On the nature of the financial system in the Euro Area: a Bayesian DSGE approach*

Stefania Villa†

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Abstract

The presence of financial frictions affects the real economy through changes in the credit spread and in the amount of lending, as demonstrated by the 2008-2009 financial crisis. This paper presents two DSGE models, which are both extensions of a Smets and Wouters (2007) economy. The first model introduces a financial accelerator *à la* Bernanke, Gertler and Gilchrist (1999), with asymmetric information originating in the demand side of the credit market. The second model incorporates financial frictions originating in the supply side of the credit market, *à la* Gertler and Karadi (2011). This paper estimates the two models with Euro Area data using Bayesian techniques. The two models are compared on the basis of: (i) the estimated parameters and the marginal data density; (ii) business cycle moments; (iii) model-implied shocks; and (iv) the forecasting performance. The main results is that the data clearly favour the model consistent with financial frictions originating on the supply side of the credit market. Sensitivity checks and extensions show that main results hold for a number of model calibrations and specifications.

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†Birkbeck College, University of London, Malet Street, London WC1E 7HX, UK and University of Foggia, Italy. *Email*: s.villa@ems.bbk.ac.uk.

1 Introduction

In the aftermath of the 2007-2009 financial turmoil, the structure of the financial system has received an increasing attention in the macroeconomic literature. The features of external financing are particularly important because of the substantial effects of lending on the real activity. Since the onset of the crisis total financing to non-financial corporations have declined both in the Euro Area (EA) and in US. In the EA loans of financial institutions to non-financial corporations (index of notional stock) decreased by more than 10 percent between 2008Q4 and 2010Q4 and the ratio of non-financial corporation loans to GDP fell as well (ECB, 2011). At their peak following the collapse of the Lehman Brothers, the spreads skyrocketed. Lenza et al. (2010) reported that the spread between unsecured deposit rates (EURIBOR) and overnight indexed swap (OIS) rates at the three-month maturity approached 200 basis points in the EA. Equivalent spreads were even higher in the US and UK.

The presence of asymmetric information in financial markets gives rise to financial frictions in DSGE models. This paper distinguishes the source of the financial frictions between informational asymmetries originating in the demand-side versus the supply-side of the credit market. This paper builds two DSGE models with financial frictions in a 'Smets and Wouters (2007)(SW) economy'. The first model, labelled as the SWBGG model, incorporates financial frictions originating in the demand side of the credit market, *à la* bernanke1999financial (BGG). In this model frictions arise because monitoring the loan applicant is costly and this drives an endogenous wedge between the lending rate and the risk free rate, i.e. the spread. Carrillo and Poilly (2010) investigate the effects of a fiscal stimulus in a SW model with the BGG type of frictions. Gelain (2010) presented a 'SW economy' with the BGG type of financial friction in order to obtain a time series for the external finance premium. The second model, labelled as the SWGK model, includes financial frictions originating in the supply side of the credit market, *à la* Gertler and Karadi (2011). The source of financial frictions is the financial intermediary, facing endogenously determined balance sheet constraints as explained in the previous chapter. The SWGK model extends the 'SW economy' to incorporate a banking sector with an endogenously determined leverage. Therefore, the SWBGG model and the SWGK model are similar in all aspects, but the financial sector and the borrowing/lending relationships arising in each model.

The two models are estimated with EA data for the period 1996Q1-2008Q3 using as observables output, consumption, investment, wage, employment, inflation and the credit spread (spread, henceforth). The comparison between the two estimated models is made along different dimensions: (i) the estimated parameters and the Bayes Factor; (ii) the comparison of the business cycle moments of the observed data along with those in the simulated models; (iii) the comparison of model-implied shocks between the two models; (iv) the forecasting performance of estimated models; and (v) impulse response function analysis and variance decomposition. Empirical evidence shows that the SWGK model is preferable according to: (i) the values of the estimated parameters and the Bayes Factor; (ii) the conformity between the model-implied moments and those generated by the data; and (iii) the forecasting performance. The main result stemming from the Bayes Factor is robust to: (i) different calibration of the leverage ratio of the SWBGG and SWGK models; (ii) another measure of the spread used as observable in the estimation procedure; and (iii) different model specifications. None of the models generates counter-intuitive impulse response functions (IRFs) and/or variance decomposition. The internal propagation mechanism differ between the two models; the spread and the leverage ratio are key elements in the transmission mechanism of the shocks.

