

# How Important are Financial Frictions in the U.S. and the Euro Area?\*

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## Abstract

This paper aims to evaluate if frictions in credit markets are important for business cycles in the U.S. and the Euro area. For this purpose, I modify the DSGE financial accelerator model developed by Bernanke, Gertler and Gilchrist (1999) by adding frictions such as price indexation to past inflation, sticky wages, consumption habits and variable capital utilization. When I estimate the model with Bayesian methods, I find that financial frictions are relevant in both areas. According to the posterior odds ratio, the data clearly favors the model with financial frictions both in the U.S. and the Euro area. Moreover, consistent with common perceptions, financial frictions are larger in the Euro area.

*Keywords:* Financial frictions, DSGE models, Bayesian estimation

*JEL:* C11, C15, E32, E40, E50, G10

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# 1 Introduction

The works of Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997), where endogenous procyclical movements in entrepreneurial net worth magnify investment and output fluctuations, constitute the corner stone of many recent theoretical papers with financial frictions. Bernanke, Gertler, and Gilchrist (1996) develop the so-called financial accelerator, a mechanism based on information asymmetries between lenders and entrepreneurs that creates inefficiencies in financial markets, which affect the supply of credit and amplify business cycles. Specifically, during booms (recessions), an increase (fall) in borrowers' net worth decreases (increases) their cost of obtaining external funds, further stimulating (reducing) investment and amplifying the effects of the initial shock. The financial accelerator approach has become wide-spread in the literature and many studies have introduced this type of frictions in DSGE models (Bernanke, Gertler, and Gilchrist (1999), henceforth BGG; Christiano, Motto, and Rostagno (2003)).

The purpose of this paper is to answer two questions. First, I want to determine if frictions in credit markets are important for business cycles, even if realistic frictions in goods and labor markets are added to a model with frictions in financial markets. After the banking crisis experienced by many countries in the 1990s and in 2008, financial market conditions have turned out to be a relevant factor for economic fluctuations. In this paper, however, I do not consider financial frictions as a source of shocks, but as a mechanism for the propagation of other shocks in the economy. The second question I investigate is whether financial frictions have a similar magnitude in the U.S. and the Euro area. There is a common perception that financial markets are more developed in the U.S. and, consequently, more efficient. This is a relevant question for better understanding the relative performance of the two areas in recent years.

To answer these two questions, I modify the standard BGG model and estimate it for U.S. and European data using Bayesian methods. I extend the BGG model by adding price indexation to past inflation, sticky wages, consumption habits and variable capital utilization. One benefit of using Bayesian methods is that we can include prior information about the parameters, especially information about structural parameters from microeconomic studies.

Despite the ample theoretical work based on the financial accelerator, more work is needed to evaluate the empirical relevance of this class of models. Christiano, Motto, and Rostagno (2003) and Christiano, Motto, and Rostagno (2008) estimate a DSGE model with a financial accelerator, but they calibrate the parameters related to the financial frictions. Christensen and Dib (2008) estimate the standard BGG model for the U.S. using maximum likelihood and find evidence in favor of the financial accelerator model. Meier and Muller (2006) also estimate a model with a financial accelerator for the U.S. but matching the impulse response functions after a monetary policy shock. They find that financial frictions do not play a very important role in the model. The results in my paper are able to reconcile the different conclusions of the previous literature. Moreover, while in the last two papers financial frictions are reduced to the elasticity of the external finance premium with respect to the change in the leverage position of entrepreneurs, in my paper I estimate the structural parameters affecting credit markets. In addition, Levin, Natalucci, and Zakrajsek (2004) use microdata to estimate the structural parameters of a canonical debt contract model with informational frictions. Using data for 900 U.S. firms over the period 1997Q1 to 2003Q3, they reject the null hypothesis of frictionless financial markets.

The paper contributes to the existing literature in three respects. It empirically investigates the importance of frictions in credit markets for business cycles both in the U.S. and the Euro area. It uses Bayesian methods to estimate a DSGE model with a financial accelerator. And unlike Christensen and Dib (2008) and Meier and Muller (2006), it can identify the structural parameters of the financial contract.

The results indicate that financial frictions are relevant in both areas. Using posterior odds ratios as the evaluation criterion, I find that the data favors a model with financial frictions both in the U.S. and the Euro area. Moreover, consistent with common perceptions, financial frictions are quantitatively more important in the Euro area.

The rest of the paper is organized as follows. In Section 2, I describe the model. Section 3 presents the estimation methodology while Section 4 presents the results. In Section 5, I discuss the results. Section 6 concludes.

## 2 The Model

The specification of the model follows the work of BGG who incorporate financial market frictions through a financial accelerator mechanism in a general equilibrium model. The basic idea of the financial accelerator is that there exists a negative relationship between the external financial premium (the difference between the cost of funds raised externally and the opportunity cost of funds) and the net worth of potential borrowers. The intuition is that firms with higher leverage (lower net worth to capital ratio) will have a greater probability of defaulting and will therefore have to pay a higher premium. Since net worth is procyclical (because of the procyclicality of profits and asset prices), the external finance premium becomes countercyclical and amplifies business cycles through an accelerator effect on investment, production and spending.

Following the recent literature in DSGE models, I extend the basic model of BGG with other features proved to be important to match the data. These include external habit formation in consumption, variable capital utilization and Calvo prices and wages with full indexation to previous period inflation. It is important to introduce these frictions since when testing for financial frictions, the results might be capturing dynamics in the data caused by other frictions. For instance, for given parameters, the response of prices after a monetary policy shock will be smoother in a model without a financial accelerator. However, introducing variable capital utilization also helps offset the fluctuations in labor productivity and affects the marginal cost, which is reflected in a more gradual response of prices. Given these additional frictions in other markets, I ask whether financial frictions are still empirically important.

Christiano, Motto, and Rostagno (2003, 2008) also extend the BGG model but with several differences. First, they include a banking sector. Second, in their paper, the return on deposits received by households is in nominal terms which allows for a “debt deflation” effect. Third, they assume there are costs for changing the investment flow while I assume there are adjustment costs in the production of capital.<sup>1</sup> Fourth, in my model, variable capital utilization arises because of higher depreciation rates, while in

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<sup>1</sup> Groth and Khan (2007) find that it is difficult to motivate investment adjustment costs from a disaggregated empirical perspective.

their model high capital utilization gives rise to higher cost in terms of goods. Last, I introduce external habit formation in consumption, while they use internal habits.

There are seven type of agents in the model: households, retailers, wholesale sector firms, capital producers, entrepreneurs, financial intermediaries and government. The following subsections describe the behavior of these agents.

## 2.1 Households

Consider a continuum of individuals, indexed by  $j$ , whose total mass is normalized to unity. In each period, each of these households maximizes its expected lifetime utility choosing a final consumption good,  $c_t^j$ , nominal bonds issued by the government,  $nb_{t+1}^j$ , and real deposits held at financial intermediates,  $d_{t+1}^j$ , which pay a real gross free risk rate  $r_t$ . Moreover, each household supplies differentiated labor services to the wholesale sector,  $l_t^j$ . Following Christiano, Eichenbaum, and Evans (2005), I assume that households buy securities with payoffs contingent on whether they can reoptimize their wages. This ensures that, in equilibrium, households are homogenous in consumption and asset holdings. Households discount the future at a rate  $\beta$ .

The representative household's period utility and budget constraint are

$$U_t = \nu_t \log(c_t^j - hc_{t-1}) - \frac{\xi_t}{2} (l_t^j)^2$$

and

$$\frac{nb_{t+1}^j}{p_t} + d_{t+1}^j + c_t^j = \frac{w_t^j}{p_t} l_t^j + r_{t-1} d_t^j + r_{t-1}^n \frac{nb_t^j}{p_t} - t_t + div_t + X_t^j,$$

where  $w_t^j$  is the nominal wage of household  $j$ ,  $p_t$  is the nominal level of prices,  $c_t$  is aggregate consumption,  $r_{t-1}^n$  is the nominal interest rate,  $t_t$  are lump-sum taxes,  $div_t$  are dividends received from ownership of firms and  $X_t^j$  are net cash inflows from participating in state-contingent security markets.  $\nu_t$  and  $\xi_t$  are shocks to consumer preferences and leisure, respectively, which follow  $AR(1)$  processes with mean equal to one.

The introduction of external habit formation in consumption mainly helps account for the gradual and hump-shaped response of consumption observed in the data after a monetary policy shock.

Households also act as monopolistically competitive suppliers of differentiated labor services to the wholesale sector, where the labor aggregator has the Dixit-Stiglitz form and  $\tau_t$  is a wage (net) mark up *iid* shock with mean  $\tau$ . I assume that households can reset their wages with probability  $(1 - \vartheta)$  at each period. Whenever the household is not allowed to reset its wage contract, wages are set at  $w_t^j = \pi_{t-1} w_{t-1}^j$ , where  $\pi_{t-1}$  is gross inflation in the previous period. The first-order condition with respect to wages is

$$\begin{aligned} & E_t \sum_{k=0}^{\infty} (\beta\vartheta)^k \nu_{t+k} (c_{t+k}^j - hc_{t-1+k})^{-1} \frac{\tilde{w}_t^j}{p_{t+k}} \frac{l_{t+k}^j}{\tau_{t+k}} \frac{\pi_t}{\pi_{t+1}} \\ &= E_t \sum_{k=0}^{\infty} (\beta\vartheta)^k \xi_{t+k} (l_{t+k}^j)^2 \frac{(\tau_{t+k} + 1)}{\tau_{t+k}}, \end{aligned}$$

where  $\tilde{w}_t^j$  is the optimal wage.

