BANCO DE PORTUGAL

Economic Research Department

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Nuno Alves

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Please address correspondence to Nuno Alves, Economic Research Department, Banco de Portugal, Av. Almirante Reis nº. 71, 1150-165 Lisboa, Portugal;
Tel: 351 213130936; Fax: 351 213107805; email: njalves@bportugal.pt

The Monetary Transmission in the US and the Euro Area: Common Features and Common Frictions*

Nuno Alves†

Banco de Portugal

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Abstract

This paper compares the monetary transmission mechanism in the US and the 3 largest economies of the euro area. We start by showing that the dynamic responses to a monetary policy shock in each of the four countries are analogous. A model with a small set of frictions that broadly accounts for these responses is then presented. The model incorporates nominal wage contracts, habits for preferences in consumption and the staggered adjustment of households' portfolios.

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†Correspondence: Nuno Alves, Economic Research Department (DEE), Banco de Portugal, R. Francisco Ribeiro, n. 2, 1150-165 Lisboa, Portugal; Tel.:351-213130936; E-mail: njalves@bportugal.pt

A common characterization of the monetary transmission mechanism in the US and the main euro area countries is therefore attainable.

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1 Introduction

The construction of a reliable monetary business cycle model has been at center stage in macroeconomics for long. This focus has been nurtured by two complementary motivations. On the one hand, the need by central banks to have a reliable description of the monetary transmission mechanism in order to take educated policy decisions. On the other, a consensus has emerged concerning the effects of monetary policy shocks in the economy (see Christiano, Eichenbaum and Evans, 1999). Following the insights of Lucas (1980), theoretical models that are able to replicate these established facts are thus best fit to be used as laboratories for other interesting economic experiments.

These motivations led to a rapidly expanding literature aimed at both describing empirically the monetary transmission mechanism and uncovering the appropriate set of frictions that should be incorporated in monetary general equilibrium models. A seminal recent contribution in this line is Christiano, Eichenbaum and Evans (2004)[1]. These authors show that a general equilibrium model with a rich set of nominal and real frictions is able to replicate the main features of the transmission mechanism in the US.

This paper builds on this literature and aims to compare and characterize the monetary transmission mechanism in the US and the 3 largest euro area economies. We start by presenting a set of responses of macroeconomic variables to a monetary policy shock in each country. The identification scheme is the same in all cases. The estimates are shown to be close not only from a qualitatively point of view but also quantitatively. This observation suggests that a common set of frictions may explain the monetary transmission mechanism in the US and the euro area.

To investigate this possibility, we construct a general equilibrium model that incorporates several features that are arguably shared by the US and the 3 major euro area economies. These features are nominal wage contracts, habits for preferences in consumption, a staggered adjustment of households' portfolios, a small degree of price-setting rigidity by firms, and the financing of working capital with financial intermediaries. We show that a single calibrated version of the model succeeds at broadly mimicking the empirical observations after a monetary policy shock in all countries.

The main conclusions of our analysis are as follows. First, there are many features of the monetary transmission mechanism that are shared between the US, Germany, France and Italy. In particular, after a monetary injection both the central bank's intervention rate and velocity fall for about a year. Further, inflation first falls or stays flat and only rises significantly after about a year of the monetary injection. The main heterogeneity across countries lies in the behavior of employment, which rises significantly in only a subset of cases and at different paces.

Second, the data reveals a significant persistence in the response of nominal and real variables after a monetary policy shock. To account for this pattern, the theoretical model has to incorporate features that generate strong endogenous propagation mechanisms. Sometimes, these features are firmly anchored on observation. In our model, this is the case of habits in preferences for consumption or of staggered wage renegotiations, which is an overriding feature in all countries under study. In other cases, modelers have less firm ground on which to base their choices. In our model, this is for example the case of the response of cash-balances to changes in the interest rate. We show that to account for both the observed low short-run and high long-run interest semi-elasticities of money demand, the model requires the staggering of portfolio decisions.

Third, the model is able to account for an inertial response of inflation after a monetary policy shock even with perfectly flexible prices (this is also emphasized in Christiano et al., 2004). The sluggishness of the inflation rate is related to the inertial behavior of the firms' marginal costs. The model also reproduces the so-called "price puzzle" after a monetary injection. This is associated to the fall in the interest rate, which is reflected in the firms' marginal costs through their financing of the wage bill. Finally, the model mimics quite accurately the fall in money velocity after a monetary injection. This is in line with the significant fall in interest rates also captured by the model.

The outline of the paper is as follows. Section 2 presents the dynamic responses of the US, Germany, France and Italy to a monetary policy shock in each country. Section 3 describes the theoretical model and relates it with the existing literature. Section 4 characterizes the mechanics of the model, compares it with the empirical evidence and performs some sensitivity exercises. Section 5 concludes.

2 The effects of monetary policy shocks in the US and the euro area

In this section we describe the response of several macroeconomic variables to a monetary policy shock in the US, Germany, France and Italy. There is already a large literature focusing on the identification of monetary policy shocks in these countries[2]. This section adds three contributions to this literature. The first is to apply a common identification scheme to all four countries. The use of a common identification scheme acts here as a disciplinary strategy. The second is to explicitly analyze labor market and monetary indicators. No study to our knowledge has so far integrated these indicators in a VAR framework applied to these four major economies. The third contribution stems from the interpretation of the VAR evidence. By taking into account the sizeable uncertainty surrounding the point estimates, we underscore the similitude between the responses across countries rather than emphasize non-significant differences[3].

Following Christiano et al. (1999), the monetary policy shocks are identified as the disturbance in the following interest rate reaction function:

$$R_t^i = f^i\left(\Phi_t^i\right) + \varepsilon_t^i$$

where R_t^i is the intervention rate of country i's monetary authority (or a short-term interest rate) and Φ_t^i is the information set available at t to country

i's monetary authority. The disturbance ε_t^i is the monetary policy shock in country i. To identify ε_t^i we assume that it is orthogonal to the elements in Φ_t^i. This corresponds to a specific timing assumption imposed to the VAR system: while the time t variables included in Φ_t^i affect R_t^i contemporaneously, these variables are not contemporaneously affected by the shock ε_t^i.

We estimate a seven-variable VAR for each country. In all cases, the variables are real GDP per capita, real private and public consumption per capita, the employment rate[4], real wages per capita, inflation (measured as the change in the GDP deflator), a short-run nominal interest rate and the per capita growth of a broad monetary aggregate[5]. A description of the data is presented in appendix A.

We assume that the time t elements of the first five variables are included in Φ_t^i[6]. In other words, the monetary authority's decisions take into account the contemporaneous information of all variables except money growth. Further, the only variable that is contemporaneously affected by the monetary policy shocks is money growth. This is the recursive nature of the system.

All VARs were estimated with four lags. The sample period varied from country to country, due to data constraints and to the exclusion of post-1998 data for euro area countries: 1959Q1-2002Q4 for the US; 1978Q1-1998Q4 for France; 1970Q1-1998Q4 for Italy; and 1970Q1-1995Q4 for Germany. The solid lines in figures 1 and 2 represent the impulse responses of the interest rate, money growth, real GDP, real consumption, inflation, the employment rate, real wages and money velocity to a negative one-standard deviation shock to the interest rate. The gray areas correspond to two standard error bands around the impulse responses[7].

There are several interesting features worth highlighting from figures 1 and 2. First, an overview of the several panels suggests that there are more common features between the transmission mechanisms in the four countries than significant differences. This confirms the results for euro area countries reported in Mojon and Peersman (2003) and Ciccarelli and Rebucci (2003).

Second, the size of the monetary shock is similar in all countries. On impact, the interest rate falls by about 70 basis points. This is a sizeable shock. Despite being of a similar magnitude compared to most studies focusing on the US, it may raise some questions on whether the identified shock is really a "pure" monetary policy shock. The fall in interest rates is quite persistent, lasting at least one year. In order to support the fall in interest rates, the monetary authority raises money growth significantly, by a comparable magnitude across countries. The rise in money growth lasts at most one year in all cases. The data is thus supportive of the existence of a liquidity effect in all countries.

Third, there is a hump-shaped response of GDP and consumption in all countries (with the exception of consumption in France), with the peak effect occurring after about 1.5 to 2 years in the case of GDP and earlier in the case of consumption. Looking at the point estimates, consumption responds less than GDP to a monetary policy shock. After a 70 b.p. fall in interest rates consumption moves up by at most 0.2-0.3 per cent. These are small numbers. From a statistical point of view, the error bands are sufficiently large to de-emphasize the differences between the response of consumption and the response of GDP.

Fourth, the main heterogeneity between countries lies in the response of labor market variables. On the one hand, there is no clear pattern in the response of real wages. While the point estimates suggest that an expansionary monetary policy shock leads to a persistent increase in real wages in the US and France, the rise in real wages in Germany and Italy seems much more short-lived. The only consistent pattern between countries is the non-significance of the overall response in real wages. On the other hand, the response of the employment rate differs between countries. It is visible from figure 2 that after a positive monetary policy shock employment in all countries rises with a hump-shaped pattern. Despite the uncertainty around the point estimates, it seems that employment rises by more and at a faster pace in the US relative to the euro area countries. However, this may be due to the fact that we estimated the VAR with hours per capita in the US case and with the employment rate in the euro area case.