According to the estimation results the presence of asymmetric information amplifies the propagation mechanism of the contractionary shocks hitting the economy. Since the financial sectors differ across the two models, the two financial shocks differ as well. In the SWBGG models, two 'financial shocks' are analysed: a shock to net worth of borrowers and an investment-specific shock. When the former hits the economy, borrowers have less wealth to contribute to the project financing. This implies that the potential divergence of interests between borrowers and lenders (the suppliers of external funds) is greater and, therefore, agency costs increase. In equilibrium lenders must be compensated for higher agency costs by a larger spread. In this class of models the spread depends inversely on borrowers' net worth. A rise in the spread causes a fall in investment and, therefore, output. An investment-efficiency shock attenuates the financial accelerator effect embedded in the model, due to the rise in the price of capital which, on one hand, leads to a fall in investment and, on the other, implies an increase in the net worth of firms. As a result, the spread decreases mitigating the impact of the contractionary shock. The monetary policy shock causes the standard transmission mechanism (Smets and Wouters, 2007), plus the financial accelerator effect stemming from the decline in the net worth of borrowers. This mechanism further reinforces the simulated contraction.

In the SWGK, there are two financial shocks: a shock to the quality of capital and a shock to the net worth of financial intermediaries. They both affect the financial intermediaries balance sheet. Financial intermediaries cannot be over-leveraged because of the incentive compatibility constraint arising from the presence of asymmetric information. Therefore, they are forced to cut bak lending and, to resptore profits, to increase the lending rate more than the increase in the policy rate. As a result, the spread increases; this causes a decline in loans and investment. The monetary policy shock determines a reduction in investment and, therefore, in the demand for loans. This implies a deterioration in the balance sheet of financial intermediaries. Due to the presence of asymmetric information, depositors require financial intermediaries not to be over-leveraged; as a consequence, the spread increases. The increase in financing costs makes lending more expensive and reduces the demand for loans, further squeezing investment. Financial frictions, therefore, exacerbate the simulated crisis.

The structure of the paper is as follows. Section 2 illustrates the two models. Section 3 describes the data and discusses the estimation strategy. Section 4 compares the two estimated versions of the models. Section 5 presents robustness checks and models' extensions. Finally, Section 6 concludes.

2 The Models

This section presents the two DSGE models, SWBGG and SWGK. Compared to the SW economy, the different features are: (i) the presence of financial frictions; (ii) non-separability over consumption and leisure in a standard utility function; (iii) internal habits in consumption; (iv) the Dixit-Stiglitz aggregator for final output and composite labour, as in Galí et al. (2011); (v) the fact that the price mark-up, wage mark-up and government shocks are modelled as in Smets and Wouters (2003), the risk-premium shock is absent whereas financial shocks are added in the models. The presence of financial frictions changes the production side of the SW economy since intermediate goods firms are involved in the decision of borrowing in addition to the standard profit maximisation activity. In order to simplify the optimisation problems of intermediate goods firms, in both models retailers are the source of price stickiness similarly to Bernanke et al. (1999) and Gertler and Karadi (2011).

In both models the economy is populated by: households; labour unions; labour packers; intermediate goods firms; capital producers; retailers; final good firms; and the policy maker. In the SWGK model the economy is also populated by financial intermediaries (FI, henceforth). While the set-up of households, the labour market, retailers, final goods firms, and the policy maker is the same among the two models, the rest of the production sector and the financial sector differ.

Households consume, save, and supply labour. A labour union differentiates labour and sets wages in a monopolistically competitive market as in Smets and Wouters (2007). Competitive labour packers buy labour from the union, package and sell it to intermediate goods firms. The good market has a similar structure: retailers buy goods from intermediate goods firms, differentiate them and sell them in a monopolistically competitive market. The aggregate final good is produced by perfectly competitive firms assembling a continuum of intermediate goods. The policy maker sets the nominal interest rate following a Taylor rule.

In the SWBGG model, intermediate goods firms solve two problems: (i) they maximize the flow of discounted profits by choosing the quantity of factors for production; and (ii) they decide the amount of borrowing from lenders. For the latter decision there is a costly state verification (CSV) problem (Townsend, 1979) and lenders must pay a fixed auditing cost to observe an individual borrower's return. This problem of asymmetric information makes external finance more expensive than internal finance. BGG show that the financial contract between lenders and borrowers implies an external finance premium which is inversely related with the net worth of potential borrowers. When borrowers have little wealth to contribute to the project financing, the potential divergence of interests between borrowers and lenders (the suppliers of external funds) is greater and, therefore, agency costs increase. In equilibrium lenders must be compensated for higher agency costs by a larger premium. Even if the BGG model incorporates financial frictions on non-financial firms and this generates a financial accelerator mechanism, FI are just a "veil" in the model. Capital producers purchase investment and depreciated capital from firms to transform them into capital sold to firms and used for production. They face adjustment costs for investment.

