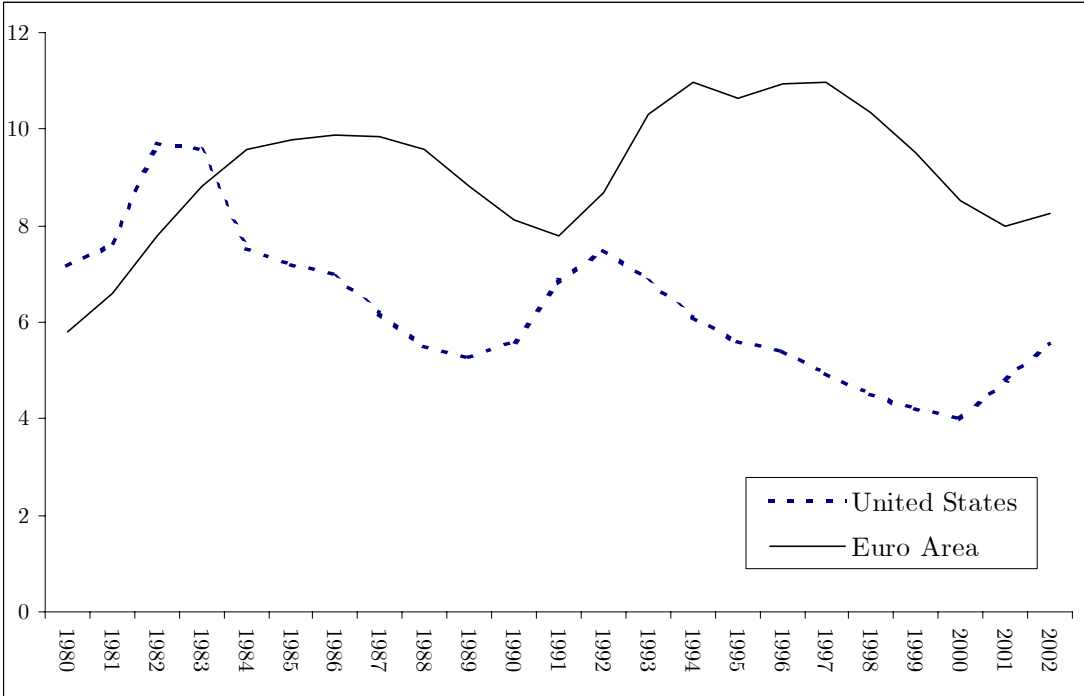
Notes: Correlations of different leads and lags of simulated series from union (U) and sticky price (SP) models with supply shocks. All series have been H-P filtered; all figures are averaged across simulations.

Table 6. Correlations of Simulated Series with Demand Shocks

	Output		Consumption		Investment		Employment		Inflation		Inter.Rate	
	U	SP	U	SP	U	SP	U	SP	U	SP	U	SP
t+3	-0.03	0.01	-0.03	-0.01	-0.02	0.02	-0.03	0.02	-0.01	0.02	0.15	0.08
t+2	-0.13	-0.07	-0.09	-0.05	-0.14	-0.08	-0.15	-0.08	-0.11	-0.07	0.36	0.32
t+1	-0.30	-0.27	-0.18	-0.15	-0.36	-0.31	-0.36	-0.31	-0.29	-0.30	0.74	0.83
t	-0.62	-0.68	-0.35	-0.37	-0.75	-0.82	-0.75	-0.81	-0.62	-0.78	-0.18	-0.15
t-1	0.16	0.13	0.13	0.09	0.17	0.15	0.18	0.14	0.12	0.13	-0.15	-0.13
t-2	0.14	0.12	0.10	0.08	0.15	0.13	0.15	0.12	0.10	0.11	-0.13	-0.11
t-3	0.12	0.10	0.08	0.06	0.13	0.11	0.14	0.10	0.10	0.10	-0.11	-0.10