Fifth, inflation initially falls in all countries. This fall is only significant from a statistical point of view in the US. An increase in inflation is only discernible after at least 1 year. However, this rise in inflation is hardly significant at any time lag in any country. Combining the response of real wages with the evolution of prices, it can be concluded that the response of nominal wages is broadly non-significant in all cases (this confirms the conclusions in Alves, 2004b).

Finally, velocity falls significantly after an expansionary monetary policy shock. The fall is persistent and lasts for at least a year. Measured by the point estimates, the maximum fall varies between 0.3 and 0.6 per cent.

The above results are consistent with the evidence presented in Christiano et al. (2004) and Edge, Laubach and Williams (2004) for the US, using

VARs with a larger set of variables[8]. They are also consistent with the results reported by Mojon and Peersman (2003) for euro area countries, using different identifying assumptions and taking into account some inter-country links.

Given this robustness, we take the evidence in figures 1 and 2 as an empirical benchmark we would like to mimic with a general equilibrium monetary model. This is the task undertaken in the following sections.

3 The model

The similitude between the observed impulse responses in the four countries suggests that a common set of frictions may be able to characterize the respective monetary transmission mechanisms in a general equilibrium framework. This section seeks to study that set of frictions. As expected, no single nominal or real friction is sufficient to capture the dynamics of the data. The model therefore embeds several frictions, which are thoroughly calibrated in section 4.

The model builds closely on Christiano et al. (2004) and corresponds to a closed-economy framework. We will show that such a model is able to capture the most salient features of the data even when applied to relatively open economies such as those of the individual euro area countries. The rest of this section will describe in turn the behavior of the households, the firms, the monetary authority and the financial intermediaries.

3.1 Households

There is a continuum of households, indexed by $j \in [0,1]$. During the period the j^{th} household makes several choices in order to maximize utility, subject to an asset evolution equation. Those choices affect all markets in the economy. It is useful to overview these decisions since they highlight the main frictions that are embedded in the model.

First, the household decides the level of consumption. Here, it is assumed that there are internal habits in consumption preferences. Second, the household supplies a differentiated type of labor to a representative firm that transforms the individual differentiated labor supplies into a homogeneous composite input. This composite is then demanded by all firms in the economy. It is assumed that in each period only a fraction of households is able to change wages. The remaining households keep their wages constant. The amount of labor supplied by each household in equilibrium is then determined by the intersection of its wage-level with the demand for labor by firms.

Third, since the wage rate and labor supply differ between households, there is a potential for heterogeneity in their allocations. To sidestep this issue, we follow most of the literature and assume that there are state-contingent securities that ensure that in equilibrium households choose the same level of consumption and asset holdings (see Erceg, Henderson and Levin, 2000, and Christiano et al., 2004).

Fourth, the household chooses the level of cash-balances and the level of deposits with the financial intermediaries to hold in each period. The latter are remunerated at a certain interest rate. It is assumed that cash-balances yield utility directly, which explains why households forego the interest to be gained with deposits. We assume that in each period only a fraction of households reoptimizes portfolios, while the remaining simply update the level of cash-balances with the previous period's inflation rate.

In the beginning of the period, all shocks in the economy occur. In our model, the only shock is a monetary injection of the monetary authority to the financial intermediaries. Households make all their decisions after observing this shock. At the end of the period, the households receive the dividends from the firms, the dividends plus the deposits (with interest) from the financial intermediaries and the returns from the state-contingent securities.

The problem of the representative household j is the following (where the notation reflects the fact that households are heterogeneous with respect to wages, labor supply and cash-balances)

$$\begin{aligned} & \max \quad E_t^j \sum_{t=0}^{\infty} \beta^t \left[u^j \left(C_t, H_{t,} 1 - N_t^j \right) + v^j \left(\frac{Q_t^j}{P_t} \right) \right] \\ st \quad M_{t+1} &= Q_t^j + W_t^j N_t^j + R_t \left(M_t - Q_t^j \right) - P_t C_t + D_t + R_t X_t + Z_t^j \quad (1) \end{aligned}$$

where C_t is time t consumption, H_t is the habit stock, which is equal to bC_{t-1}, $\left(1 - N_t^j\right)$ is household j's leisure, $\frac{Q_t^j}{P_t}$ are real cash balances, M_t is the household's stock of money held at the beginning of time t, W_t^j is the nominal wage rate, N_t^j is the labor supply, $\left(M_t - Q_t^j\right)$ are deposits with the financial intermediaries, D_t are dividends from the firms, $R_t X_t$ are profits of the financial intermediaries, which arise due to the monetary injections X_t of the central bank, and Z_t^j is the net cash flow arising from the participation in the state-contingent market in period t.

Consumption C_t is a composite good (with differentiated goods indexed by a), defined as

$$C_t = \left[\int_0^1 c_t(a)^{\frac{\epsilon-1}{\epsilon}} da \right]^{\frac{\epsilon}{\epsilon-1}} \tag{2}$$

where $\epsilon > 1$ is the elasticity of substitution between any two goods.

The aggregate price level P_t is defined as

$$P_t = \left[\int_0^1 P_t(a)^{1-\epsilon} da \right]^{\frac{1}{1-\epsilon}} \tag{3}$$

where $P_t(a)$ is the price of each type of good a in units of money.

We assume that preferences are separable in consumption and leisure, and have the following functional form:

$$u^j \left(C_t, H_{t,} 1 - N_t^j \right) = \frac{1}{1-\sigma} \left(C_t - H_t \right)^{1-\sigma} - \frac{\left(N_t^j \right)^{1+\chi}}{1+\chi} \tag{4}$$

3.2 The portfolio decision

The empirical responses to a monetary policy shock presented in section 2 confirm the existence of a strong liquidity effect in all four countries under study. In order to reproduce this liquidity effect in our model we segment the financial market, by assuming that only a subset of agents are optimally participating in the market in each period. This device is reminiscent of the "limited participation" framework introduced by Lucas (1990) and Fuerst (1992).

We model this financial market segmentation by following Calvo (1983). More concretely, we assume that households face an exogenously given probability of optimally choosing their portfolios in each period. This probability is given by $(1 - \xi_q)$. This assumption can be motivated by the existence of costs related to the gathering of the information necessary to take the optimal portfolio decision. The households who do not optimize their portfolios update their cash-balances with the previous period's rate of inflation π_{t-1}, as follows:

$$Q_t^j = \pi_{t-1} Q_{t-1}^j \tag{5}$$

When household j has the opportunity to reoptimize portfolios, she takes into account that in each of the following periods such an opportunity only arises with probability $(1 - \xi_q)$. The first-order condition of the household's problem thus corresponds to a weighted average of current and expected gaps between the marginal utility from holding cash balances and the marginal utility from holding deposits, as follows[9]:

$$E_t^j \sum_{i=0}^{\infty} \left(\beta \xi_q\right)^i \left[v_{q,t+i}^j - u_{C,t+i}^j (R_{t+i} - 1) \right] = 0 \tag{6}$$

with

$$q_{t+1} = \frac{\widetilde{Q}_t \pi_t \pi_{t+1} ... \pi_{t+i-1}}{P_{t+i}}$$

where $\widetilde{Q}_t$ is the value of cash-balances at time t if household j reoptimizes at time t[10].

We consider a general form for the v function, such as

$$v_t = \psi \frac{(q_t)^{1-\gamma}}{1-\gamma} \tag{7}$$

Log-linearizing (6) around a zero inflation steady-state and combining the portfolio decisions of the optimizers with those of the non-optimizers yields the following equation for the evolution of aggregate cash-balances (where a hat over a variable denotes the per cent deviation from the steady state):

$$\begin{aligned} \widehat{q}_t \;=\;& \frac{\beta\xi_q}{1+\beta\xi_q^2}E_t\widehat{q}_{t+1} + \frac{\xi_q}{1+\beta\xi_q^2}\widehat{q}_{t-1} + \frac{\beta\xi_q}{1+\beta\xi_q^2}E_t\widehat{\pi}_{t+1} + \frac{\xi_q}{1+\beta\xi_q^2}\widehat{\pi}_{t-1} \\ & -\frac{\xi_q(1+\beta)}{1+\beta\xi_q^2}\widehat{\pi}_t - \frac{1}{\gamma}\frac{\left(1-\beta\xi_q\right)\left(1-\xi_q\right)}{1+\beta\xi_q^2}\left[\widehat{u}_{C,t} + \frac{R}{R-1}\widehat{R}_t\right] \end{aligned} \tag{8}$$

When portfolios are set flexibly equation (8) reduces to

$$\widehat{q}_t = -\frac{1}{\gamma}\left(\widehat{u}_{C,t} + \frac{R}{R-1}\widehat{R}_t\right) \tag{9}$$

There are important differences between (8) and (9). In particular, when portfolios are sticky, expectations concerning the future and past level of real cash-balances and the dynamics of inflation influence the current period's demand for real cash-balances.