In the SWGK model, the production sector is also made of intermediate goods firms and capital producers. The intermediate goods firms finance their capital acquisitions each period by obtaining funds from the FI; there are no financial frictions in this activity. To acquire the funds to buy capital, firms issues claims equal to the number of units of capital acquired. They maximise profits by choosing the quantity of factors of production. Capital producers buy capital from intermediate goods firms and then repair depreciated capital and builds new capital. They then sell both the new and re-furbished capital. In addition, the supply-side of the credit market, i.e. FI, is explicitly modelled. In particular, FI lend funds to intermediate goods firms earning a stochastic return and pay to households a non-contingent real gross return on liabilities. There is imperfect information between depositors/households and FI and perfect information between FI and firms. The moral hazard problem consists in the fact that the banker can choose to divert a fraction of available funds from the projects and transfer it back to the household of which she is member.

2.1 Households

The economy is populated by a continuum of households indexed by $j \in (0,1)$. Each household's preferences are represented by the following intertemporal utility function:

$$U_0(j) = E_t \sum_{t=0}^{\infty} \beta^t \left[U\left(C_t(j), 1 - L_t(j)\right) \right] \tag{1}$$

where $\beta \in (0,1)$ is the discount factor and $L_t(j)$ is labour supply in terms of hours worked. Total time available to households is normalized to unity, thus $1 - L_t(j)$ represents leisure time. The SWGK model assumes a specific structure for the households discussed in Gertler and Karadi (2011) and briefly presented in Subsection2.6.

Each period the representative household enters period t with real deposits in the FI and real government bonds. Both intermediary deposits and government debt are one period real bonds that pay the gross real interest rate, R_t, between $t-1$ and t. As in Gertler and Karadi (2011), both instruments are riskless and are thus perfect substitutes. During period t, the household chooses to consume $C_t(j)$; supplies $L_t(j)$ hours of work; and allocates savings in deposits at the FI and in government bonds $B_{t+1}(j)$. Each household gains an hourly real wage, $W_t^h(j)/P_t$; and dividend payments, $\int_0^1 \Omega_{bt} di$, from bankers. In addition, the government grants transfers TR_t and imposes real lump-sum taxes T_t. The household's intertemporal budget constraint can thus be expressed as:

$$C_t(j) + B_{t+1}(j) \leq \frac{W_t^h(j)}{P_t} L_t(j) + R_t B_t(j) + \int_0^1 \Omega_{bt} db + TR_t - T_t \tag{2}$$

Maximization yields the following first-order conditions with respect to $C(j)$, $B_{t+1}(j)$ and $L_t(j)$:

$$U_{Ct}(j) = mu_t(j) \tag{3}$$

$$\beta E_t[R_{t+1} mu_{t+1}(j)] = mu_t(j) \tag{4}$$

$$-U_{Lt}(j) = mu_t(j) \frac{W_t^h(j)}{P_t} \Leftrightarrow \frac{U_{Lt}(j)}{U_{Ct}(j)} = -MRS_t \equiv -\frac{W_t^h(j)}{P_t} \tag{5}$$

where $mu_t(j)$ is the Lagrange multiplier associated to the budget constraint and let $\Lambda_{t,t+1} \equiv \frac{mu_{t+1}}{mu_t}$.

2.2 Wage stickiness

Monopolistic competition in the labour market is introduced *à la* Smets and Wouters (2007). Households supply homogeneous labour to monopolistic labour unions which differentiate it. Labour service used by intermediate goods firms is a composite of differentiated types of labour indexed by $l \in (0,1)$:

$$L_t = \left[\int_0^1 L_t(l)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} \, dl \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}} \tag{6}$$

where ε_w is the elasticity of substitution across different types of labour. Labour packers solve the problem of choosing the varieties of labour to minimise the cost of producing a given amount of the aggregate labour index, taking each nominal wage rate $W_t(l)$ as given:

$$\min_{L_t(l)} \int_0^1 W_t(l) \, L_t(l) \, dl \tag{7}$$

$$\text{s.t.} \left[\int_0^1 L_t(l)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} \, dl \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}} \geqslant \bar{L} \tag{8}$$

The demand for labour is given by:

$$L_t(l) = \left(\frac{W_t(l)}{W_t} \right)^{-\varepsilon_w} L_t \tag{9}$$

where W_t is the aggregate wage index. Plugging the labour demand (9) into equation (6) yields:

$$W_t = \left[\int_0^1 W_t(l)^{1-\varepsilon_w} \, dl \right]^{\frac{1}{1-\varepsilon_w}} \tag{10}$$