## 2.2 Retailers

Firms in the final good sector produce a consumption good,  $y_t$ , in a perfectly competitive market, combining a range of intermediate goods,  $y_t^s$ ,  $s \in (0, 1)$ . The production function transforming intermediate goods into final output is the usual Dixit-Stiglitz aggregator where  $\lambda_t \geq 0$  is a (net) mark up *iid* shock with mean  $\lambda$ . Firms take prices as given and choose  $y_t^s$  to minimize costs subject to the Dixit-Stiglitz aggregator. The first-order conditions of this problem imply

$$y_t^s = \left( \frac{p_t}{p_t^s} \right)^{(\lambda_t+1)/\lambda_t} y_t.$$

## 2.3 Wholesale Sector Firms

The existing range of intermediate inputs are produced by a continuum of monopolistically competitive firms indexed by  $s \in [0, 1]$ . Each firm hires the services of capital,  $k_t^s$ , and labor,  $L_t^s$ , to face the demand curve for its product. It rents capital from an entrepreneurial sector, which owns the capital stock.

Firms produce according to Cobb-Douglas production function:

$$y_t^s = a_t (k_t^s)^\alpha (L_t^s)^{1-\alpha},$$

where  $a_t$  is a productivity shock which follows a first-order autoregressive process with mean one. Each intermediate goods firm chooses capital and labor to minimize its total costs, taking factor prices as given:

$$\min_{L_t^s, k_t^s} \frac{w_t}{p_t} L_t^s + z_t k_t^s,$$

subject to the production function, where  $z_t$  is the real rental price of capital.

Moreover, wholesale firms have market power and can choose prices to maximize expected profits with probability  $1 - \theta$  in each period (Calvo, 1983). Firms that cannot choose prices index their prices according to the last period's inflation rate:  $p_t^s = \pi_{t-1} p_{t-1}^s$ . For those firms that can choose prices,  $\hat{p}_t$ , the first-order condition is

$$\begin{aligned} & E_t \sum_{k=0}^{\infty} (\beta\theta)^k m_{t,t+k} y_{t+k} (1/\lambda_{t+k}) \left[ \frac{\hat{p}_t}{p_{t-1} \pi_{t+k}} \right]^{-1/\lambda_{t+k}} \\ &= E_t \sum_{k=0}^{\infty} (\beta\theta)^k m_{t,t+k} y_{t+k} (\lambda_{t+k} + 1) / \lambda_{t+k} s_{t+k} \left[ \frac{\hat{p}_t}{p_{t-1} \pi_{t+k}} \right]^{-(\lambda_{t+k} + 1)/\lambda_{t+k}}, \end{aligned}$$

where  $\beta^k m_{t,t+k} = \beta^k \frac{u_c(t+k)}{u_c(t)}$  is the stochastic discount factor between periods  $t$  and  $t+k$  and  $s_t$  is the real marginal cost. Profits are distributed to households.

## 2.4 Capital Producers

The physical stock of capital,  $\tilde{k}_t$  (where the  $t$  subscript indicates when capital is actually used), is produced by a continuum of competitive firms indexed by  $j$ . At the end of each period, these firms produce new capital goods combining investment  $i_t^j$  and the existing capital stock. Capital producers buy the undepreciated capital stock at the end of each period and after producing the new capital, they sell it back to the entrepreneurs at a relative price  $q_t$ .<sup>2</sup> I assume there are increasing marginal adjustment costs in the production of capital: investment expenditures,  $i_t^j$ , deliver  $\Phi\left(\frac{i_t^j}{\tilde{k}_t^j}\right) \tilde{k}_t^j$  new capital goods. This generates a weaker response of investment to any shock and a price of capital relative to consumption goods different from one.

I assume that investment decisions are made one period in advance, while the price of capital adjusts immediately after a shock. This assumption helps account for a gradual

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<sup>2</sup> We can assume that capital-producing firms are owned by entrepreneurs. After entrepreneurs repurchase the old stock of capital, used capital depreciates.

response of investment to shocks affecting the real interest rate, a strong feature observed in the data. Capital producers solve the following problem:

$$\max_{i_{t+1}^j} E_t \left[ q_{t+1} \Phi \left( \frac{i_{t+1}^j}{\tilde{k}_{t+1}^j} \right) \tilde{k}_{t+1}^j - i_{t+1}^j \right],$$

where near the steady state  $\Phi > 0$ ,  $\Phi'(\cdot) > 0$ ,  $\Phi''(\cdot) < 0$ . I also assume that in steady state, the relative price of capital is one. In the empirical part, I estimate  $\varphi$ , the elasticity of the price of capital with respect to the investment-capital ratio in the steady state:

$$\varphi = \Phi'' \left( \frac{i}{\tilde{k}} \right) \left( \frac{i}{\tilde{k}} \right).$$

The law of motion of the aggregate capital stock is

$$\tilde{k}_{t+1} = \Phi \left( \frac{i_t}{\tilde{k}_t} \right) \tilde{k}_t + (1 - \delta(u_t)) \tilde{k}_t,$$

where  $u_t$  is the rate of capital utilization,  $\delta(u_t) \in (0, 1)$  is a convex depreciation function with  $\delta'(\cdot) > 0$ , and  $\delta''(\cdot) > 0$  around the steady state. I choose the function  $\delta(u_t)$  such that  $\delta(0) = 0$ ,  $\delta(\infty) = 1$  and in steady state,  $\delta(1) = \delta$ .

## 2.5 Entrepreneurs and Financial Intermediaries

Entrepreneurs own the physical stock of capital,  $\tilde{k}_t$ , and provide capital services,  $k_t$ . They finance capital purchases both with their own net worth and debt. Capital services are related to the physical stock of capital by

$$k_t = u_t \tilde{k}_t.$$

Entrepreneurs are risk neutral and have finite horizons:  $\gamma < 1$  is their probability of survival to the next period. This assumption rules out the possibility of entrepreneurs accumulating enough wealth to be fully self-financed: part of their capital must be financed through bank loans with a standard debt contract.

At the end of period  $t$ , entrepreneurs decide how much to borrow. Then, at the beginning of period  $t + 1$ , after observing all the shocks, they choose how intensely to use their capital.

### 2.5.1 Optimal Contract

As in BGG, the return on capital depends on both aggregate and idiosyncratic shocks. The ex-post return on capital for entrepreneur  $i$  is  $\omega_{t+1}^i r_{t+1}^k$ , where  $\omega^i$  is an *i.i.d.* log-normal random variable with pdf  $F(\omega)$  and mean one.<sup>3</sup> The riskiness of entrepreneurs is determined by the variance of the idiosyncratic shock,  $\sigma_\omega$ . The average return of capital in the economy is

$$r_{t+1}^k = \frac{u_{t+1} z_{t+1} + (1 - \delta(u_{t+1})) q_{t+1}}{q_t}.$$

Entrepreneurs finance their capital stock at the end of period  $t$  with their own net worth at the end of the period,  $n_{t+1}^i$ , and banks loans,  $b_{t+1}^i$ :

$$q_t \tilde{k}_{t+1}^i = n_{t+1}^i + b_{t+1}^i.$$

The entrepreneur borrows from a financial intermediary that obtains its funds from households, with an opportunity cost equal to the riskless gross rate of return,  $r_t$ . At  $t + 1$ , entrepreneurs settle their bank loans. Those entrepreneurs with large  $\omega_{t+1}^i$  ( $\omega_{t+1}^i > \varpi_{t+1}^i$ ) pay back the loan to the bank. Entrepreneurs with  $\omega_{t+1}^i < \varpi_{t+1}^i$  declare default and after being monitoring, give all their resources to the bank. The cutoff value  $\varpi_{t+1}^i$  is determined in an optimal contract between the lender and entrepreneurs.

Financial frictions arise in the economy because following a “costly state verification” approach, the lenders must pay a fixed auditing cost to observe an individual borrower’s realized return. Monitoring costs are assumed to be a proportion  $\mu$  of the realized gross payoff to the firms’ capital, i.e., monitoring costs equal  $\mu \omega_{t+1}^i r_{t+1}^k q_t \tilde{k}_{t+1}^i$ .<sup>4</sup> When  $\mu = 0$ , we are in the special case of frictionless financial markets.

Moreover, since the entrepreneur is risk neutral, he only cares about the mean return on his wealth. He guarantees the lender a return that is free of any systematic risk: he offers a state-contingent contract, conditional on  $r_{t+1}^k$ , that guarantees the lender a expected return equal to the riskless rate.

Under these assumptions, the optimal contract is chosen to maximize expected entrepreneurial utility, conditional on the expected return of the lender, for each possible

<sup>3</sup> As in Christiano, Motto, and Rostagno (2003), I assume that after entrepreneurs have purchased capital, they draw an idiosyncratic shock which changes their effective capital stock from  $\tilde{k}_{t+1}^i$  to  $\omega_{t+1}^i \tilde{k}_{t+1}^i$ .

<sup>4</sup>The relevant price here is  $q_t$  since capital price gains are included in  $r_{t+1}^k$ .

realization of  $r_{t+1}^k$ , being equal to the riskless rate,  $r_t$ .