3.3 The wage decision

The wage decision is based on Erceg et al. (2000) and corresponds to the "hybrid wage Calvo model" presented in Alves (2004b). In this model, households have their nominal wages fixed for a number of periods, as in Erceg et al. (2000). The difference between the hybrid wage Calvo model and the standard wage Calvo model lies in the behavior of the agents who are able to change wages in each period. In particular, we assume here that a fraction $(1-\phi)$ of those agents behaves optimally and a fraction ϕ merely sets the nominal wage equal to the previous average reset wage plus inflation[11].

Households are monopolistic suppliers of their own differentiated labor N_t^j. Households sell their labor to a representative and competitive firm (the aggregator) that transforms the individual differentiated labor supplies into a homogeneous composite input N_t. All firms in the economy hire this composite labor input (and by the same amount).

The production function of the aggregator is the following:

$$N_t = \left[\int_0^1 \left(N_t^j\right)^{\frac{1}{\lambda_w}} dj\right]^{\lambda_w} \tag{10}$$

The problem of the aggregator is to minimize the cost of producing a given amount of N_t taking the wage of household j as given. The first order condition to this problem yields

$$N_t^j = \left[\frac{W_t^j}{W_t}\right]^{\frac{\lambda_w}{1-\lambda_w}} N_t \tag{11}$$

which represents the demand for each household's differentiated type of labor. $\frac{\lambda_w}{1-\lambda_w}$ is the elasticity of substitution among the different types of labor. The price of N_t is the aggregate wage rate, which equals

$$W_t = \left[\int_0^1 \left(W_t^j\right)^{\frac{1}{1-\lambda_w}} dj\right]^{1-\lambda_w} \tag{12}$$

In each period only a fraction $(1-\xi_w)$ of the households is able to change the nominal wage. This probability is independent of the individual history of each household. The fraction ξ_w that is unable to change wages keeps them constant. From the fraction $(1-\xi_w)$ that is able to change wages only a subset $(1-\phi)$ behaves optimally while the remaining ϕ merely update the previous average reset nominal wage with lagged inflation.

These non-optimal wage setters can be rationalized by observing that many wage bargains merely emulate the behavior of leading unions, industries or groups of leading firms. This type of behavior corresponds to $\phi > 0$.

Note that this contrasts with recent contributions (as in Christiano et al., 2004, or Smets and Wouters, 2003a and 2003b) where it is assumed that the fraction of households that is not able to reoptimize in each period updates nominal wages with the lagged inflation rate. In these models, there is a continuous indexation of wages to inflation. This is clearly at odds with experience in modern low inflation economies, where wage negotiations usually settle nominal wages for one year or multiples of one year (see Taylor, 1999). This is our basis for preferring the hybrid wage Calvo specification.

Aggregate nominal wage level in this set-up is given by:

$$W_t = \left[(1-\xi_w) \widetilde{W}_t^{*\frac{1}{1-\lambda_w}} + \xi_w \left(W_{t-1}\right)^{\frac{1}{1-\lambda_w}} \right]^{1-\lambda_w} \tag{13}$$

where $\widetilde{W}_t^*$ is the average reset wage in period t.

The nominal wage growth in this case is described by the following equation[12]:

$$
\begin{aligned}
\Delta\widehat{W}_t \;=\; & \frac{\beta\xi_w}{\phi(1-\xi_w+\xi_w\xi_w\beta)+\xi_w}E_t\Delta\widehat{W}_{t+1}+\frac{\phi\xi_w}{\phi(1-\xi_w+\xi_w\xi_w\beta)+\xi_w}\Delta\widehat{W}_{t-1} \\
& -\left[\frac{\phi\xi_w\beta(1-\xi_w)}{\phi(1-\xi_w+\xi_w\xi_w\beta)+\xi_w}\right]\widehat{\pi}_t+\left[\frac{\phi(1-\xi_w)}{\phi(1-\xi_w+\xi_w\xi_w\beta)+\xi_w}\right]\widehat{\pi}_{t-1} \\
& +\frac{(\lambda_w-1)}{\chi\lambda_w+\lambda_w-1}\frac{(1-\phi)(1-\xi_w)(1-\xi_w\beta)}{\phi(1-\xi_w+\xi_w\xi_w\beta)+\xi_w}\left[-\widehat{u}_{C,t}+\chi\widehat{N}_t-\widehat{w}_t\right] \qquad (14)
\end{aligned}
$$

In the hybrid wage Calvo model, nominal wage inflation depends on future and lagged nominal wage growth and current and lagged inflation. This allows the nominal wage to exhibit a significant degree of nominal wage inertia, in line with the data for several developed economies (see Alves, 2004b).

3.4 Firms

Firms have access to a labor-only production technology

$$y_t(a)=[n_t(a)]^{1-\alpha} \qquad (15)$$

The firms hire the composite domestic labor at the aggregate wage rate W_t and need to borrow their wage bill from the financial intermediaries at a rate of interest R_t.

Using the clearing condition that consumption of each good equals output, we can write the demand for firm a's output as follows:

$$y_t(a)=\left[\frac{P_t(a)}{P_t}\right]^{-\epsilon}Y_t \qquad (16)$$

To take into account the possibility of heterogeneous price behavior by firms, we again follow Calvo (1983) and assume that in each period only a fraction $(1 - \xi_p)$ of firms is able to change prices optimally. We also assume, as in the portfolio decision, that firms who do not reoptimize simply update their prices with lagged inflation.

The problem of each firm is to choose the price to maximize its expected profits. The problem of a firm who is able to change the price at time t is the following:

$$Max \quad \pi_t = E_t \sum_{i=0}^{\infty} (\xi_p \beta)^i \Lambda_{t,t+i} \left[\begin{array}{c} \frac{P_t(a)\pi_t \pi_{t+1} \ldots \pi_{t+i-1}}{P_{t+i}} y_{t,t+i}(a) \\ -\frac{1}{1-\alpha} \frac{W_{t+i}}{P_{t+i}} R_{t+i} N_{t+i}^{\alpha} y_{t,t+i}(a) \end{array} \right] \tag{17}$$

where $\Lambda_{t,t+i}$ is a discount factor related to the marginal utility of consumption of the households. Note that $y_{t,t+i}(a)$ is the demand for firm a's output at time $t + i$ conditional on the choice of price at time t, i.e., $P_t(a)$.

Given the demand (16), $y_{t,t+1}(a)$ is equal to

$$y_{t,t+1}(a) = \left(\frac{P_t(a)\pi_t \pi_{t+1} \ldots \pi_{t+i-1}}{P_{t+i}} \right)^{-\epsilon} Y_{t+i} \tag{18}$$

Replacing (18) in (17), log-linearizing the first order condition of (17) with respect to $P_t(a)$ around a zero inflation steady state, and aggregating the log-linearized equations for both optimizing and non-optimizing firms yields the following equation for aggregate inflation:

$$\widehat{\pi}_t = \frac{\beta}{1+\beta} E_t \widehat{\pi}_{t+1} + \frac{1}{1+\beta} \widehat{\pi}_{t-1} + \frac{(1-\xi_p)(1-\xi_p \beta)}{\xi_p (1+\beta)} \left(\widehat{w}_t + \widehat{R}_t + \alpha \widehat{N}_t \right) \tag{19}$$

In the Calvo framework, inflation thus depends on expectations of future inflation and on lagged inflation. This latter term appears due to the assumption that non-optimizing firms update their prices with lagged inflation (see Christiano et al., 2004).

3.5 Monetary authority

The monetary authority injects reserves to the system through a lump-sum transfer X_t to the financial intermediaries. The cash-flow in the economy implies that $M_{t+1} = M_t + X_t$.

The monetary authority is assumed to follow an autoregressive process for the rate of money growth, of the form

$$\widehat{\eta}_t = \widehat{\eta} + \rho\widehat{\eta}_{t-1} + \varepsilon_t \tag{20}$$

where $\widehat{\eta}_t$ is the net growth rate of money supply and ε_t is a money supply shock, with zero mean and standard deviation ε. The mean net growth rate is equal to $\widehat{\eta}$. The response of money growth to a policy shock follows a first-order autoregressive process with coefficient ρ.

3.6 Financial intermediaries

There is complete integration of financial markets. The financial intermediaries channel the supply of loans to the respective demand. The supply of loans corresponds to the sum of the monetary injection X_t with the deposits from the households $(M_t - Q_t)$. The demand for loans comes from the firms and equals the wage bill W_tN_t.

3.7 Clearing conditions

In equilibrium, all markets clear. The loan market clearing condition is:

$$W_t N_t = M_t - Q_t + X_t \tag{21}$$

The clearing of the goods market implies that consumption of each good a equals output:

$$c_t(a) = y_t(a) \tag{22}$$

The linearized resource constraint can be written, to a first-order approximation, as follows[13]:

$$\widehat{C}_t = (1 - \alpha)\, \widehat{N}_t \tag{23}$$

4 The mechanics of the model

This section presents the predictions of the model and compares them with the impulse response functions after a monetary policy shock in the US, Germany, France and Italy. We start by extensively discussing the parameterization of the model (subsection 4.1). Subsection 4.2 characterizes the monetary transmission mechanism in the model and compares it with the data. Subsection 4.3 presents some sensitivity results concerning some of the parameters of the model.