The labour unions play the same role of retailers in the goods market. They adjust wages infrequently following the Calvo scheme. Let σ_w be the probability of keeping wages constant and $(1 - \sigma_w)$ the probability of changing wages. In other words, each period there is a constant probability $(1 - \sigma_w)$ that the union is able to adjust the wage, independently of past history. This implies that the fraction of unions setting wages at t is $(1-\sigma_w)$. For the other fraction that cannot adjust, the wage is automatically increased at the aggregate inflation rate. As explained by Cantore et al. (2010), the wage for non-optimising unions evolves according to the following trajectory $W_t^*(l)$, $W_t^*(l) \left(\frac{P_t}{P_{t-1}} \right)^{\sigma_{wi}}$, $W_t^*(l) \left(\frac{P_{t+1}}{P_{t-1}} \right)^{\sigma_{wi}}$, ..., where σ_{wi} denotes the degree of wage indexation.

The union chooses W_t^* to maximise:

$$E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \left(\beta\sigma_w\right)^s \left[L_{t+s}(l) W_t^*(l) \left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\sigma_{wi}} - L_{t+s}(l) W_{t+s}^h\right] \tag{11}$$

subject to the labour demand (9), and the indexation scheme so that $L_{t+s}(l) = \left[\frac{W_t^*(l)}{W_{t+s}} \left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\sigma_{wi}}\right]^{-\varepsilon_w}$. The first order condition is:

$$E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \left(\beta\sigma_w\right)^s L_{t+s}(l) \left[W_t^* \left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\sigma_{wi}} - W_{t+s}^h M_{w,t}\right] = 0 \tag{12}$$

where the time varying gross wage mark-up $M_{w,t} = \frac{\varepsilon_w}{\varepsilon_w - 1} u_t^w$ and u_t^w is the wage mark-up shock which follows a AR(1) process, ρ_w is an autoregressive coefficient and ε_t^w is a serially uncorrelated, normally distributed shock with zero mean and standard deviation σ^{wm}. The dynamics of the aggregate wage index is:

$$W_{t+1} = \left[\left(1-\sigma_w\right)\left(W_{t+1}^*(l)\right)^{1-\varepsilon_w} + \sigma_w \left(W_t \frac{\left(P_t/P_{t-1}\right)^{\sigma_{wi}}}{P_{t+1}/P_t}\right)^{1-\varepsilon_w}\right]^{\frac{1}{1-\varepsilon_w}} \tag{13}$$

where W^* is the nominal wage chosen by optimizing unions.

2.3 Price stickiness

Similarly to the labour market, competitive final goods firms buy intermediate goods from the retailers and assemble them. Final output is a composite of intermediate goods indexed by $f \in (0,1)$ differentiated by retailers:

$$Y_t = \left[\int_0^1 Y_t\left(f\right)^{\frac{\varepsilon-1}{\varepsilon}} df\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{14}$$

where ε is the elasticity of substitution across varieties of goods. Final goods firms solve the problem of choosing $Y_t\left(f\right)$ to minimise the cost of production:

$$\min_{Y_t(f)} \int_0^1 P_t\left(f\right) Y_t\left(f\right) df \tag{15}$$

$$\text{st} \left[\int_0^1 Y_t\left(f\right)^{\frac{\varepsilon-1}{\varepsilon}} df\right]^{\frac{\varepsilon}{\varepsilon-1}} \geqslant \bar{Y} \tag{16}$$

The demand function for intermediate good f is given by:

$$Y_t\left(f\right) = \left(\frac{P_t\left(f\right)}{P_t}\right)^{-\varepsilon} Y_t \tag{17}$$

where P_t is the aggregate wage index. Plugging the demand (17) into equation(14) yields:

$$P_t = \left[\int_0^1 P_t\left(f\right)^{1-\varepsilon_w} df \right]^{\frac{1}{1-\varepsilon}} \tag{18}$$

Retailers simply purchase intermediate goods at a price equal to the marginal cost and differentiate them in a monopolistically competitive market. Retailers set nominal prices in a staggered fashion *à la* Calvo (1983). Each retailer resets its price with probability $1 - \sigma_p$. For the fraction of retailers that cannot adjust, the price is automatically increased at the aggregate inflation rate. As explained by Cantore et al. (2010) the price for non-optimising retailers evolves according to the following trajectory $P_t^*\left(f\right)$, $P_t^*\left(f\right)\left(\frac{P_t}{P_{t-1}}\right)^{\sigma_{pi}}$, $P_t^*\left(f\right)\left(\frac{P_{t+1}}{P_{t-1}}\right)^{\sigma_{pi}}$, ..., where σ_{pi} denotes the degree of price indexation. The real price Φ_t charged by intermediate goods firms in the competitive market represents also the real marginal cost common to all final good firms, i.e. $MC_t = \Phi_t$.