In equilibrium, the intermediary holds a pooled, and perfectly safe portfolio and the entrepreneurs absorb any aggregate risk. In other words, ex-ante the intermediary knows it will get  $r_t$  in return for its total loans to entrepreneurs, while for entrepreneurs the repayment to the bank depends on the ex-post realization of  $r_{t+1}^k$ .

Summarizing, the optimal contract will be incentive compatible, characterized by a schedule of state contingent threshold values of the idiosyncratic shock  $\varpi_{t+1}^i$ , such that for values of the idiosyncratic shock greater than the threshold, the entrepreneur is able to repay the lender, and for values below the threshold, the entrepreneur declares default and the lender obtains  $(1 - \mu) \omega_{t+1}^i r_{t+1}^k q_t \tilde{k}_{t+1}^i$ . Only one-period contracts between borrowers and entrepreneurs are feasible.

BGG show that two first-order conditions hold in the optimal contract between entrepreneurs and banks, namely:

$$E_t \left\{ (1 - \Gamma(\varpi_{t+1}^i)) \frac{r_{t+1}^k}{r_t} + \lambda(\varpi_{t+1}^i) \left[ (\Gamma(\varpi_{t+1}^i) - \mu G(\varpi_{t+1}^i)) \frac{r_{t+1}^k}{r_t} - 1 \right] \right\} = 0$$

and

$$[\Gamma(\varpi_{t+1}^i) - \mu G(\varpi_{t+1}^i)] r_{t+1}^k q_t \tilde{k}_{t+1}^i = r_t [q_t \tilde{k}_{t+1}^i - n_{t+1}^i],$$

where  $\mu G(\varpi_{t+1}^i) = \mu \int_0^{\varpi_{t+1}^i} \omega dF(\omega)$  is expected monitoring costs,  $\Gamma(\varpi_{t+1}^i) = (1 - F(\varpi_{t+1}^i)) \varpi_{t+1}^i + G(\varpi_{t+1}^i)$  is the expected gross share of profits going to the lender, and  $\lambda(\varpi_{t+1}^i) = \frac{\Gamma'(\varpi_{t+1}^i)}{\Gamma'(\varpi_{t+1}^i) - \mu G'(\varpi_{t+1}^i)}$ .

From the first first-order condition, we see that when financial markets are frictionless,  $\mu = 0$ ,  $\lambda(\varpi_{t+1}^i) = 1$  and  $E_t r_{t+1}^k = r_t$ : the ex-ante return on capital equals the risk free rate when there are no monitoring costs.

The second first-order condition guarantees that the financial intermediary receives an expected return equal to the opportunity cost of its funds.

From the first equation, we also see that in equilibrium  $\varpi_{t+1}^i$  is the same for all entrepreneurs, and will depend on the external financial premium. Aggregation is then straightforward and it can be shown that capital expenditures by each entrepreneur  $i$  are proportional to his net worth.

Aggregate entrepreneurial net worth (in consumption units) at the end of period  $t$ ,

$n_{t+1}$  is given by

$$n_{t+1} = \gamma \left\{ r_t^k q_{t-1} \tilde{k}_t - \left[ r_{t-1} \left( q_{t-1} \tilde{k}_t - n_t \right) + \mu \int_0^{\bar{\omega}_t} \omega dF(\omega) r_t^k q_{t-1} \tilde{k}_t \right] \right\} + w^e,$$

where  $\gamma$  is the fraction of entrepreneurs surviving to the next period, and  $w^e$  are government net transfers to entrepreneurs. In each period, a fraction  $(1-\gamma)$  of new entrepreneurs enters the market receiving some transfers and the wealth of the fraction that did not survive is given to the government.

### 2.5.2 Optimal Capital Utilization Decision

After observing the shocks at the beginning of period  $t + 1$ , entrepreneurs decide how intensively to use their capital. Higher capital utilization is costly because of higher depreciation rates.<sup>5</sup> This is an important assumption because it allows for variable capital utilization, a relevant feature in the data. Entrepreneurs choose capital utilization,  $u_{t+1}$  to solve

$$\max_{u_{t+1}} \left[ \frac{u_{t+1} z_{t+1} + (1 - \delta(u_{t+1})) q_{t+1}}{q_{t+1}} \right].$$

## 2.6 Monetary and Fiscal Policy

The monetary authority conducts monetary policy by controlling the gross nominal interest rate,  $r_t^n$ . For convenience, I assume a cashless economy, but the monetary authority can set the interest rate directly in the inter-bank market. The loglinearized monetary policy rule is

$$\hat{r}_t^n = \rho^r \hat{r}_{t-1}^n + (1 - \rho^r) [\gamma^\pi E \hat{\pi}_{t+1} + \gamma^y \hat{y}_t / 4] + \hat{\varepsilon}_t^r,$$

where letters with a hat represent log deviations from the steady state,  $\hat{\varepsilon}_t^r$  is an *iid* monetary policy shock with mean zero and  $\hat{\pi}_{t+1}$  is the inflation rate in  $t + 1$ .

Government consumption expenditures,  $g_t$ , follow a first-order autoregressive process. The government finances its expenditures by lump-sum taxes,  $t_t$ , and nominal bonds,  $nb_{t+1}$ . I assume the government elastically supplies bonds until the bond market clears and the resulting fiscal surplus/deficit is adjusted with lump-sum taxes to the households.

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<sup>5</sup>This approach has been used by Baxter and Farr (2005), among others.

## 2.7 Competitive Equilibrium

In a competitive equilibrium, all the above optimality conditions are satisfied. In addition, markets clear. The aggregate resource constraint is

$$y_t = c_t + i_t + g_t + \mu \int_0^{\bar{\omega}_t} \omega dF(\omega) r_t^k q_{t-1} \tilde{k}_t.$$

Final goods are allocated to consumption, investment, government expenditure and monitoring costs associated with defaulting entrepreneurs. Furthermore, credit markets clear and  $b_t = d_t$ .

## 3 Methodology for Estimation and Model Evaluation

To solve the model, I loglinearize the equilibrium conditions around their steady state values. In Appendix A, the loglinearized version of the model is presented. Then, the method described in Sims (2002) (and the companion matlab code gensys.m) is used to solve the linearized model.

The model has a total of 29 free parameters. As in previous studies, some of these parameters are calibrated before estimation since the data contains little information about them. The steady state rate of depreciation of capital  $\delta$  is set equal to 0.025, which corresponds to an annual rate of depreciation of ten percent. The discount factor  $\beta$  is set at 0.99, which corresponds to an annual real rate of four percent in steady state. The steady state share of government spending is set equal to 19.5 percent.<sup>6</sup> The parameter of the Cobb-Douglas production function,  $\alpha$ , is set equal to 0.33, while the steady state price and wage mark ups,  $\lambda$  and  $\tau$ , are set at 20 percent. These values imply steady state consumption and investment ratios of 60.9 and 19.6 percent in models without financial frictions.<sup>7</sup> Following the calibration of Baxter and Farr (2005),  $\delta''/\delta'$  is set equal to one. The steady state probability of default,  $F(\varpi)$ , is set to three percent per year, the same

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<sup>6</sup> Since this number does not include transfers, we can assume the same value for the U.S. and the Euro area.

<sup>7</sup> In models with a financial accelerator, these ratios will also depend on the risk premium.

value as BGG.<sup>8</sup> Last, the fraction of entrepreneurs surviving to the next period,  $\gamma$ , is set to 0.985 which implies that, on average, entrepreneurs live for sixteen years.

The remaining 20 parameters are estimated using Bayesian procedures. I start by solving the model for an initial set of parameters. Then, the Kalman Filter is used to calculate the likelihood function of the data (for given parameters). Combining prior distributions with the likelihood of the data gives the posterior kernel which is proportional to the posterior density. Since the posterior distribution is unknown, I use Markov Chain Monte Carlo (MCMC) simulation methods to conduct inference about the parameters.

To check convergence, I run different chains starting from different and dispersed points. Each set of estimates is based on two different chains starting from the mode of the posterior plus-minus two standard deviations, with a total of 200,000 draws in each simulation and a burn-in period of 40,000.<sup>9</sup> Convergence was monitored calculating the potential scale reduction as described in Gelman, Carlin, Stern, and Rubin (2004), which declines to 1 as convergence is achieved. This ratio was computed for all parameters.

The data used for the estimation corresponds to seven variables of the model: real output, real consumption, real investment, hours worked, nominal interest rate, inflation and real wages. I do not include any financial variables in the estimation. To compare the model with and without financial frictions, the former will have a natural advantage if financial variables are included since the BGG model performs poorly in terms of financial variables when  $\mu = 0$ .

The data used in the estimation is quarterly data between 1980Q1 and 2007Q4. All data is linearly detrended (see Appendix B for details).

### 3.1 Prior Distribution

All prior distributions were selected from the beta, gamma and uniform distributions, depending on the supports and characteristics of the parameters. The prior distributions are the same for the U.S. and the Euro area and are shown in Table 1.

Regarding the shocks affecting the economy, the autoregressive coefficients have a

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<sup>8</sup> De Fiore and Uhlig (2005) report that average default rates are similar in the U.S. and the Euro area, i.e. between 3 and 4.5 percent.

<sup>9</sup> The percentage of draws in the MCMC that generated a unique solution was between 96 to 99.5.

beta distribution with mode 0.85 and standard error 0.1, while the standard deviations for the shocks follow a gamma distribution with mode 0.01 and standard error 0.1.