4.1 Calibration

The calibration of the model's parameters is based as much as possible on microeconomic and macroeconomic evidence. We will pursue a common calibration for the four countries, since most of the evidence suggests similar structural preference and technology parameters between these countries. There are 15 parameters to calibrate: β, b, σ, χ, λ_w, ξ_w, α, $\frac{\epsilon}{1-\epsilon}$, ξ_p, ρ, $\widehat{\eta}$, ε, ξ_q, γ and ψ. We will analyze each of these in turn.

To calibrate the steady state annualized real interest rate, we note that during the last four decades, the average real interest rate usually stood between 3 and 4 per cent in all four countries[14]. We thus set $\beta = 1.03^{-0.25}$, which corresponds to the level of real interest rates at the end of the sample period.

The parameter b governing the degree of habit persistence is hard to measure from either micro or macro studies. The micro studies usually focus on households' decisions revealed in expenditure surveys. These surveys usually confirm the importance of habits in consumption but are inconclusive concerning their size (see Deaton, 1992). The macro studies usually calibrate b to match moments of the data or certain asset price phenomena. In these studies the estimates for b[15] are always quite large, as can be illustrated by the following sample of representative studies: Christiano and Fisher (2003) estimate $b = 0.76$; Fuhrer (2000) estimates b to lie between 0.8 and 0.9; Christiano et al. (2004) estimate $b = 0.63$ for the US; Smets and Wouters (2003a and 2003b) estimate $b = 0.66$ for the US and $b = 0.60$ for the euro area; finally, Heaton (1995) reports $b = 0.94$. Given the disparity of these estimates we settle for $b = 0.80$. In subsection 4.3 some sensitivity analysis concerning this parameter is undertaken.

As for σ we follow the literature and choose $\sigma = 1.5$. Concerning χ, we assume, as in Christiano et al. (2004), that $\chi = 1$. Given the existence of wage contracts in the economy, it can be shown that the short-run labor supply elasticity will be high irrespective of the value of χ. This is consistent with the macroeconomic evidence that usually reports high values for that elasticity.

We now turn to the parameters related to the households' wage decision: λ_w, ϕ and ξ_w. Concerning the latter, Taylor (1999) presents evidence that wage re-negotiations usually occur annually (or, in some cases with formal contracts, in multiples of a year). This would suggest an average wage duration equal to a year, i.e., $\xi_w = 0.75$. However, we have to take into account that in each quarter there are significant flows of workers across the labor market states of employment, unemployment, not in the labor force and between jobs. This implies a lower value for ξ_w. We thus calibrate the average wage duration to equal 3 quarters. This is close to the value of $\xi_w = 0.64$ estimated for the US by Christiano et al. (2004). As for the fraction of backward wage-setters we consider $\phi = 0.5$ as our baseline. In subsection 4.3 some sensitivity analysis concerning the values of both ϕ and ξ_w is undertaken. Finally, there are no reliable microeconomic studies focusing on the wage mark-up. While Christiano et al. (2004) assume $\lambda_w = 1.05$, Smets and Wouters (2003a and 2003b) estimate $\lambda_w = 1.26$ for the US and $\lambda_w = 1.29$ for the euro area. Without any *a priori* reasoning, we set $\lambda_w = 1.15$.

The steady state labor income share $(1 - \alpha)$ is extensively studied in

Gollin (2002). He computes estimates of the labor share for a large sample of countries, taking into account the income of the self-employed and proprietors. His estimates[16] for the labor share are 0.664 for the US, 0.681 for France and 0.707 for Italy (the data does not allow to correct the German data). We thus consider $\alpha = 0.33$ to be a good approximation of the capital income share in the four countries.

As regards the flexible-price markup level $\theta = \frac{\epsilon}{1-\epsilon}$ we follow Martins, Scarpetta and Pilat (1996). They study the mark-ups for 36 manufacturing industries. The average mark-up in their sample is 1.17 for the US, 1.25 for Germany, 1.21 for France and 1.19 for Italy. We therefore calibrate the mark-up in the model as $\theta = 1.2$.

The degree of price setting rigidity is determined by parameter ξ_p. There is a vast literature arguing that the data points to a high ξ_p[17]. However, recent microeconomic surveys have shown that the average consumer price duration in the US is small, around 4 months (see Bils and Klenow, 2002). Further, as argued in Alves (2004a), prices respond contemporaneously and significantly to technology shocks in the four countries of our sample. This evidence suggests that an exogenous restriction on the price-setting ability of firms - which is implicit in the Calvo mechanism - can only have a minor role on the average firm's behavior. We thus set $\xi_p = 0.333$, which corresponds to an average price duration of 1.3 quarters.

The following three parameters ($\widehat{\eta}$, ρ and ε) relate to the money supply process. We will consider that money in the model corresponds to the broad aggregate $M2$ in the data[18]. We thus calibrate the average quarterly growth rate of money supply in the four countries of our sample as $\widehat{\eta} = 0.018$[19].

The other two parameters ρ and ε represent the money supply path that supports the interest rate change after a monetary policy shock (see Christiano, Eichenbaum and Evans, 1998). In section 2 we concluded that after an unexpected fall in interest rates of around 70 basis points, the broad monetary aggregate increases by about 0.2 per cent in all countries (although there is considerable uncertainty surrounding the point estimate). This is the value used in our calibration. As for the persistence of the money supply process, the monetary policy shocks identified in section 2 support our choice of $\rho = 0.5$ for all countries in the sample.

The three final parameters focus on the households' portfolio decisions: ξ_q, γ and ψ. The only study we are aware of that deals explicitly with the frequency with which households trade financial assets is Vissing-Jorgensen (2002), but it focuses on financial assets held outside bank accounts, such as stocks, bonds and mutual funds. This study concludes that in the US the fraction of agents holding such assets and trading them during a year is between one third and one half. This suggests that households do not reoptimize their portfolios continuously and supports a version of the model with staggered portfolios. However, this conclusion is downplayed by two factors: first, the behavior concerning risky financial assets may be different from the behavior concerning bank accounts; second, even if we observe a non-continuous participation in the financial market by households, we always need to analyze the reasons for this discontinuity (since portfolios could seem rigid simply because there were no underlying reasons to change them). These considerations lead us to settle for a moderate degree of rigidity of portfolios, equal to $\xi_q = 0.67$.

The parameter γ was calibrated in order to reproduce the interest semi-elasticity of the demand for cash-balances. We assume that the aggregate $M1$ is a good proxy for cash-balances Q in the model. There is by now a considerable literature focusing on the differences between the short and long-run dimensions of this elasticity (see Christiano et al., 1999, and Lucas, 2000). Table 1 highlights this heterogeneity. The table calculates the short-run semi-interest rate elasticity of $M1$ using the method proposed by Christiano et al. (1999)[20]. The table also shows the short and long-run elasticities estimated by Taylor (1993) for his multicountry macroeconometric model. The table underscores that while the short-run semi-interest rate elasticities of $M1$ are below 0.7 in all countries, the long-run elasticity is several orders of magnitude higher (as high as 7.0 in the US, according to Lucas, 2000).

From equation (9) we know that with flexible portfolios the short-run semi-interest rate elasticity of Q is $-\frac{1}{4\gamma(R-1)}$[21]. In contrast, with sticky portfolios the short-run interest semi-elasticity of Q can be computed from equation (8) and equals $-\frac{\left(1-\beta\xi_q\right)\left(1-\xi_q\right)}{1+\beta\xi_q^2}\frac{1}{4\gamma(R-1)}$, when all other variables are held constant. In the long run there are no rigidities and we are back to the flexible portfolio case. This reasoning suggests that with staggered portfolios we can reconcile the short and long run differences in the semi-interest rate elasticity of $M1$. This is not attainable in a model with flexible portfolios.

Taking into account the evidence in Table 1, we calibrate the short-run interest semi-elasticity of M1 demand to be -0.37, which corresponds to the average response in the four countries. This implies $\gamma = 2$ in our baseline specification. With this value, the long-run interest semi-elasticity of $M1$ demand is 4.9, in line with the evidence presented in Taylor (1993). Both the short and long-run elasticities are thus replicated in the model.

The final coefficient in our list is ψ. This parameter was calibrated in order to reproduce the size of the liquidity effect in the period of the shock.

Table 2 presents a summary of all the calibration.

4.2 The model and the data

This subsection describes and explains the main properties of the model. The model was solved using the undetermined coefficients method presented in Christiano (2002).

The lines with crosses in figures 3 and 4 show the predictions of the baseline model in comparison with the empirical two standard-error intervals estimated in section 2. The model is able to capture the most salient features of the data after a monetary policy shock. In fact, the theoretical impulse responses after a monetary shock lie inside or close to the confidence bands in most cases. In the following, we will characterize more thoroughly the predictions of the model and trace them to the respective underlying frictions.