A retailer resetting its price in period t maximises the following flow of discounted profits with respect to P_t^*:

$$E_t \sum_{s=0}^{\infty} (\sigma_p \beta)^s \Lambda_{t,t+s} \left[Y_{t+s}(f) P_t^*(f) \left(\frac{P_{t+s-1}}{P_{t-1}} \right)^{\sigma_{pi}} - Y_{t+s}(f) P_{t+s} MC_{t+s}) \right] \tag{19}$$

subject to the demand function (17), and the indexation scheme so that $Y_{t+s}(f) = \left[\frac{P_t^*(f)}{P_{t+s}} \left(\frac{P_{t+s-1}}{P_{t-1}} \right)^{\sigma_{pi}} \right]^{-\varepsilon}$. Let MC_t^n denote the nominal marginal cost. The gross mark-up charged by final good firm f can be defined as $M_t(f) \equiv P_t(f)/MC_t^n = \frac{P_t(f)}{P_t} / \frac{MC_t^n}{P_t} = p_t(f)/MC_t$. In the symmetric equilibrium all final good firms charge the same price, $P_t(f) = P_t$, hence the relative price is unity, $p_{it} = 1$. It follows that, in the symmetric equilibrium, the mark-up is simply the inverse of the marginal cost.

The first order condition for this problem is:

$$E_t \sum_{k=0}^{\infty} (\sigma_p \beta)^s \Lambda_{t,t+s} Y_{t+s}(f) \left[P_t^*(f) \left(\frac{P_{t+s-1}}{P_{t-1}} \right)^{\sigma_{pi}} - M_{p,t} P_{t+s} MC_{t+s}) \right] = 0 \tag{20}$$

Similarly to the labour market, the gross time varying price mark up is $M_{p,t} = \frac{\varepsilon}{\varepsilon-1} u_t^p$ and u_t^p is the price mark-up shock, which follows a AR(1) process, ρ_p is an autoregressive coefficient and ε_t^p is a serially uncorrelated, normally distributed shock with zero mean and standard deviation σ^{pm}.

The equation describing the dynamics for the aggregate price level is given by:

$$P_{t+1} = \left[(1 - \sigma_p)(P_{t+1}^*(f))^{1-\varepsilon} + \sigma_p \left(P_t \left(\frac{P_t}{P_{t-1}} \right)^{\sigma_{pi}} \right)^{1-\varepsilon} \right]^{1/(1-\varepsilon)} \tag{21}$$

2.4 Policymaker

The policymaker sets the nominal interest rate according to the following Taylor rule:

$$\frac{R_t^n}{R^n} = \left(\frac{R_{t-1}^n}{R^n}\right)^{\rho_i} \left[\left(\frac{\Pi_t}{\Pi}\right)^{\rho_\pi} \left(\frac{Y_t}{Y_t}\right)^{\rho_y}\right]^{1-\rho_i} \left(\frac{\Pi_t}{\Pi_{t-1}}\right)^{\rho_{\Delta\pi}} \left(\frac{Y_t/Y_{t-1}}{Y_t^*/Y_{t-1}^*}\right)^{\rho_{\Delta y}} \varepsilon_t^r \tag{22}$$

and:

$$R_{t+1} = E_t\left[\frac{R_t^n}{\Pi_{t+1}}\right], \tag{23}$$

where R_t^n is the nominal gross interest rate and ε_t^r is the monetary policy shock. The meanings of the parameters of equation (22) are standard (Smets and Wouters, 2007).

2.5 Production and financial sector *à la* Bernanke, Gertler and Gilchrist

The presence of financial frictions on the demand side of the credit market alters the set-up of intermediate goods firms and capital producers compared to the SW economy.

2.5.1 Capital producers

Following Gelain (2010), capital producers purchase at time t investment and depreciated capital from firms to transform them into capital sold to firms and used for production at time $t+1$. Following Christiano et al. (2005), capital producers face adjustment costs for investment. The law of motion of capital is then equal to:

$$K_{t+1} = (1-\delta)K_t + x_t\left[1 - \digamma\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{24}$$

The adjustment cost function $\digamma$ satisfies the following properties: $\digamma(1) = \digamma'(1) = 0$, and $\digamma''(1) = \xi > 0$. As shown in the Appendix, the steady state of the model does not depend on the adjustment cost parameter ξ. The exogenous shock x_t follows an autoregressive process:

$$\log(x_t) = \rho_x \log(x_{t-1}) + \varepsilon_t^x, \tag{25}$$

where ρ_x is an autoregressive coefficient and ε_t^x is a serially uncorrelated, normally distributed shock with zero mean and standard deviation σ^x. The shock to the marginal efficiency of investment varies the efficiency with which the final good can be transformed into physical capital and it affects net worth of intermediate goods firms through changes in the price of capital[1]