The priors for the long-run weights on inflation and output in the central bank reaction function are based on Clarida, Gali, and Gertler (2000), where  $\gamma^\pi$  and  $\gamma^y$  are gamma distributed with mode 2 and 0.5, respectively.<sup>10</sup> The interest rate smoothing parameter,  $\rho_r$ , follows a beta distribution with mode 0.85.

Many of the priors are standard and follow the literature (Smets and Wouters (2007), Adolfson, Laséen, Lindé, and Villani (2007)). The habit persistence parameter,  $h$ , has a beta distribution with mode 0.70. The parameters determining prices and wages follow a beta distribution. The modes of the Calvo parameters  $\theta$  and  $\vartheta$ , the probability of not adjusting prices and wages, were set equal to 0.70, so that, on average, prices and wages adjust every ten months.

Some of the parameters are particular to the way I capture some frictions in the model. This is true for the elasticity of the capital price to the investment-capital ratio,  $\varphi$ . BGG set this parameter equal to  $-0.25$  while King and Wolman (1996) use a value of  $-2$  based on estimations of Chirinko (1993). Since there is not enough information about this parameter, I use a uniform prior distribution between  $-2$  and  $0$ .

Other non-standard parameters in the model are those related to the financial frictions. Since the assessment of the importance of financial frictions relies on a clear identification of monitoring costs,  $\mu$ , and the steady state external risk premium (the difference between the cost of funds raised externally and the opportunity cost of funds),  $r^k - r$ , I chose very diffuse priors for these parameters. I chose a uniform prior between  $0$  and  $0.50$  for  $\mu$ . This range includes all the values used in the literature without putting particular weight on any of them. Finally, the prior for the steady state external risk premium,  $r^k - r$ , was set gamma distributed with a mode of  $0.005$ , which corresponds to an annual  $2\%$  risk premium as in BGG, and a large standard error: the prior implies that the annualized steady state premium lies with  $95\%$  probability between  $100$  and  $500$  basis points. This range is much larger than the one reported in De Fiore and Uhlig (2005) who report average risk premiums on bonds and loans between  $160$  and  $340$  basis

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<sup>10</sup> Estimates are robust using a prior gamma distribution with mode  $1.5$  and standard deviation  $0.2$  for  $\gamma^\pi$ .

points in the U.S. and the Euro area. Of course this is the average premium, and at any particular point in time the premium can differ from its steady state value.

## 3.2 Model Comparison

To pairwise compare the performance of the different models, I calculate the posterior odds ratio. Since I set the prior odds equal to one, the posterior odds ratio is the ratio of the marginal data densities between any two models. I use the modified harmonic mean to approximate the marginal likelihood.

# 4 Results

## 4.1 U.S.

### 4.1.1 Frictions in the U.S.

In Table 2, I report the log marginal data density and posterior odds ratio for the two versions of the model: with and without credit frictions. The posterior odds ratio of the model with financial frictions against the model without financial frictions is  $10^{13}$  to one, which is decisive evidence against the model without a financial accelerator. This extends the findings by Christensen and Dib (2008) who estimate the standard BGG model with maximum likelihood and provide evidence in favor of a financial accelerator.

In addition to the prior distributions, Table 1 also reports the mean and the 5th and 95th percentile of the posterior distribution for U.S. data.<sup>11</sup> The table shows that the estimated mean of monitoring costs is sixteen percent. This result is in line with the results of Levin, Natalucci, and Zakrajsek (2004). Using microdata for 900 U.S. firms over the period 1997Q1 to 2003Q3, they estimate that time-varying monitoring cost moved between eight and sixteen percent between 1997 and 1999. When they smooth through a spike in 1998Q4, the average monitoring costs during this period is close to twelve percent

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<sup>11</sup> In results available on request, I show that all the posterior estimates converge to a stationary distribution. The only parameters which presents some doubts is the variance of the wage mark up shock,  $\sigma^\tau$ , and the Calvo wage parameter,  $\vartheta$ . However, small changes in these parameters do not affect the properties of the model when the impulse response functions are plotted. Moreover, the data is informative to identify all the parameters.

of the realized gross payoff to the firms' capital. After the fall of the stock market in 2000, monitoring costs went up to reach values as high as forty percent, and then once more declined in 2003.

#### 4.1.2 Parameter Estimates for the U.S.

Table 1 shows that the estimated posterior mean of the risk premium in steady state,  $r^k - r$ , implies an annual premium of 3.2 percent, which falls in the 1.9-3.4 interval reported in De Fiore and Uhlig (2005). Together with other parameters, this value implies that the investment-output ratio and consumption-output ratio in steady state are 16 and 64 percent, respectively. Moreover, the fraction of GDP used in bankruptcy costs is around 0.5 percent on average, and in steady state the ratio of government net transfers to entrepreneurs to net worth,  $w^e/n$ , is -1.7 percent.<sup>12</sup> The 95 percent simulated interval for the ratio of capital to net worth for the U.S. was between 2.6 and 4.6. These values are a little bit higher than the value of 2 usually used in the literature.

Table 1 indicates that the four autoregressive shocks affecting the economy are very persistent as compared to the priors.

The habit persistence parameter has a posterior mean of 0.84 as compared to the prior mean of 0.70. The posterior mean of  $\theta$  implies that prices on average adjust once every fourteen months. In the case of wages, the average duration of contracts is estimated at seven months. In general, these values are similar to the results in Smets and Wouters (2007).

The elasticity of capital price with respect to the investment capital ratio,  $\varphi$ , has a posterior mean of -0.41.

The posterior mean for the coefficient on future inflation,  $\gamma^\pi$ , is 2.1, while the coefficients on output,  $\gamma^y$ , and past interest rate,  $\rho_r$ , have a posterior mean of 0.44 and 0.63 respectively.

When the model is estimated without monitoring costs (no financial accelerator), the results are robust for most of the parameters. However, there are some differences. First,

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<sup>12</sup> These values imply an elasticity of the external finance premium with respect to the leverage ratio of 0.04, which is the same value estimated by Christensen and Dib (2008). The implied standard deviation of the idiosyncratic shock,  $\sigma_\omega$ , is 0.15.

the variances of the shocks are larger in the model without frictions. This implies that the model without financial frictions needs larger shocks to match the data.

Second, the elasticity of the price of capital with respect to the investment-capital ratio,  $\varphi$ , is higher in the model with financial frictions. A possible explanation is that investment reacts more to shocks in a model with a financial accelerator, which requires higher adjustment costs to match the dynamics of investment in the data. However, financial frictions are important to match other features of the model. In other words, while  $\varphi$  mainly affects investment through a capital price channel, financial frictions matter also to explain movements of other variables in the model. A more extended discussion about this point is included in Section 5.

Last, monetary policy reacts slightly more to output in the case with financial frictions which dampens the amplification of output fluctuations caused by the financial accelerator.

## **4.2 Euro Area**

### **4.2.1 Frictions in the Euro Area**

Table 2 shows that the posterior odds ratio for the hypothesis of financial frictions versus no financial frictions in the Euro area is  $10^4$  to one, which clearly favors a model with monitoring costs. Table 3 shows that the posterior mean of monitoring costs in the Euro area is 27 percent, seventy percent higher than the cost estimated for the U.S., and outside the 95 percent confidence bands for the U.S. As for the U.S., the data thus prefers a model with credit market imperfections, but these imperfections are larger in the Euro area.

### **4.2.2 Parameter Estimates for the Euro Area**

Table 3 reports the mean and the 5th and 95th percentile of the posterior distribution of the model with and without financial frictions in the Euro area.<sup>13</sup> The posterior distribution of the parameters using European data is in general very similar to that

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<sup>13</sup> In the case of the Euro area, all the posterior estimates converge to a stationary distribution, and none of the parameters present identification problems.

of the U.S. This indicates that the shocks driving the economy and the transmission mechanisms in the two areas are not too different. However, some parameters display more distinct differences.

The fact that monitoring costs are larger in the Euro area drives up the external risk premium: in the Euro area, the posterior mean of the annual risk premium is 5.2 percent in steady state. This value is higher than the one reported in De Fiore and Uhlig (2005) for Euro data: they report a risk premium on loans and bonds between 1.6 and 3.4 percent. The estimated risk premium implies that in steady state, the investment and consumption ratio to output are 14.4 and 65.4 percent, respectively, and that the fraction of GDP used in bankruptcy cost is 0.7 percent.

In the case of the Euro area, in steady state  $w^e/n$  is -2.2 percent, and the capital to net worth ratio lies with 95 percent probability between 2.2 and 3.5 which is consistent with the values reported in McClure, Clayton, and Hofler (1999).<sup>14</sup>

Concerning the size of the shocks, monetary shocks are smaller in the Euro area while productivity shocks are larger, which is consistent with the results Smets and Wouters (2005). When it comes to persistence, shocks are more persistent in the U.S., specially technology shocks.

The mean of habit consumption in the Euro area is 0.71. Prices and wages adjust on average every eleven and eight months respectively. The elasticity of the price of capital with respect to the investment capital ratio,  $\varphi$ , is more than twice larger in the Euro area, with a mean value of -1.1. Given larger monitoring costs in the Euro area, the model requires higher adjustment costs in investment to dampen the response of investment after a shock. In the model, the effects of higher adjustment costs dominate and investment responds less in the Euro area (see Figure 3).

The coefficients in the monetary rule are similar in both areas, and different from the prior, thereby suggesting that both areas have responded in a similar way to expected inflation and output in the last decades.