A first interesting feature of the model is that an unexpected and persistent monetary injection by the monetary authority produces a significant and persistent liquidity effect. This fall in interest rates lasts at least a year. To understand the features of the model that explain these developments it is useful to focus on the loan market clearing condition (21) and on the demand for cash-balances (8).

In the period of the shock, the monetary injection is channeled to the financial intermediaries and adds to the supply of loans in the financial market.

This injection creates a relative abundance of liquidity in the financial markets. Simultaneously, the households make their portfolio decisions, which also influence the supply of loans via the deposits with the financial intermediaries. Both in the data and in the model, q_t surges in the period of the shock and remains above steady state for over a year.

This increase in q_t in the period of the shock is mainly associated with two factors. First, households wish to smooth consumption due to the habit formation in preferences for consumption so they choose not to channel too much funds as deposits with the financial intermediaries (recall that households maximize their consumption by making interest-bearing deposits instead of holding cash-balances). Second, the excess liquidity in the financial market must be absorbed by firms, which demand loans from the financial intermediaries in order to borrow their wage bill in advance. To induce firms to absorb this extra liquidity, the interest rate must fall. Since the interest rate is the opportunity cost of holding cash-balances, households have an additional incentive to increase q_t due to the fall in R_t.

The persistent liquidity effect after a monetary policy shock is associated with the persistent rise in real cash-balances held by households. This persistence is related to three factors. First, the short-run semi-interest rate elasticity of q_t is small in the model, so changes in interest rates or in the marginal utility of consumption have small effects on the path of q_t. Second, there is a sluggish adjustment of prices (which will be explained below), which contributes to the smoothness of real cash-balances. Third, the variables affecting the marginal utility of consumption are also smoothed due to the habit formation in preferences for consumption. These three features explain why the model reproduces a persistent liquidity effect.

A second feature of the model that is worth noting is the hump-shaped response of GDP, consumption and labor (since the model has no role for capital, these three variables move proportionally). The peak effect in these variables occurs 3 quarters after the shock. This feature is due to the assumption of strong habit formation in preferences for consumption.

Third, the dimension in which the model is least successful when compared to the cross-country evidence is in tracking the response of the employment rate to the monetary policy shock. In fact, the response of employment is clearly more sluggish in the data relative to the model, in particular in Germany and France. This suggests that further work on the structural modeling of the labor market is required.

A fourth feature of the model is the sluggish response of both inflation and wages to the policy shock. Inflation falls on impact and rises slowly thereafter, reaching a maximum only about a year after the shock. The impulse responses estimated in section 2 imply a very protracted response of inflation in the four countries. In fact, inflation never rises significantly above zero in any case. Therefore we conclude that the baseline model can only capture the main qualitative features of the inflation response to a monetary policy shock.

Concerning the wage response, the small positive change in real wages is short-lived, since they return to their pre-shock level after about a year. The behavior of wages is rooted in the assumption of wage contracts with an average duration of three quarters. These contracts imply a slow and gradual adjustment of nominal wages, due to two reasons. First, a significant fraction of households keep their nominal wages fixed each period. Second, the fraction of agents that is able to change wages optimally balances the expected marginal utility of leisure with the expected marginal utility of wage income. However, they know that the labor demand targeted at their labor services changes when they adjust their wages[22]. Since households have a desire to smooth labor supply over time, they choose not to change wages by much. Finally, the fraction of households that chooses wages with a simple rule-of-thumb also contributes to smoothen the nominal wage response.

The behavior of inflation is closely related to the evolution of wages. To gain intuition on this result it is best to start by analyzing the case of completely flexible price-setting behavior by firms. In this case, prices are set as a constant mark-up over nominal marginal costs. The latter depend on nominal wages, the level of employment and the interest rate (due to the firms' financing of the wage bill). Equation (12) shows that with nominal wage contracts, the elasticity of aggregate wages with respect to changes in consumption and labor is very small. Thus nominal wages only change gradually after a monetary injection. Employment also rises slowly, since the households' demand for goods rises sluggishly, due to the habits in preferences for consumption. Finally, the interest rate falls on impact. This last feature explains why inflation falls in the period of the shock.

The model is thus able to reproduce an inertial behavior of inflation even with perfectly flexible prices, as in Christiano et al. (2004). The additional impact of assuming that a third of the firms do not choose prices optimally in each quarter (as implicit in our baseline calibration) has only minor general equilibrium effects. These will be assessed in the next subsection.

Another feature of the model worth emphasizing is the behavior of velocity. Consistent with the data, the models predict a significant fall of velocity in the period of the shock, that persists for about a year. This is in line with the behavior of interest rates, as would be suggested by most empirical models aiming to characterize velocity. This contrasts with cash-in-advance specifications of money demand, which usually imply a constant and exogenously given level of velocity.

Figures 3 and 4 also present the results of a different calibration exercise, aimed at improving the fit of the model. The solid lines in those figures represent the response of the model when three parameters of the baseline calibration are changed. These are the degree of habit persistence ($b = 0.85$), the fraction of backward-looking wage setters ($\phi = 0.85$) and the degree of price rigidity ($\xi_p = 0.83$). The model with this increased degree of built-in rigidity is able to fit the data more accurately. In particular, the inertia in inflation and real wages and the hump-shaped response in real variables are much closer to the empirical estimates. This exercise illustrates two ideas. First, adding flexibility to the calibration obviously does not harm the ability of the model to fit the data. Second, allowing parameters to vary in order to achieve the best fit may be a misleading strategy, since the resulting parameter values may simply be incomprehensible. Here, this is the case of ϕ or ξ_p, which are implausibly high in this new calibration. This suggests that adding degrees of freedom to the calibration when a model does not fit the data to precision may be a counterproductive strategy.

4.3 Sensitivity analysis

In this subsection we conduct four sensitivity exercises related to the parameterization of the model. These concern the degree of habit in preferences for consumption, the degree of Calvo price rigidity, the degree of Calvo wage rigidity and the fraction of backward-looking wage-setters. In each case, we present the results for the baseline calibration (solid line) coupled with the predictions of models with lower and higher degrees of rigidity (dashed line and line with crosses, respectively). The figures also show the empirical confidence bands estimated for the US. Except for the parameters under analysis in each case, the remaining calibration of the model stays unchanged[23].

The first column in figure 5 presents the predictions of the model for varying degrees of habit formation in preferences for consumption. It is clear that the degree of habit formation is important from both a qualitative and quantitative points of view. Changes in habit persistence affect both the inertia of inflation and the persistence in output after a monetary policy shock. In fact, a higher degree of habits in consumption implies that households have a higher desire to smooth consumption, which explains the smaller consumption change in the period of the shock. The smoother increases in consumption and employment imply that inflation falls more in the period of the shock. Also, as the degree of habit persistence rises, the inertial behavior of inflation also rises.

The second column in figure 5 assesses the impact of changing the degree of Calvo price duration, ranging from complete price flexibility to annual price changes. The figure shows that, except for the inertia in inflation, and the concomitant evolution of real wages, the model's response to a monetary injection stays virtually unchanged. This suggests that the cost of modeling prices as flexible in terms of the models' predictions for real variables is not significant (this conclusion is reminiscent of Christiano et al, 2004).

The third column in figure 5 displays the sensitivity of the results for varying degrees of wage rigidity, from close to full wage flexibility to an average wage contract duration of 6 quarters. It is visible that this friction has a very important impact on the predictions of the model. With mostly flexible wages, the model implies smaller consumption and output responses. Although difficult to discern due to the scaling of the figure, the peak effect occurs one period after the shock. This contrasts sharply with the results obtained with longer wage contracts, where the peak response of output occurs after 1 year.

Finally, the fourth column in figure 5 presents the predictions of the model for various fractions of backward-looking wage-setters, ranging from one third to two thirds of the households who change wages in each period. As in the case of price rigidity, the main impact from varying that fraction is visible in the nominal variables, namely in the rate of inflation. In contrast, the impact on the path of GDP or consumption is overall negligible.

In sum, these sensitivity exercises highlight that the main frictions in the model are habits in preferences for consumption and nominal wage contracts. Assuming fully flexible prices does not deteriorate the performance of the real-side of the model.

5 Conclusion

The similitude of the monetary transmission mechanism among countries is usually undervalued in order to highlight the respective differences. This paper argued that this set of differences might be smaller than usually thought. In fact, empirical and theoretical evidence was presented suggesting that a common characterization of the monetary transmission mechanism in the US, Germany, France and Italy is realistic.

On the empirical side, we extended the existing cross-country VAR evidence by including labor market and monetary variables in the analysis. We concluded that the four countries present analogous impulse response functions following a monetary policy shock. This empirical similitude implies that a single model may explain the broad features of the data. We presented such a model and argued that a common calibration for the four countries is plausible. The model embodies nominal wage contracts, habits for preferences in consumption and a staggered adjustment of households' portfolios.

A small set of frictions is therefore able to account for the main characteristics of the monetary transmission mechanism in developed economies. This implies that issues related to the real effects of monetary policy or to the evaluation of the optimal monetary policy may be discussed within a common framework.

Our analysis suggests that an important heterogeneity in the data concerns the allocations in the labor market after a monetary shock. In particular, the empirical impulse responses of employment following a monetary shock differed significantly between the US and Germany. These countries are quite different in terms of their labor market institutions. It may thus be necessary to embed these institutional frictions in the model in order to replicate the differences in the data.