The maximization problem in real terms is the following:

$$\max_{I_t} E_t \beta \Lambda_{t,t+1} \left[Q_t \left(K_{t+1} - (1-\delta) K_t \right) - I_t \right] \tag{26}$$

where Q_t is the relative price of capital goods. The optimality condition, resulting from substituting equation (24) in the profit function (26), is a Tobin's Q equation, which relates the price of capital to the marginal adjustment cost and represents the supply of capital:

$$1 = Q_t x_t \left[1 - F\left(\frac{I_t}{I_{t-1}}\right) - F'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right) \right] + \beta E_t \left[\Lambda_{t,t+1} Q_{t+1} x_{t+1} F'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \right] \tag{27}$$

2.5.2 Intermediate goods firms

Intermediate goods firms produce goods in a perfectly competitive market and they borrow in order to finance the acquisition of capital. They solve two optimization problems: (i) they maximize the flow of discounted profits by choosing the quantity of factors for production; and (ii) they decide their loan demand.

The first problem consists in maximising the following flow of profits:

$$E_t \beta \Lambda_{t,t+1} \left[\Phi_t Y_{t+1} - Z^k_{t+1} K_{t+1} - \frac{W_{t+1}}{P_{t+1}} L_{t+1} \right] \tag{28}$$

where Φ_t is the competitive real price at which intermediate good is sold and Z^k_t is the real rental price of capital. Maximisation yields the following first order conditions with respect to capital and labour:

$$Z^k_t = MC_t MP^K_t \tag{29}$$

$$\frac{W_t}{P_t} = MC_t MP^L_t \tag{30}$$

where MP^K_t– the marginal product of capital – is the derivative of the production function with respect to capital and MP^{LK}_t – the marginal product of labour – is the derivative of the production function with respect to labour. The real price Φ_t represents the shadow value of output and hence, given perfect competition in the market, it also represents its real marginal cost, MC_t.

[1] Justiniano et al. (2010) find in medium-scale DSGE model with standard frictions and without financial frictions that this shock is the prime driver of economic fluctuations.

Following Gelain (2010), firms also decide the optimal capital utilization rate solving the following maximisazition problem:

$$\max_{U_t} Z_t^k U_t K_{t-1} - \Psi(U_t) K_{t-1} \tag{31}$$

where $\Psi(U_t)$ represent the costs of changing capital utilization, with $\zeta = \Psi''(U_t)/\Psi'(U_t)$. This optimization problem is summarized by the following equilibrium condition:

$$Z_t^k = \Psi'(U_t) \tag{32}$$

Intermediate goods firms face also the problem of choosing the demand for capital. In order to ensure that entrepreneurial net worth will never be enough to fully finance capital acquisitions, it is assumed that each firm survives until the next period with probability θ and her expected lifetime is consequently $1/(1-\theta)$. At the same time, the same number of new firms enter and receive a transfer, N_t^e, from households so that the total number of intermediate goods firms is constant. This transfer ensures that new firms have at least a small but positive amount of net worth so that they can buy capital. At the end of period t, firms buy capital K_{t+1} that will be used throughout time $t+1$ at the real price Q_t. The cost of purchased capital is then $Q_t K_{t+1}$. A fraction of capital acquisition is financed by their net worth, N_{t+1}, and the remainder by borrowing, $Q_t K_{t+1} - N_{t+1}$, from a financial intermediary that obtains funds from household deposits and faces an opportunity cost equal to the risk-free rate, R_t^n. Total amount of lending/borrowing is:

$$loan_{t+1} = Q_t K_{t+1} - N_{t+1} \tag{33}$$

In equilibrium households deposits at the intermediaries are equal to the total amount of loans to intermediate goods firms. The optimal capital demand is then:

$$E_t\left[R_{t+1}^k\right] = E_t\left[\frac{Z_{t+1}^k + (1-\delta)Q_{t+1}}{Q_t}\right] \tag{34}$$

The expected marginal external financing cost, $E_t\left[R_{t+1}^k\right]$, is equal to the expected marginal return on capital given by the marginal productivity of capital and the value of one unit of capital used in time $t+1$.