As in the case of the U.S., the response of the interest rate to output is slightly

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<sup>14</sup> These values imply an elasticity of the external finance premium with respect to the leverage ratio of 0.08, which is twice larger than in the U.S. The implied standard deviation of the idiosyncratic shock,  $\sigma_\omega$ , is 0.21.

stronger in the model with financial frictions, while the variances of the shocks are larger in the model without a financial accelerator.

## 5 Discussion

The results show that frictions in financial markets are important both in the U.S. and the Euro area. Moreover, these frictions are larger in the Euro area. This is in line with independent observations suggesting that financial markets are more developed and integrated in the U.S., and that the institutional and legal framework in the two areas differ. Evidently, such discrepancies translate into a less efficient credit market. Moreover, the U.S. has a more fragmented banking sector than the Euro area and a larger number of publicly listed firms 'per capita', which may also imply a more transparent and competitive market.

A number of studies have documented this kind of differences in financial markets on the two sides of the Atlantic. For instance, Cecchetti (1999) shows the Thomson rating to be lower in the U.S., meaning a more efficient banking system. Moreover, while the return on assets is higher in the U.S., loan losses are lower. In the model, loan losses are an increasing function of monitoring costs and though, consistent with higher monitoring costs in the Euro area.

De Fiore and Uhlig (2005) find that investment of the corporate sector relies much more heavily on bank finance in the Euro area than in the U.S.: bank to bond finance ratios are 7.3 and 0.74, respectively. If we also consider that the cost of acquiring information is higher for banks, these two facts imply higher monitoring cost in the Euro area, consistent with the results in my paper. However, in contrast to my paper, De Fiore and Uhlig report that risk premiums on loans are higher in the U.S.

Table 4 reports some selected moments of the data and the simulated model.<sup>15</sup> Overall the table shows that the model overpredicts the volatility of output, consumption and employment which is a common problem in DSGE models.<sup>16</sup> However, the model does

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<sup>15</sup> The posterior moments were computed for a sample of 500 simulations for 100 periods from 100 draws of the posterior. To avoid autocorrelation the draws from the posterior were picked in fixed intervals.

<sup>16</sup> See, for instance, Adolfson, Laséen, Lindé, and Villani (2007), Christensen and Dib (2008) and

better at capturing the relative volatilities respect to output, specially in the case of the Euro area. Moreover, the model with financial frictions performs better than the standard model. The table also shows correlations with output. Again the model with financial frictions does better, but both models have problems replicating the positive correlation of output with the interest rate (and inflation in the case of the U.S.).

## 5.1 Impulse Response Functions

The financial market structure can play an important role in the transmission mechanism of shocks and the decisions of firms. The fact that the Euro area presents more frictions in credit markets than the U.S. might generate different investment dynamics. For example, a model with larger monitoring costs has a more powerful financial accelerator and hence greater response of investment to a monetary policy shock *ceteris paribus*.

Figures 1 and 2 show the mean impulse response functions to selected shocks of equal size for the U.S. and the Euro area. The figures show the responses of the estimated financial accelerator model, the estimated model without financial frictions and the estimated financial accelerator model switching financial frictions off. The first thing to notice is that the financial accelerator amplifies the responses of investment but not of output. The finding that the importance of credit frictions for output fluctuations is minor coincides with the results of Christensen and Dib (2008). However, contrary to my results, they find that the presence of the financial accelerator amplifies and propagates the effects of demand shocks on investment, but it dampens those of supply shocks. I find that the financial accelerator amplifies the response of investment also after supply shocks.<sup>17</sup> This is consistent with the original work of BGG where the financial accelerator amplifies the response of investment also after a productivity shock. One explanation for this is that Christensen and Dib (2008) consider nominal contracts. In that case, the fall of inflation after a supply shock increases the real cost of the debt, pushing net worth down and increasing the external finance premium. As a result, in their model investment reacts less after supply shocks when financial frictions are present.

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Smets and Wouters (2003).

<sup>17</sup> This is true for all shocks in the model.

Second, after a contractive monetary policy shock inflation falls more in a model with financial frictions. This is the case because the higher fall in asset prices ( $q$ ) in the financial accelerator model has an extra effect amplifying the fall in the rental price of capital and thus marginal costs and inflation.

These figures are also helpful to understand the main mechanisms behind the financial accelerator. For instance, after a monetary policy tightening asset prices and net worth fall. Since entrepreneurs are now higher leveraged, they will have a higher probability to default and the external financial premium rises in the financial accelerator model. This makes borrowing more expensive and investment and asset prices fall even further when financial frictions are present.

Figure 3 plots in the same graph impulse response functions of the financial accelerator model to selected shocks for the U.S. and the Euro area. Moreover, the figure plots the responses of the model for the Euro area but assuming the same shocks structure as in the U.S.<sup>18</sup> A way to interpret this figure is if the star line is on top of the straight line, this means that the transmission mechanisms in the two areas are equal (for given shocks). Differences between these two lines are only explained for differences in the other structural parameters, and are independent of the shocks hitting the two economies.

Even though monitoring costs are larger in the Euro area, the response of investment after a shock is lower. This is mostly driven by larger capital adjustment costs in the Euro area which offset the larger size of frictions in credit markets. In that sense, the lower volatility of investment in the Euro area reported in Table 4 is mainly due to larger capital adjustment costs.<sup>19</sup>

Moreover, in the case of technology shocks, the different persistence of this shock in the two areas can explain part of the different transmission mechanisms.

It is worth to notice that even though the response of investment and output is offset because of larger capital adjustment costs in the Euro area, the existence of larger financial frictions have important implications for asset prices and the risk premium.

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<sup>18</sup> Differently from the previous figures, I do not plot the mean impulse response functions, but the impulse response functions evaluated at the posterior mean. This is necessary since I want to include in the same plot counterfactual impulse response functions for alternative structure of the shocks.

<sup>19</sup> De Walque, Smets, and Wouters (2005) also find that adjustment costs in capital accumulation are larger in the Euro area.

Last, Figure 4 shows counterfactual impulse response functions. The figure displays the responses of the financial accelerator model at the mean of the parameters for the U.S. and the responses of the same model changing three parameters. In particular,  $\mu$  and  $r^k - r$  are set to 0.27 and 0.013 as the estimated mean for the Euro area and  $\varphi$  is arbitrarily set to -0.60 in order to match the response of investment after a monetary policy shock (given higher financial frictions higher adjustment costs are needed to match the response of investment). The purpose of doing so is solely to show that financial frictions and capital adjustment costs are not observational equivalent and the response of investment (and other variables) after different shocks make it possible to separately identify these frictions.

The first thing to point out is that even though this combination of parameters generates similar responses of investment after most of the shocks, the response after a consumption preference shock is very different (30 basis points after one period). Second, the larger response of asset prices in the counterfactual scenario generates a different response of marginal costs, and thus of inflation, especially after monetary and technology shocks. In particular, after a monetary shock asset prices fall more the larger frictions (both financial and capital adjustment) pushing the rental price of capital down. This amplifies the fall in marginal costs and thus generates a larger fall of inflation. In the case of technology shocks, the larger increase in asset prices has the opposite effect, generating a lower fall in marginal costs, and thus a lower fall in inflation.

Summarizing, it is only by considering the response of macro variables to a large number of shocks, that we can disentangle the effects of financial frictions and capital adjustment costs. Considering only one shock, one could find a combination of these frictions that generate reasonable similar responses.

This result explains the differences found in previous papers estimating the financial accelerator model. For instance, Meier and Muller (2006) find that after a monetary policy shock, a model with financial frictions does not necessarily better fit the data. However, they do not consider the response of the economy to other shocks. On the other hand, this paper extends the findings by Christensen and Dib (2008) who using maximum likelihood provide evidence in favor of a financial accelerator.

## 6 Conclusions

I study an extended version of the BGG model augmented with other frictions, such as price indexation to past inflation, sticky wages, consumption habits and variable capital utilization. This model allows us to quantify credit market frictions in an economically meaningful way. The model is estimated using Bayesian techniques for both the U.S. and the Euro area.

The results indicate that financial frictions are relevant in both areas, but quantitatively more important in the Euro area. This suggests that the financial market structure can play an important role in the transmission mechanism of shocks and the decisions of firms. The fact that the Euro area has larger credit market frictions might lead one to believe that it has different investment dynamics than in the U.S. In actual fact, however, the response of investment is lower in the Euro area given higher capital adjustment costs which offset the financial accelerator effects on investment. Higher financial frictions in the Euro area do generate different responses of asset prices and the external risk premium, though. I show that only considering the response of the variables to a large number of shocks makes it possible to disentangle these two effects.

As mentioned before, the paper only analyzes whether financial frictions are important as a source of propagation of shocks. A natural extension of the model should allow for financial frictions as a source of shocks: shocks originating from the financial side of the economy. This can be an important component when comparing business cycle dynamics in the U.S. and in the Euro area.

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## A The log-linearized model

To solve the model, I loglinearize the equilibrium conditions around their steady state values. Letters with a hat represent log deviations from the steady state at time  $t$ , and letters without a subscript represent the steady state values of the variables.

The loglinearized versions of aggregate demand and supply are

$$\hat{y}_t = \frac{c}{y}\hat{c}_t + \delta\frac{\tilde{k}}{y}\hat{i}_t + \frac{g}{y}\hat{g}_t + \frac{\mu G(\varpi)r^k\tilde{k}}{y}(\hat{r}_t^k + \hat{q}_{t-1} + \hat{k}_t) + \frac{\mu r^k G'(\varpi)\tilde{k}\varpi}{y}\hat{\varpi}_t \quad (1)$$

and

$$\hat{y}_t = \hat{a}_t + \alpha\hat{k}_t + (1 - \alpha)\hat{L}_t, \quad (2)$$

where  $\delta$  is the steady state capital depreciation.