Another issue worth analyzing deeper is the methodological assumptions needed to achieve the persistence of macroeconomic variables after a monetary shock. The literature has proposed either to calibrate the elasticity of the response of certain variables or, alternatively, to assume a non-continuous opportunity to change those variables (or the presence of adjustment costs). We think that the choice between these strategies must rely not only on the predictions of the respective models - which are sometimes indistinguishable - and on parsimony reasons, but also on their adherence to empirical features described in micro and macro studies. In particular, the distinction between the short-run and long-run dimensions may be particularly difficult. In our model, this was illustrated in the modeling of the households' portfolio behavior.

A straightforward extension of this work is to incorporate other shocks in the analysis. The main difficulty in this respect is that the response of the economy to these shocks is a function of the monetary policy reaction function. The problem arises because the four countries above did not arguably pursue a stable monetary policy rule in the sample period under study. Therefore, discriminating the role of frictions and the role of the monetary policy decisions in the propagation of the shocks becomes a demanding task. Further investigation along these lines is still warranted.

Notes

[1]Other models that have recently built on Christiano et al. (2004) are for example Altig, Christiano, Eichenbaum and Linde (2002), Amato and Laubach (2003) and Smets and Wouters (2003a and 2003b). Some of these models are analyzed in Woodford (2003).

[2]See, in particular, Sims (1992), Christiano et al. (1999), Mojon and Peersman (2003) and Angeloni, Kashyap, Mojon and Terlizzese (2003).

[3]A cross-country comparison between point estimates can be found, for example, in Angeloni et al. (2003).

[4]In the case of the US, total hours per capita were used.

[5]This aggregate is M2 in all countries except Germany, where M3 was used.

[6]As highlighted in Christiano et al. (1999), the impulse response functions are independent of the ordering of the variables in Φ^i.

[7]These are Monte Carlo Bayesian confidence intervals, computed using random draws from the posterior distribution of the covariance matrix of innovations and the reduced form coefficient matrix.

[8]Amato and Laubach (2003) also report non-significant responses of real wages and inflation to monetary policy shocks in the US, using a smaller VAR and a more recent sample period.

[9]An appendix with the full derivation of the portfolio decision is available upon request.

[10]Note that $\widetilde{Q}_t$ is not indexed by j since all households that are able to reoptimize choose the same level of cash-balances.

[11]This formulation is inspired in the Hybrid Phillips curve proposed in Galí and Gertler (1999).

[12]A full derivation of the hybrid wage model is presented in an appendix available upon request.

[13]The aggregate goods market clearing conditions is given by $C_t = \Xi_t (N_t)^{1-\alpha}$, where $\Xi_t = \left(\frac{P_t^*}{P_t}\right)^{\epsilon} \left(\frac{W_t^*}{W_t}\right)^{\frac{\lambda_w(1-\alpha)}{\lambda_w - 1}}$, with $P_t^* = \left[\int_0^1 P_t(a)^{-\epsilon} da\right]^{-\frac{1}{\epsilon}}$ and $W_t^* = \left[\int_0^1 \left(W_t^j\right)^{\frac{\lambda_w}{1-\lambda_w}} dj\right]^{\frac{1-\lambda_w}{\lambda_w}}$. As shown in Erceg et al. (2000) and Christiano et al. (2004), Ξ_t is constant to a first-order approximation.

[14]The real interest rate is defined as the difference between the 10-year government bond yield and the annual change in the consumer price index.

[15]We are simplifying the exposition by neglecting that in some cases habits are modeled as additive (as in this paper or in Christiano and Fisher, 2003, for example) and in others as multiplicative (as in Fuhrer, 2000). Further, habits can be internal or external.

[16]We report the numbers of "adjustment 3" in Gollin (2002). This adjustment involves imputing a wage to entrepreneurs and own-account workers.

[17]See, for example, the partial equilibrium analysis of Galí and Gertler (1999) or Galí, Gertler and López-Salido (2003) and the general equilibrium estimates of Smets and Wouters (2003a and 2003b).

[18]In the case of Germany, the broad aggregate is $M3$.

[19]The average quarterly growth of M2 was 1.8 per cent in the US (between 1959 and 2002), 1.9 percent in Germany (between 1969 and 1998), 1.5 per cent in France (between 1977 and 1998) and 2.4 per cent in Italy (between 1975 and 1998).

[20]These authors show that a consistent estimate of the short-run semi-interest rate elasticity of $M1$ can be calculated by dividing the contemporaneous response of $M1$ to a monetary policy shock by the contemporaneous response of the interest rate to that shock. We implemented this methodology by estimating VARs with four lags of GDP, consumption, inflation, real wages, the employment rate, the short-run interest rate and the change in M1. In the US, the employment rate was replaced by total hours per capita.

[21]Note that we multiplied the net interest rate by 4, in order to calculate the elasticity with respect to the annual interest rate. Moreover, the elasticity is calculated for a constant marginal utility of consumption.

[22]This change in demand is positively related to the elasticity of substitution between labor types.

[23]With the exception of ψ which varies in order to reproduce the size of the liquidity effect on impact.

A Description of the data

Data for the US

The series used for the US were the following: non-farm business sector gdp deflator (source: BEA); Gross Domestic Product, in chained (1996) dollars (source: BEA); household consumption of nondurable goods and services plus government consumption (Source: BEA); Federal Funds rate (source: IMF); real wages were computed with nominal wages per hour (source: BLS) and the GDP deflator (source: BEA); total hours in the non-farm business sector (Source: BLS); employment rate (source: BLS); M1 and M2 (source:

IMF); and, population (source: IMF).

Data for Italy

The series used for Italy were the following: GDP at basic prices deflator (source: Conistat); value added at basic prices (source: Conistat); household and government consumption expenditures (source: IMF); three-month money market interest rate (source: IMF); real wages were computed with wages per person and the GDP deflator (source: IMF); civilian employment and employment rate (source: OECD); M1 and M2 (source: IMF); and, population (source: IMF).

Data for France

The series used for France were the following: non-financial enterprises producer prices (source: INSEE); Gross Domestic Product (source: INSEE); household and government consumption expenditures (Source: IMF); call money rate (source: IMF); real wages were computed with nominal wages per hour (source: BLS) and the GDP deflator (source: IMF); employees in market industry and services and employment rate (source: OECD); M1 and M2 (source: IMF); and, population (source: IMF).

Data for Germany

The series used for Germany were the following: GDP deflator (source: IMF); GDP volume at 1995 prices (source: IMF); household and government consumption expenditures (Source: IMF); call money rate (Source: IMF); real wages were computed with nominal hourly earnings in manufacturing (source: OECD) and the GDP deflator; wage and salary earners (source: Bundesbank); employment rate (source: Bundesbank); M1 and M3 (source: IMF); and, population (source: IMF).

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	Short-run elasticity		Long-run elasticity
	Using CEE (1999)	From Taylor (1993)	From Taylor (1993)
US	−0.38	−0.22	−4.73
Germany	−0.65	−0.65	−2.13
France	−0.13	−0.32	−0.99
Italy	−0.32	−0.39	−3.67

Table 1: Semi-interest rate elasticity of the demand for M1

Preferences and technology					Policy rule		
β	b	α	χ	σ	ρ	$\widehat{\eta}$	ε
0.993	0.8	0.33	1	1.5	0.5	0.018	0.002

Portfolio decision			Wage decision			Price decision	
ξ_q	γ	ψ	ξ_w	λ_w	ϕ	ξ_p	$\frac{\epsilon}{1-\epsilon}$
0.67	2	0.0005	0.67	1.15	0.5	0.333	1.2