BGG assume that an agency problem makes external finance more expensive than internal funds and solve a financial contract that maximises the payoff to the firms subject to the lender earning the required rate of return. Firms are risk neutral while households are risk averse; according to the financial contract the firms absorb any aggregate risk. Following Townsend (1979), lenders must pay a fixed auditing cost to observe an individual borrower's return. The monitoring cost is a proportion M of the realized gross payoff to the firm's capital. The financial contract implies an external finance premium $EP(\cdot)$ that depends on the inverse of the firm's leverage ratio.[2] Hence, in equilibrium, the marginal external financing cost must equate the external finance premium gross of the riskless real interest rate:

$$E_t\left[R^k_{t+1}\right] = E_t\left[EP\left(\frac{N_{t+1}}{Q_t K_{t+1}}\right) R_{t+1}\right] \tag{35}$$

with $EP'(\cdot) < 0$ and $EP'(1) = 1$. As the borrower's equity stake in a project $N_{t+1}/Q_t K_{t+1}$ falls (i.e. the leverage ratio rises) the loan becomes riskier and the cost of borrowing rises. Linearisation of equation (35) yields:[3]

$$\hat{R}^k_{t+1} = \hat{R}_t + \varkappa(\hat{Q}_t + \hat{K}_{t+1} - \hat{N}_{t+1}) \tag{36}$$

where $\varkappa \equiv -\frac{\partial R^k}{\partial \frac{N}{K}} \frac{N/K}{R^k} = -\frac{EP'(\cdot)}{R^k} \frac{N}{K} R$ measures the elasticity of the external finance premium with respect to the leverage position of intermediate goods firms. The external finance premium is the difference between the cost of external and internal funds,

$$EP_t = E_t\left[\frac{R^k_t}{R_t}\right] \tag{37}$$

Aggregate entrepreneurial net worth evolves according to the following law of motion:

$$N_{t+1} = \left\{\theta[R^k_t Q_{t-1} K_t - E_{t-1}\left[R^k_t (Q_{t-1} K_t - N_t)\right]] + (1-\theta) N^e_t\right\} \varepsilon^{nb}_t \tag{38}$$

where the first component of the right-hand-side represents the net worth of the θ fraction of surviving entrepreneurs net of borrowing costs carried over from the previous period, and N^e_t is the transfer that newly entering entrepreneurs receive. The term ε^{nb}_t represents a shock to the firm's net worth with zero mean and standard deviation σ^{nb}.

The resource constraint completes the model:

$$Y_t = C_t + I_t + G_t + \Psi(U_t) K_{t-1} + \mathcal{M}_t \tag{39}$$

[2] See BGG for the derivation of the financial contract and for the aggregation. The leverage ratio is defined throughout the paper as the ratio between total funds and internal funds.

[3] A variable with a 'hat' denotes a percentage deviation from steady state.

where $\mathcal{M}_t$ represents monitoring costs.

2.6 Production and financial sector *à la* Gertler and Karadi

In the SWGK model the financial frictions originates in the financial intermediaries. A finite horizon for them is introduced in order to avoid the possibility that they can reach the point where they can fund all investment from their own capital. Within each household there are two types of members at any point in time: the fraction g of the household members are workers and the fraction $(1-g)$ are bankers. The turnover between bankers and workers is as follows: every banker stays banker next period with a probability θ, which is independent of history. Therefore, every period $(1-\theta)$ bankers exit and become workers. Similarly, a number of workers become bankers, keeping the relative proportion of each type of agents constant. The household provides its new banker with a start-up transfer, which is a small fraction of total assets, χ. Each banker manages a financial intermediary. The set up of financial intermediaries follows Gertler and Karadi (2011), however the following equilibrium conditions are reported here to facilitate the interpretation of parameters in Subsection 3.1 and of the impulse responses in Subsection 4.5.

The problem of moral hazard implies that households/depositors require the FI not to be over-leverage. In terms of equation, this translates in the following constraint for FI:

$$Q_t S_t = lev_t N_t \tag{40}$$

where N_t is FI capital (or net worth), S_t is the quantity of financial claims on intermediate goods firms, Q_t is the price of each claim and lev_t stands for the FI leverage ratio and N_t is FI capital (or net worth). According to equation (40) the assets the FI can acquire depend positively on its net worth. The agency problem introduces an endogenous capital constraint on the bank's ability to acquire assets.

Total net worth is the sum of net worth of existing bankers, N^e, and net worth of new bankers, N^n. As far as the first is concerned, net worth evolves as:

$$N^e_{t+1} = \{\theta[(R^k_{t+1} - R_{t+1})lev_t + R_{t+1}]N_t\}\exp(\varepsilon^n_t) \tag{41}$$

where ε^n_t is a shock to FI capital. Net worth of new bankers is:

$$N^n_t = \chi Q_t S_t \tag{42}$$

where χ is the fraction of total assets given to new bankers.