The consumption Euler equation, the arbitrage condition for nominal bonds and the law of motion of real wages are

$$\hat{c}_t = \frac{(1-h)}{(1+h)}(\hat{v}_t - E_t\hat{v}_{t+1}) + \frac{h}{(1+h)}\hat{c}_{t-1} - \frac{(1-h)}{(1+h)}\hat{r}_t + \frac{E_t\hat{c}_{t+1}}{(1+h)}, \quad (3)$$

$$\hat{r}_t^n = \hat{r}_t + E_t\hat{\pi}_{t+1}, \quad (4)$$

$$E_t \left\{ \begin{array}{l} \eta_0\hat{w}_{t-1}^r + \eta_1\hat{w}_t^r + \eta_2\hat{w}_{t+1}^r + \eta_3\hat{\pi}_{t-1} + \eta_4\hat{\pi}_t + \eta_5\hat{\pi}_{t+1} + \eta_6\hat{L}_t + \\ \eta_7((1-h)^{-1}\hat{c}_t - \hat{v}_t - (1-h)^{-1}h\hat{c}_{t-1}) + \eta_8\hat{\xi}_t + \eta_9\hat{\tau}_t \end{array} \right\} = 0, \quad (5)$$

where  $b_w = [(\tau + 1) + \tau] / [(1 - \vartheta)(1 - \beta\vartheta)]$  and

$$\eta = \begin{pmatrix} b_w\vartheta \\ -b_w(1 + \beta\vartheta^2) + (\tau + 1) \\ \beta\vartheta b_w \\ b_w\vartheta \\ -\vartheta b_w(1 + \beta) \\ b_w\beta\vartheta \\ \tau \\ \tau \\ \tau \\ \tau \frac{\tau}{\tau+1} \end{pmatrix} = \begin{pmatrix} \eta_0 \\ \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ \eta_5 \\ \eta_6 \\ \eta_7 \\ \eta_8 \\ \eta_9 \end{pmatrix}.$$

The demands for labor and capital in the wholesale sector, where factor prices are equal to marginal productivity plus real marginal cost,  $\widehat{s}_t$ , are given by

$$\widehat{y}_t - \widehat{L}_t + \widehat{s}_t = \widehat{w}_t^r \quad (6)$$

and

$$\widehat{s}_t + \widehat{y}_t - \widehat{k}_t = \widehat{z}_t. \quad (7)$$

A Phillips curve can be derived from the wholesale sector optimization problem for prices, where  $(1 - \theta)$  is the probability of adjusting prices and  $\lambda$  is the net price mark up in steady state:

$$\widehat{\pi}_t = \frac{\widehat{\pi}_{t-1}}{(1 + \beta)} + \frac{\beta}{(1 + \beta)} E_t \widehat{\pi}_{t+1} + \frac{(1 - \theta)(1 - \beta\theta)}{(1 + \beta)\theta} \widehat{s}_t + \frac{(1 - \theta)(1 - \beta\theta)}{(1 + \beta)\theta} \frac{\lambda}{(\lambda + 1)} \widehat{\lambda}_t. \quad (8)$$

Capital producers' optimality condition is

$$E_t \widehat{q}_{t+1} + \varphi \left[ \widehat{i}_{t+1} - \widehat{k}_{t+1} \right] = 0. \quad (9)$$

This equation links asset prices and investment, where  $\varphi = \Phi'' \left( \frac{i}{k} \right) \left( \frac{i}{k} \right)$  is the elasticity of the price of capital with respect to the investment-capital ratio.

The equilibrium conditions of the entrepreneurs are

$$E_t \widehat{r}_{t+1}^k - \widehat{r}_t = E_t \widehat{\varpi}_{t+1} \varpi \frac{r^k}{r} (1 - \Gamma(\varpi)) \left[ \frac{\Gamma''(\varpi)}{\lambda(\varpi)\Gamma'(\varpi)} - \frac{\Gamma''(\varpi)}{\Gamma'(\varpi)} + \frac{\mu G''(\varpi)}{\Gamma'(\varpi)} \right], \quad (10)$$

$$[(1 - F(\varpi)) - \mu G'(\varpi)] \frac{\widetilde{k} r^k}{n r} \varpi \widehat{\varpi}_{t+1} + \left[ \frac{\widetilde{k} - n}{n} \right] (\widehat{r}_{t+1}^k - \widehat{r}_t) = \widehat{k}_{t+1} + \widehat{q}_t - \widehat{n}_{t+1}, \quad (11)$$

$$\widehat{k}_t = \widehat{u}_t + \widehat{k}_t, \quad (12)$$

and

$$\widehat{z}_{t+1} = \frac{\delta''(1)}{\delta'(1)} \widehat{u}_{t+1} + \widehat{q}_{t+1}. \quad (13)$$

Equations (10) and (11) are the first-order conditions of the optimal lending contract. Equation (12) relates capital services to the capital stock, while equation (13) is the optimality condition for capital utilization.

The loglinearized return on capital is

$$\widehat{r}_{t+1}^k = \frac{z}{r^k} \widehat{z}_{t+1} + \frac{(1-\delta)}{r^k} \widehat{q}_{t+1} - \widehat{q}_t. \quad (14)$$

Equations (15) and (16) are the law of motion of net worth and capital, respectively:

$$\widehat{n}_{t+1} = \gamma \left\{ \begin{aligned} & \left( \frac{\widetilde{k} - \mu G(\varpi) \widetilde{k}}{n} \right) r^k \widehat{r}_t^k + \left( \frac{r^k \widetilde{k} - \widetilde{k} r - \mu G(\varpi) r^k \widetilde{k}}{n} \right) \widehat{q}_{t-1} + \left( \frac{r^k - r - \mu G(\varpi) r^k}{n} \right) \widetilde{k} \widehat{k}_t \\ & - \left( \frac{\widetilde{k} - n}{n} \right) r \widehat{r}_{t-1} + r \widehat{n}_t - \left( \frac{\mu r^k G_w \widetilde{k}}{n} \right) \varpi \widehat{\varpi}_t \end{aligned} \right\} \quad (15)$$

and

$$\widehat{k}_{t+1} = \delta \widehat{i}_t + (1-\delta) \widehat{k}_t - \delta'(1) \widehat{u}_t. \quad (16)$$

The loglinearized monetary policy rule is

$$\widehat{r}_t^n = \rho^r \widehat{r}_{t-1}^n + (1-\rho^r)(\gamma^\pi E \widehat{\pi}_{t+1}) + (1-\rho^r)(\gamma^y \widehat{y}_t)/4 + \widehat{\varepsilon}_t^r. \quad (17)$$

There exist seven shocks in the model. The monetary policy, price mark up and wage mark up shocks are white noise shocks. The rest of the shocks in the model, labor supply, consumption preferences, government spending and technology, follow a first-order autoregressive process.

## B Data

U.S. data was taken from the Bureau of Economic Analysis of the U.S. Department of Commerce (BEA), the Board of Governors of the Federal Reserve System and the Bureau of Labor Statistics (BLS). Real output is measured by real GDP converted into per capita terms divided by the population aged above sixteen (P16). Real consumption is real personal consumption expenditures divided by P16. Real investment is real gross private domestic investment also in per capita terms. Hours worked are measured by the product of average weekly hours in the private sector times the employment-population

ratio. The nominal interest rate is the Federal Funds Rate, and inflation is calculated as the difference of the GDP deflator. Real wages are measured by the average hourly earnings of production workers in real terms.

European data was taken from the AWM database, ECB Working Paper Series No 42. Real output is measured by real GDP converted into per capita terms divided by the labor force. Real consumption is real consumption divided by the labor force. Real investment is real gross investment also in per capita terms. To calculate hours worked, I use data on total employment, and transform it into hours worked using the same criterion as Adolfson, Laséen, Lindé, and Villani (2007). They assume that in any period, only a constant fraction of firms,  $\xi_e$ , is able to adjust employment to its desired total labor input. This results in the following equation for employment:

$$\Delta \widehat{e}_t = \beta \Delta \widehat{e}_{t+1} + \frac{(1 - \xi_e)(1 - \beta \xi_e)}{\xi_e} (\widehat{l}_t - \widehat{e}_t),$$

where  $\widehat{e}_t$  is total employment. In contrast to them, I do not estimate  $\xi_e$ , but following their results I fix it equal to 0.70. The nominal interest rate is the quarterly short-term interest rate, and inflation is calculated as the difference of the GDP deflator. Real wages are measured by the wage rate deflated by the GDP deflator.