Table 2: The benchmark calibration

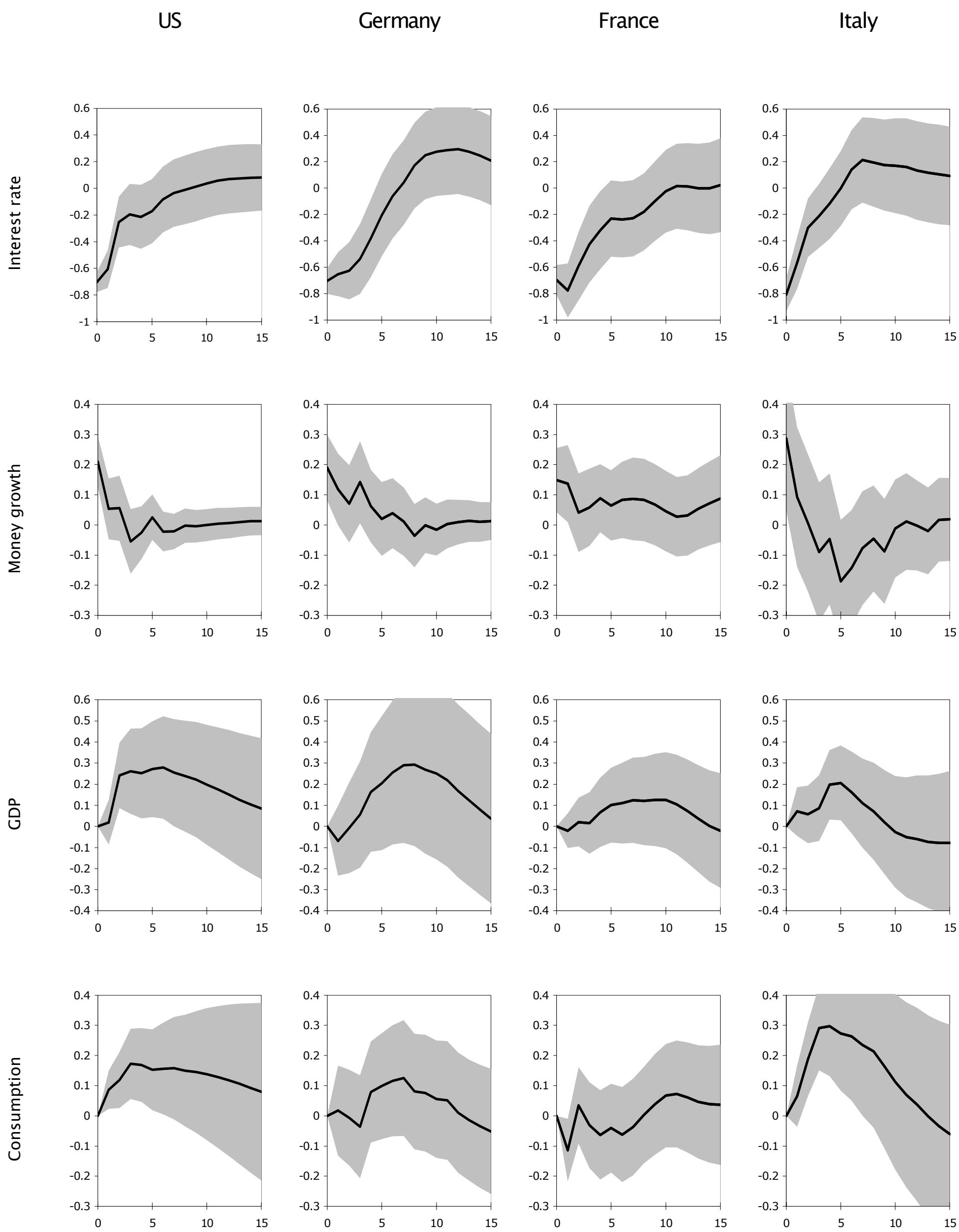


Figure 1: Impulse response functions after a monetary policy shock.

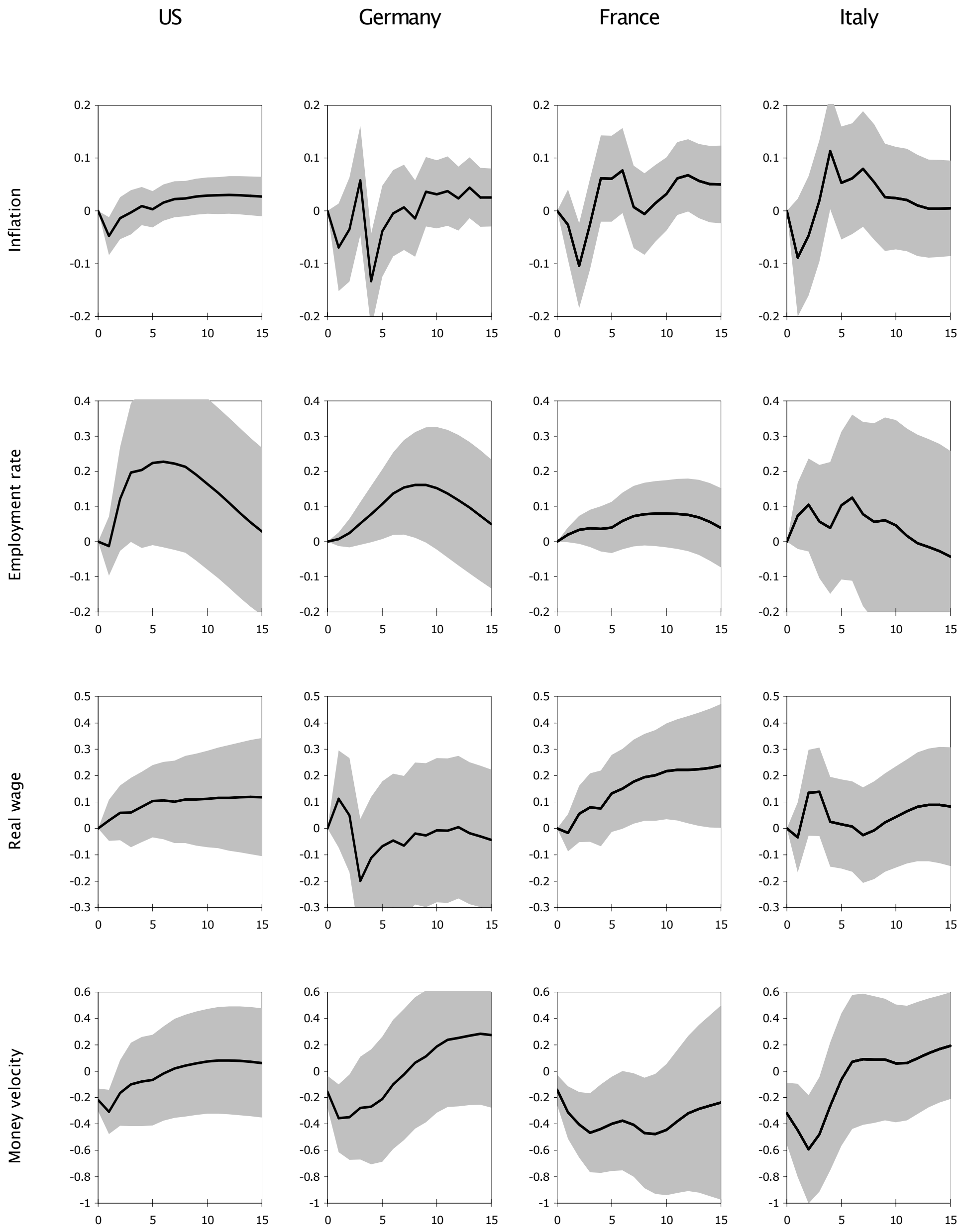


Figure 2: Impulse response functions after a monetary policy shock (continued).