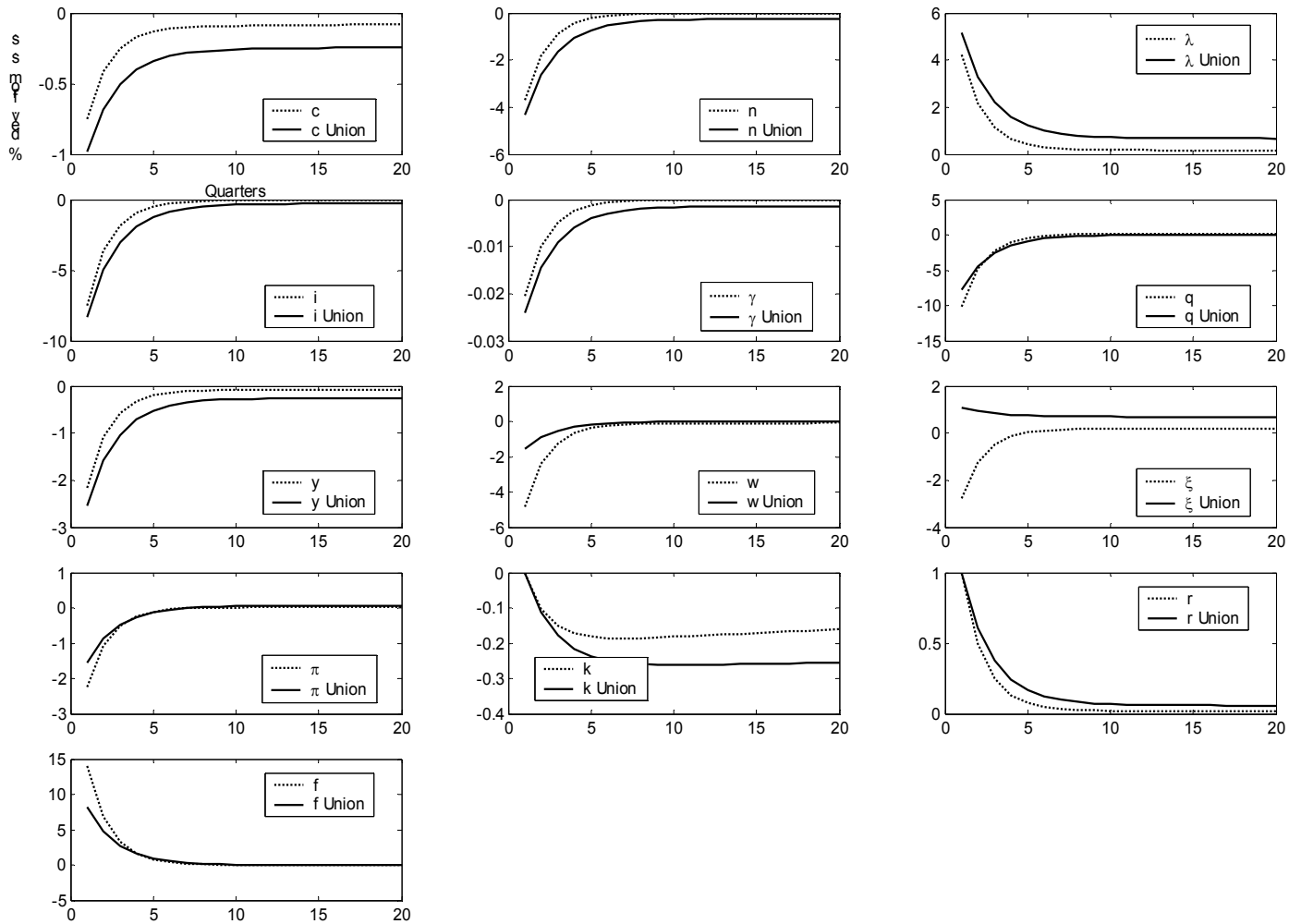
Notes: Correlations of different leads and lags of simulated series from union (U) and sticky price (SP) models with demand shocks. All series have been H-P filtered; all figures are averaged across simulations.