## C Tables and Figures

**Table 1: Prior and Posterior Distribution for the U.S.**

Parameter	Prior			Financial accelerator			No fin. accelerator		
	Type	Mode	St. Er.	5%	Mean	95%	5%	Mean	95%
$\sigma_r$	Gam	0.01	0.1	0.002	0.002	0.002	0.002	0.002	0.003
$\sigma_a$	Gam	0.01	0.1	0.005	0.006	0.007	0.005	0.006	0.007
$\sigma_g$	Gam	0.01	0.1	0.014	0.016	0.019	0.017	0.019	0.021
$\sigma_\nu$	Gam	0.01	0.1	0.036	0.050	0.069	0.051	0.073	0.102
$\sigma_\xi$	Gam	0.01	0.1	0.043	0.052	0.062	0.069	0.083	0.098
$\sigma_\lambda$	Gam	0.01	0.1	0.268	0.331	0.403	0.297	0.379	0.477
$\sigma_\tau$	Gam	0.01	0.1	1.574	2.256	2.706	2.278	3.008	3.761
$\rho^r$	Beta	0.85	0.1	0.563	0.626	0.682	0.587	0.648	0.703
$\rho^a$	Beta	0.85	0.1	0.879	0.934	0.979	0.923	0.964	0.990
$\rho^g$	Beta	0.85	0.1	0.903	0.941	0.974	0.935	0.959	0.981
$\rho^\nu$	Beta	0.85	0.1	0.844	0.891	0.929	0.859	0.908	0.94
$\rho^\xi$	Beta	0.85	0.1	0.973	0.985	0.995	0.973	0.984	0.993
$\gamma^\pi$	Gam	2.00	0.1	1.957	2.115	2.271	2.031	2.182	2.342
$\gamma^y$	Gam	0.50	0.05	0.368	0.440	0.516	0.342	0.405	0.471
$\theta$	Beta	0.70	0.1	0.762	0.786	0.808	0.777	0.802	0.825
$\varphi$	Unif	-1*	0.58	-0.497	-0.415	-0.336	-0.366	-0.295	-0.23
$\mu$	Unif	0.25*	0.14	0.091	0.159	0.237	-	-	-
$r^k - r$	Gam	0.005	0.003	0.005	0.008	0.011	-	-	-
$\vartheta$	Beta	0.70	0.1	0.518	0.592	0.639	0.587	0.643	0.692
$h$	Beta	0.70	0.05	0.78	0.836	0.887	0.847	0.889	0.925

Note: \* Mean

**Table 2: Model Comparison**

	Log marginal data density		Posterior odds
	FA	no FA	
U.S.	2463.3	2431.5	$10^{13}$
Euro Area	2528.6	2518.1	$10^4$

Note: Posterior odds of the hypothesis FA versus no FA

**Table 3: Prior and Posterior Distribution for the Euro Area**

Parameter	Prior			Financial accelerator			No fin. accelerator		
	Type	Mode	St. Er.	5%	Mean	95%	5%	Mean	95%
$\sigma_r$	Gam	0.01	0.1	0.001	0.001	0.002	0.002	0.002	0.002
$\sigma_a$	Gam	0.01	0.1	0.011	0.013	0.014	0.010	0.011	0.013
$\sigma_g$	Gam	0.01	0.1	0.015	0.017	0.019	0.013	0.015	0.017
$\sigma_\nu$	Gam	0.01	0.1	0.022	0.030	0.041	0.027	0.039	0.055
$\sigma_\xi$	Gam	0.01	0.1	0.033	0.041	0.052	0.054	0.064	0.075
$\sigma_\lambda$	Gam	0.01	0.1	0.168	0.210	0.26	0.205	0.266	0.334
$\sigma_\tau$	Gam	0.01	0.1	1.956	2.623	3.191	2.435	3.063	3.771
$\rho^r$	Beta	0.85	0.1	0.692	0.738	0.78	0.702	0.748	0.788
$\rho^a$	Beta	0.85	0.1	0.519	0.594	0.668	0.576	0.664	0.751
$\rho^g$	Beta	0.85	0.1	0.817	0.885	0.954	0.867	0.923	0.969
$\rho^\nu$	Beta	0.85	0.1	0.851	0.905	0.948	0.921	0.949	0.968
$\rho^\xi$	Beta	0.85	0.1	0.981	0.990	0.997	0.980	0.989	0.996
$\gamma^\pi$	Gam	2.00	0.1	1.913	2.064	2.225	2.030	2.179	2.336
$\gamma^y$	Gam	0.50	0.05	0.341	0.403	0.469	0.316	0.377	0.442
$\theta$	Beta	0.70	0.1	0.690	0.721	0.752	0.725	0.756	0.784
$\varphi$	Unif	-1*	0.58	-1.338	-1.099	-0.884	-0.683	-0.554	-0.438
$\mu$	Unif	0.25*	0.14	0.120	0.271	0.369	-	-	-
$r^k - r$	Gam	0.005	0.003	0.006	0.013	0.017	-	-	-
$\vartheta$	Beta	0.70	0.1	0.599	0.645	0.682	0.621	0.663	0.702
$h$	Beta	0.70	0.05	0.636	0.708	0.783	0.719	0.781	0.836

Note: \* Mean

**Table 4: Selected Moments**

	US			Euro Area		
	data	FA model	no FA model	data	FA model	no FA model
	Standard Deviation (%)					
output	1.7	[3.3,12]	[4.6,18]	1.7	[2.4,9.2]	[3.6,14]
consumption	1.8	[4.1,15]	[5.7,23]	1.9	[3.2,12]	[4.7,18]
investment	9.7	[8.5,21]	[9.7,29]	4.3	[3.8,11]	[4.7,15]
inflation	.39	[.46,1.3]	[.55,1.8]	0.4	[.49,1.0]	[.52,1.3]
interest rate	.54	[.53,1.5]	[.66,2.0]	0.4	[.47,1.1]	[.55,1.4]
real wages	3.0	[1.9,5.1]	[2.3,6.5]	1.7	[1.6,4.2]	[1.8,4.8]
employment	2.2	[4.1,14]	[5.7,21]	1.8	[3.5,12]	[4.8,17]
	Relative Volatility to Output					
output	1	1	1	1	1	1
consumption	1.06	[1.05,1.52]	[.97,1.64]	1.14	[1.16,1.52]	[1.15,1.58]
investment	5.60	[1.30,3.47]	[1.08,3.09]	2.57	[.86,2.17]	[.73,1.94]
inflation	.23	[.09,.17]	[.08,.14]	.24	[.10,.25]	[.08,.17]
interest rate	.31	[.09,.22]	[.08,.19]	.24	[.09,.26]	[.08,.20]
real wages	1.72	[.24,1.01]	[.20,.88]	1.02	[.26,1.06]	[.23,.74]
employment	1.25	[.87,1.61]	[.91,1.58]	1.05	[.98,1.81]	[1.07,1.58]
	Correlation with Output					
output	1	1	1	1	1	1
consumption	.74	[.87,.99]	[.80,.99]	.94	[.93,1.0]	[.92,1.0]
investment	.72	[.14,.88]	[.17,.93]	.67	[.21,.93]	[.30,.96]
inflation	.17	[-.96,-.55]	[-.98,-.71]	-.21	[-.88,-.26]	[-.94,-.51]
interest rate	.34	[-.94,-.30]	[-.96,-.51]	.21	[-.88,-.09]	[-.94,-.40]
real wages	.29	[-.79,.49]	[-.85,.42]	.75	[-.85,.35]	[-.91,-.03]
employment	.62	[.73,.99]	[.81,.99]	.15	[.70,.98]	[.87,.99]

Note: For the model, the 95th interval is reported.

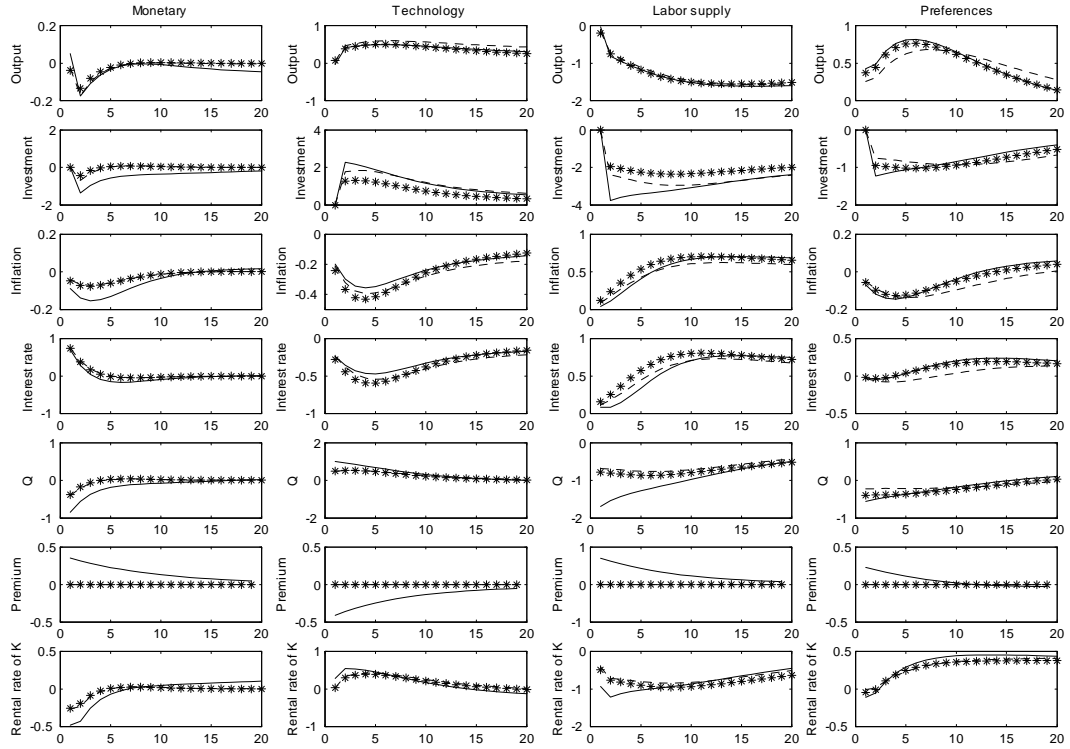


Figure 1: U.S. impulse response functions to equal size shocks. Solid line: estimated financial accelerator model. Dashed line: estimated no financial friction model. Star: estimated financial accelerator model switching financial frictions off. Values expressed as percentage deviation from steady state values, and in the case of inflation, the nominal interest rate and premium as annual percentage points.