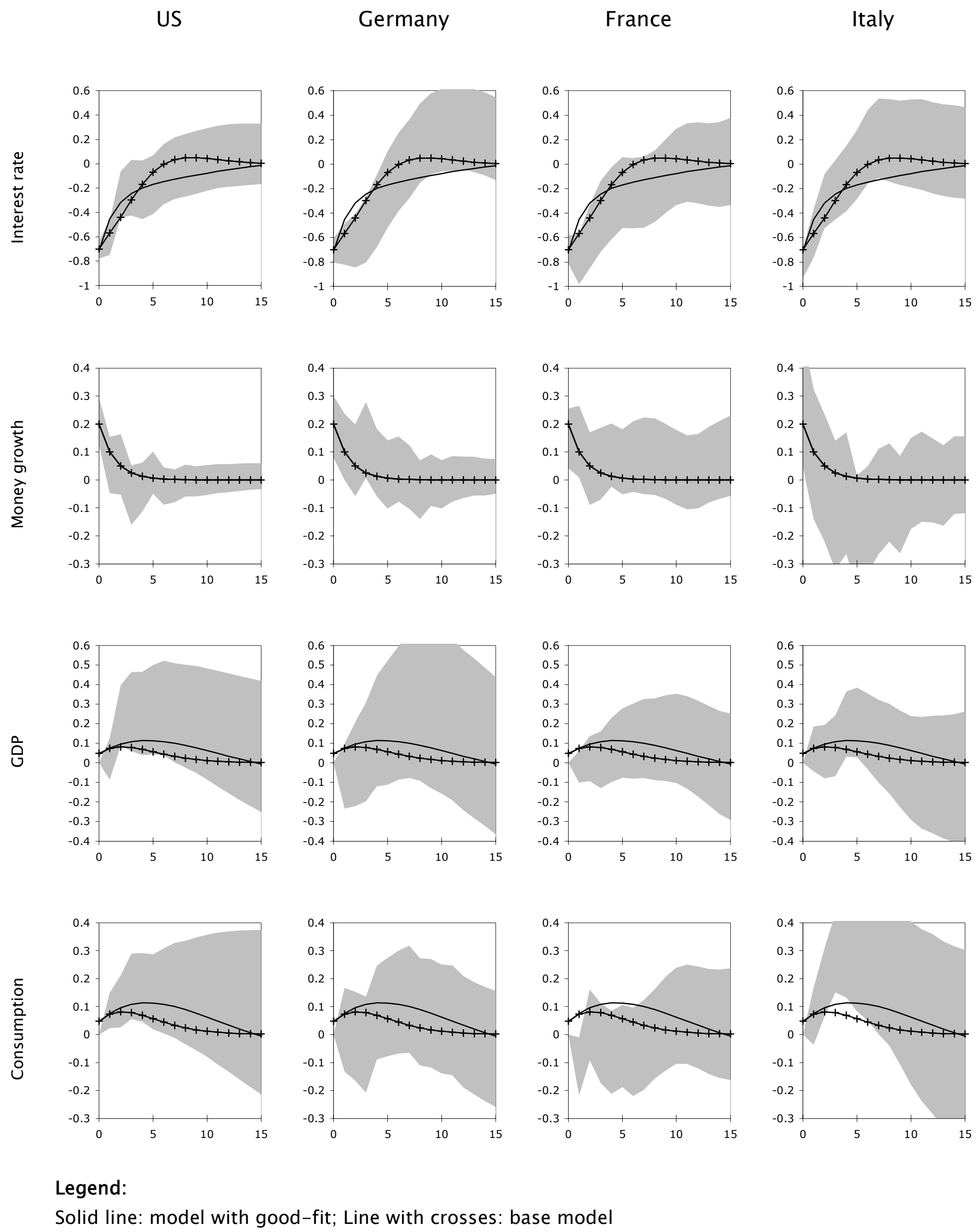
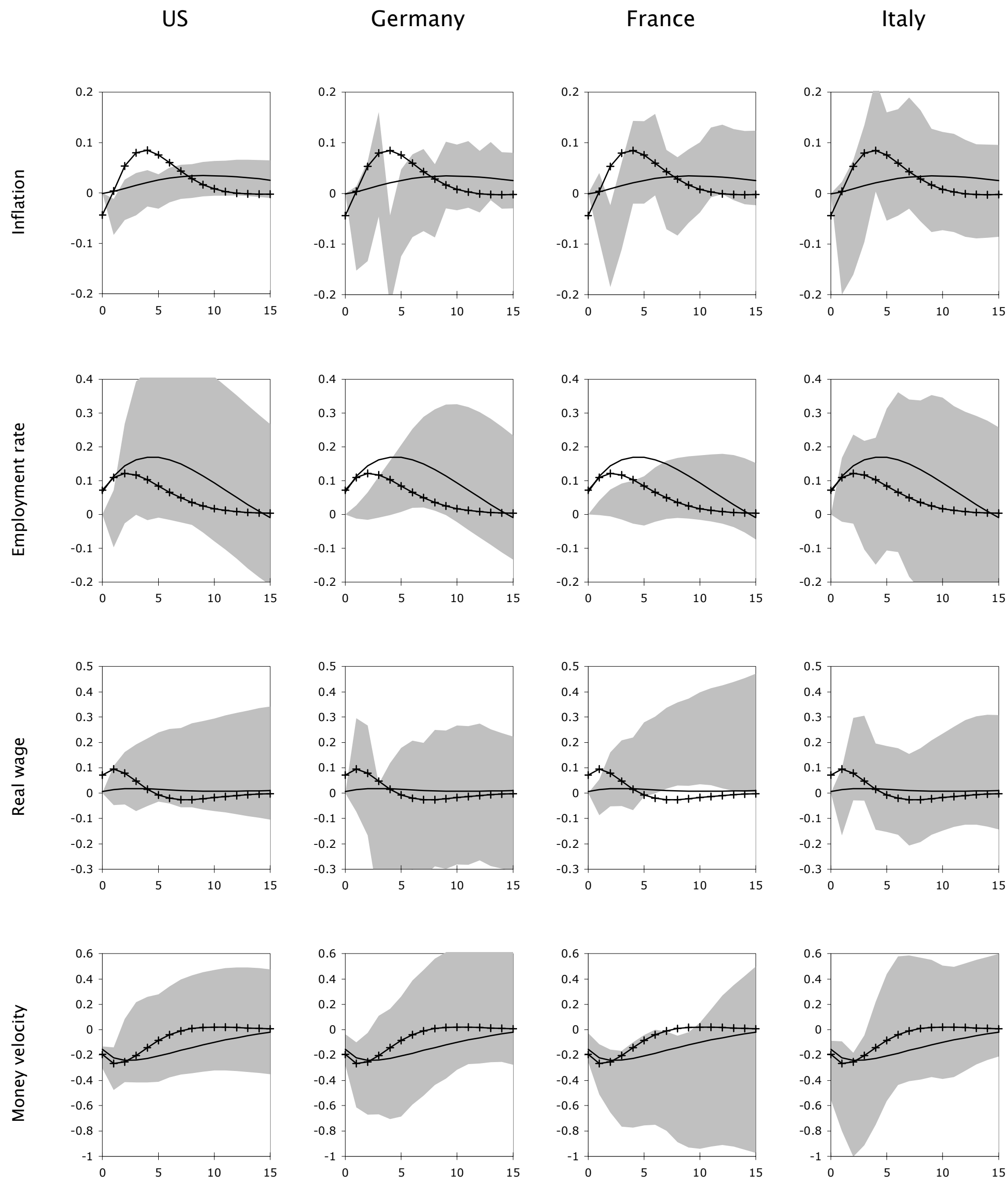


Figure 3: Empirical and theoretical impulse responses after a monetary policy shock.



Legend
Solid line: model with good-fit; Line with crosses: base model

Figure 4: Empirical and theoretical impulse responses after a monetary policy shock (continued).

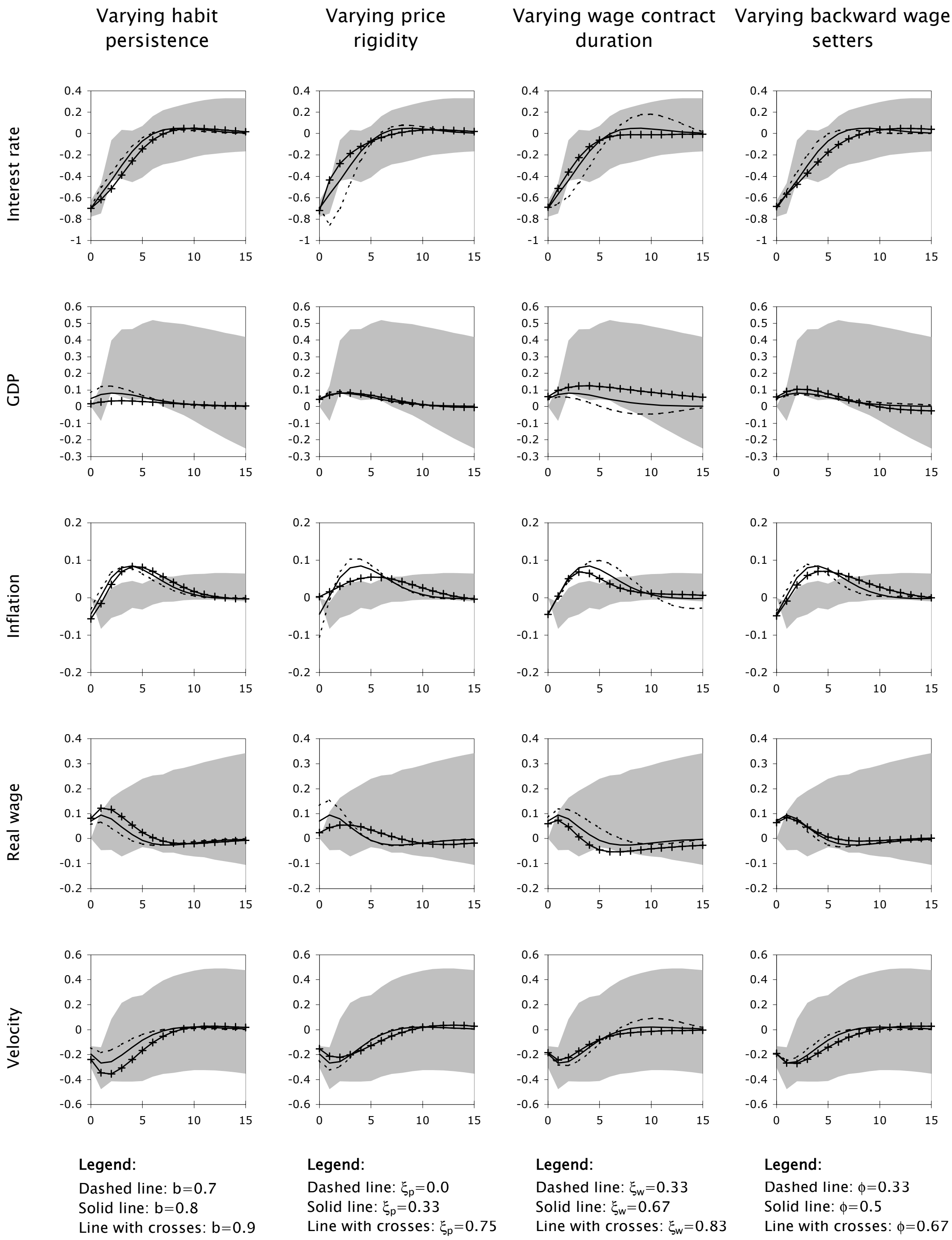


Figure 5: Empirical and theoretical responses after a monetary policy shock: some sensitivity exercises.

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