Figure 1. Unemployment Rates in the Euro Area and the United States



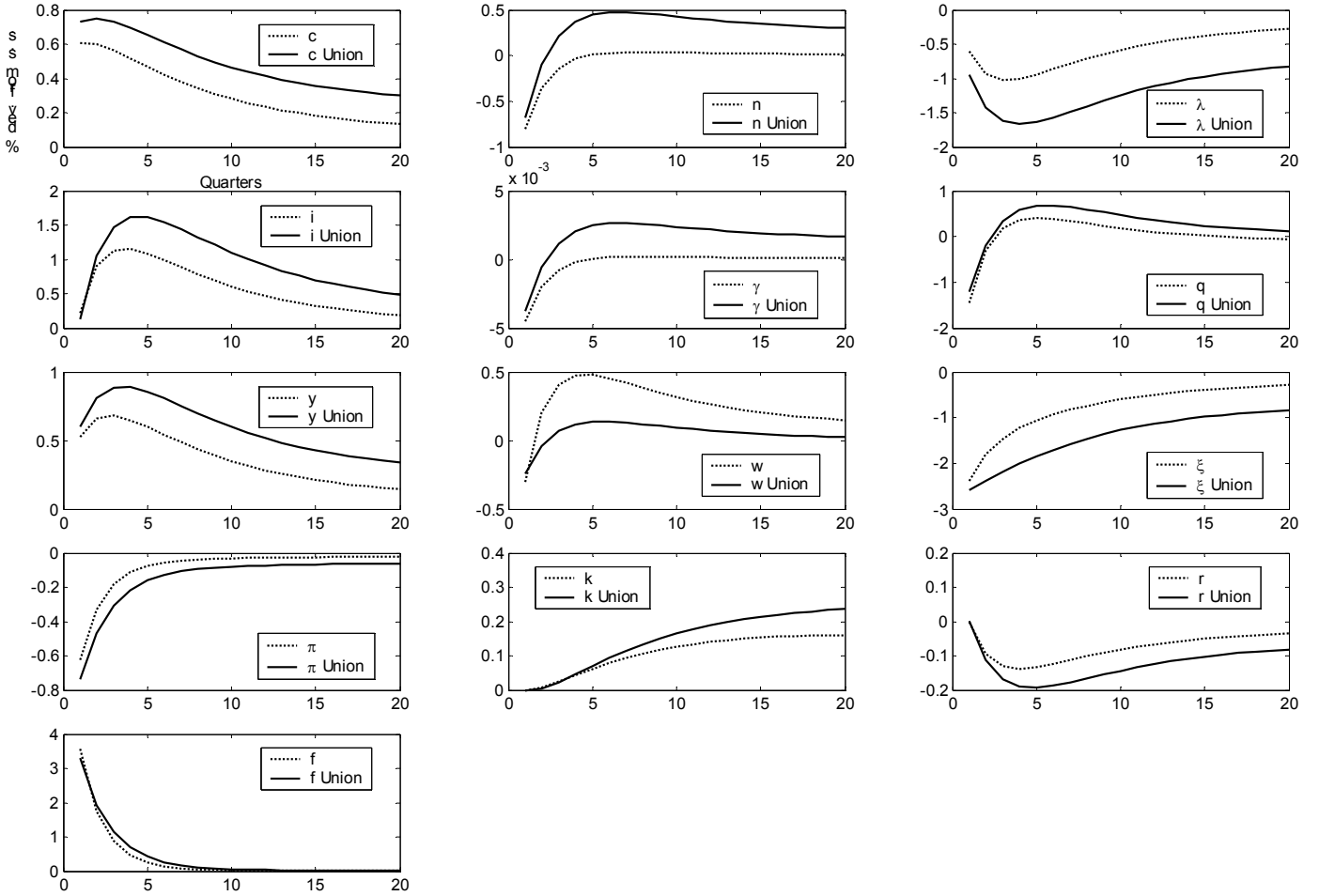
The panel shows unemployment rate for the euro area (straight line) and the United States (dashed line). Source: OECD, Outlook (2002).

Figure 2. Impulse Response Functions to a Monetary Policy Shock



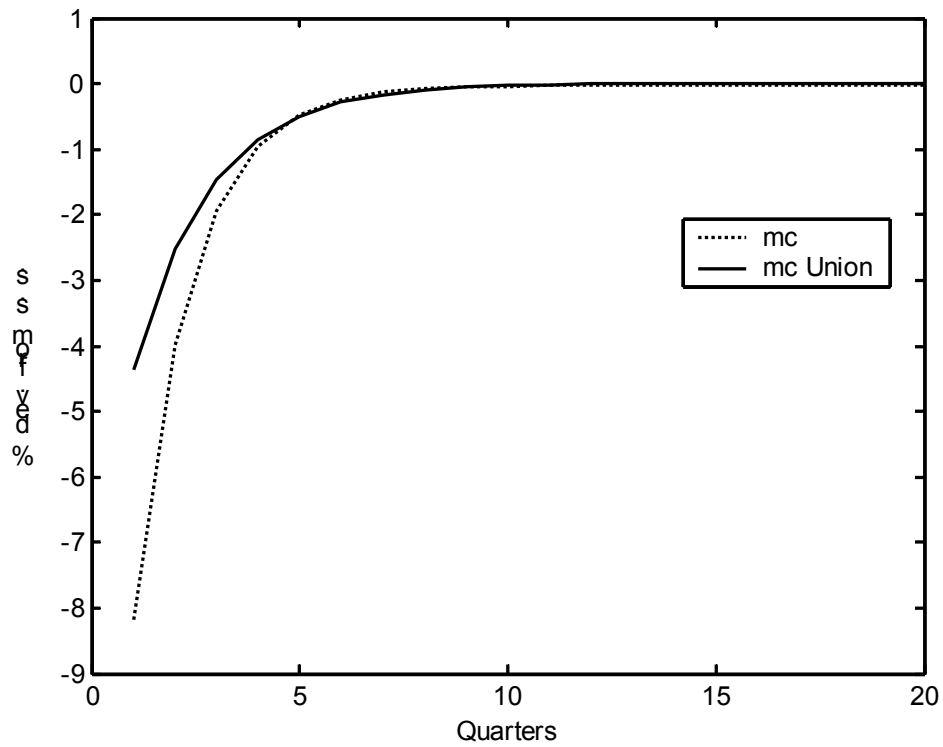
Each panel shows the percentage-point response of the union (straight line) and baseline (dashed line) models' variables to one standard deviation monetary policy shock.

Figure 3. Impulse Response Functions to a Productivity Shock



Each panel shows the percentage-point response of the union (straight line) and baseline (dashed line) models' variables to one standard deviation productivity shock.

Figure 4. Real Marginal Costs



The panel shows the percentage-point response of the union (straight line) and baseline (dashed line) models' variable to one standard deviation shock.