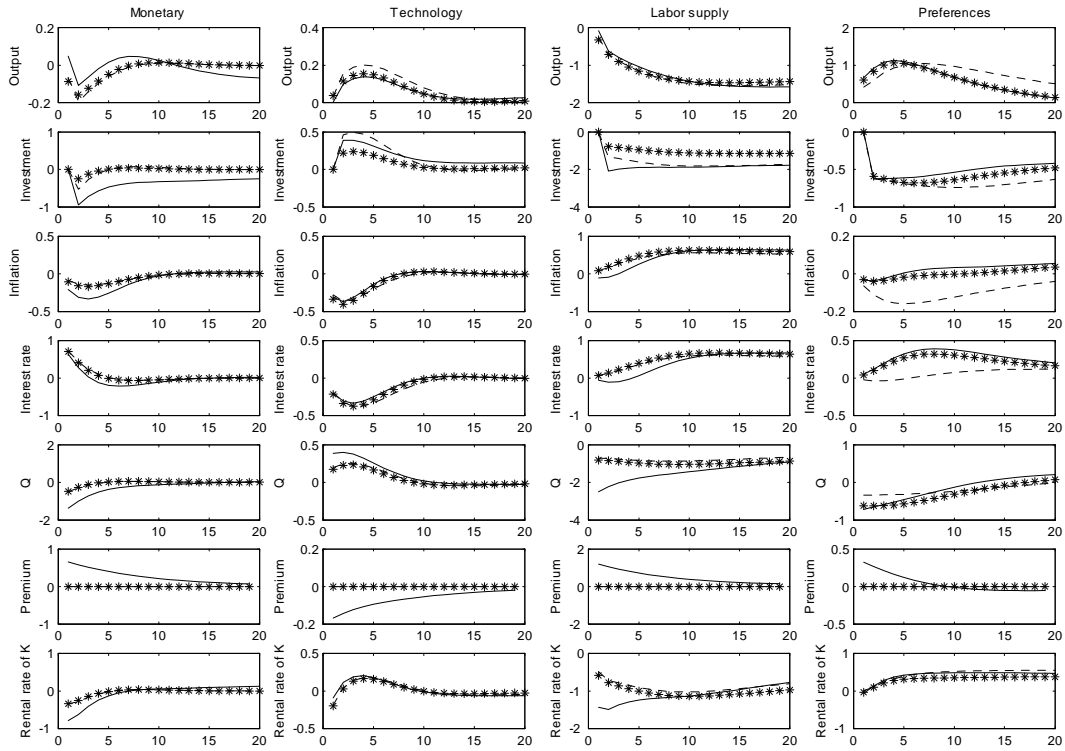


Figure 2: Euro area impulse response functions to equal size shocks. Solid line: estimated financial accelerator model. Dashed line: estimated no financial friction model. Star: estimated financial accelerator model switching financial frictions off. Values expressed as percentage deviation from steady state values, and in the case of inflation, the nominal interest rate and premium as annual percentage points.

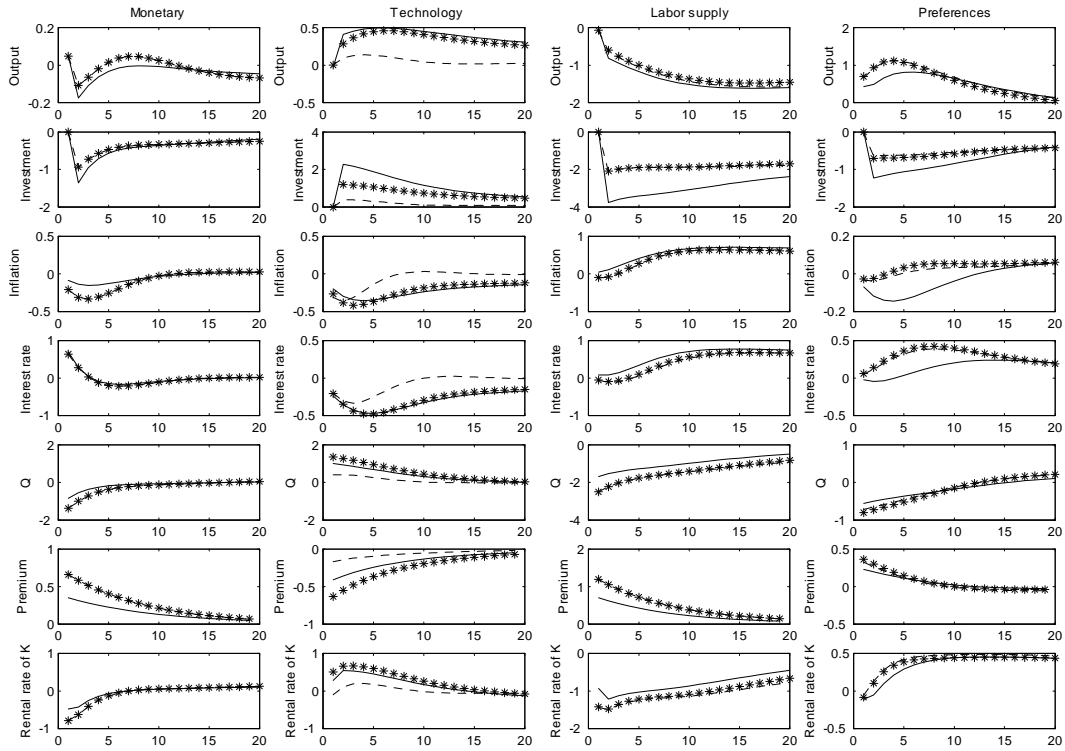


Figure 3: Impulse Response functions for the model with monitoring costs and equal size of shocks. Solid line: U.S. data. Dashed line: European data. Star line: European data but using the estimated persistence and variance of the U.S. shocks. Values expressed as percentage deviation from steady state values, and in the case of inflation, the nominal interest rate and premium as annual percentage points.

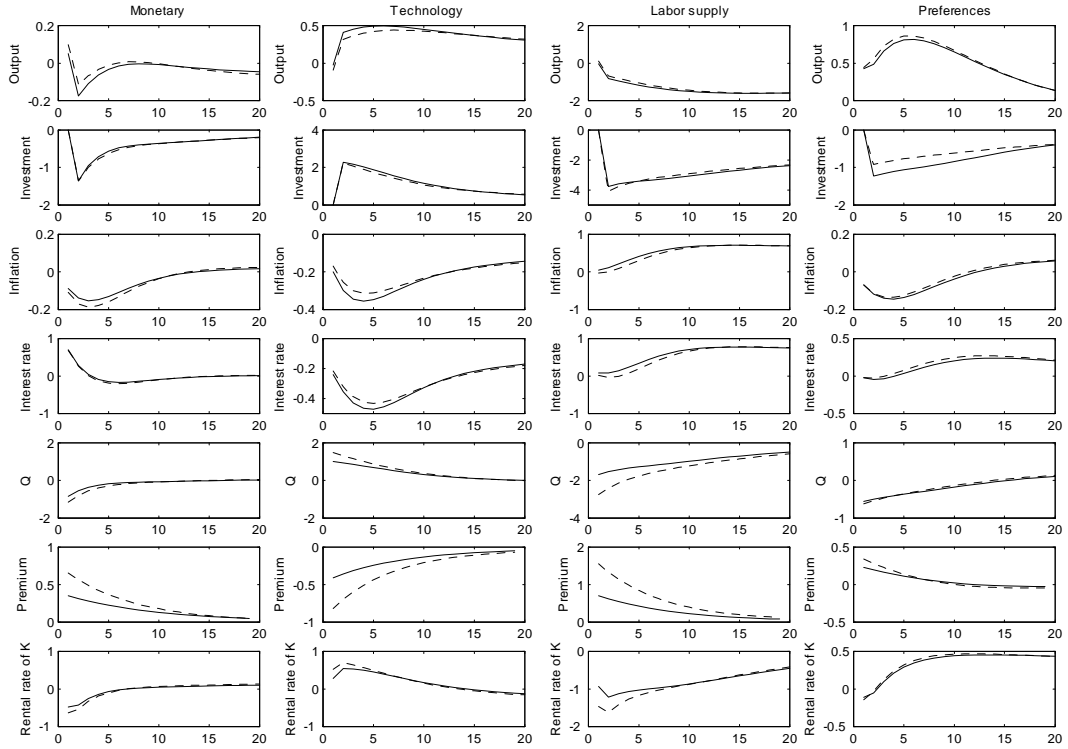


Figure 4: Counterfactual. Solid line: IRFs of the financial accelerator model evaluated at the posterior mean for U.S. data. Dashed line: IRFs of the financial accelerator model evaluated at the posterior mean for U.S. data and setting  $\mu = 0.27$ ,  $(r^k - r) = 0.013$ , and  $\varphi = -0.60$ . Values expressed as percentage deviation from steady state values, and in the case of inflation, the nominal interest rate and premium as annual percentage points.