The specification of the investment adjustment costs as in SW changes the equilibrium conditions of capital producers reported in Gertler and Karadi (2011). And the presence of fixed costs in production changes the equilibrium conditions of intermediate goods firms. Therefore equilibrium conditions of both agents are reported below.

2.6.1 Capital producers

The set up of capital producers is similar to that in the SWBGG model, with the addition of a shock to the quality of capital, ψ_t. At the end of period t, competitive capital producing firms buy capital from intermediate goods firms and then repair depreciated capital and builds new capital. They then sell both the new and re-furbished capital. The value of a unit of new capital is Q_t. Their profit is the difference between the revenue from selling the net capital and the costs of buying capital from intermediate firms and the investment needed to build new capital. The law of motion of capital is equal to:

$$K_{t+1} = (1 - \delta(U_t))\psi_t K_t + \left[1 - F\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{43}$$

where the depreciation function $\delta(U_t)$ has the following properties: $\delta'(U_t) > 0$, and $\delta''(U_t) > 0$ and $\zeta = \delta''(U_t)/\delta'(U_t)$. The shock to the quality of capital, ψ_t, follows a AR(1) process ρ_k is an autoregressive coefficient and ε_t^k is a serially uncorrelated, normally distributed shock with zero mean and standard deviation σ^k. The solution to the optimisation problem of capital producers yields the following equation linking asset prices and investment:

$$1 = Q_t\left[1 - F\left(\frac{I_t}{I_{t-1}}\right) - F'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right)\right] + \beta E_t\left[\Lambda_{t,t+1} Q_{t+1} F'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right] \tag{44}$$

2.6.2 Intermediate goods firms

Intermediate goods firms maximize profits in a perfectly competitive market and borrow from FI. At the end of period t they acquire capital from capital producers for use in production in subsequent period. After production in period $t + 1$, they can sell capital to capital producers without adjustment costs at the firm level. The firm finances its capital acquisitions each period by obtaining funds from the financial sector. Total revenue is given by the output produced and the capital sold to the capital producers (which is subject to a shock). After production, the number of unit of capital left over is $(Q_{t+1} - \delta(U_{t+1}))\psi_{t+1} K_{t+1}$.

The profit function is given by:

$$E_t\beta\Lambda_{t,t+1}\left[\Phi_{t+1}Y_{t+1}+(Q_{t+1}-\delta(U_{t+1}))\psi_{t+1}K_{t+1}-R^k_{t+1}Q_tK_{t+1}-\frac{W_{t+1}}{P_{t+1}}L_{t+1}\right] \tag{45}$$

Profit maximization yields the following first-order conditions with respect to capital, labour and utilization rate:

$$R^k_{t+1}Q_t = MC_{t+1}MP^K_{t+1}+\left[Q_{t+1}-\delta(U_{t+1})\right]\psi_{t+1} \tag{46}$$

$$MC_{t+1}MP^L_{t+1}=\frac{W_{t+1}}{P_{t+1}} \tag{47}$$

$$\delta'(U_t)\psi_tK_t = MC_{t+1}MP^U_{t+1} \tag{48}$$

where MP^u_{t+1} is the derivative of the production function with respect to the utilization rate.

There is perfect info between firms and banks. However the incentive compatibility constraint affects the supply of funds available to firms and therefore, the required rate of return on capital these firms have to pay. Each intermediate goods firm finances the acquisition of capital, K_{t+1}, by obtaining funds from the FI. The firm issues S_t state-contingent claims equal to the number of units of capital acquired and prices each claim at the price of a unit of capital Q_t:

$$Q_tK_{t+1}=Q_tS_t \tag{49}$$

2.7 Functional forms

Following Gertler and Karadi (2011), the utility function specialises as:

$$U_t\left(\cdot\right)=\ln\left(C_t-hC_{t-1}\right)-\frac{L_t^{1+\phi}}{1+\phi} \tag{50}$$

where h measures the degree of superficial internal habits in consumption and ϕ is the inverse of the Frisch elasticity of labour supply. The marginal utility is therefore:

$$U_{Ct}=(C_t-hC_{t-1})^{-1}-\beta hE_t[C_{t+1}-hC_t]^{-1}$$

The production function slightly differs among the two models because of the presence of the shock to the quality of capital, ψ_t, in the SWGK model as shown in equation (52), absent in equation (51):

$$Y_t = A_t(U_t K_t)^\alpha L_t^{1-\alpha} - \Theta \tag{51}$$

$$Y_t = A_t(U_t K_t \psi_t)^\alpha L_t^{1-\alpha} - \Theta \tag{52}$$

and A_t is the transitory technology shock follows an autoregressive process:

$$\log(A_t) = \rho_a \log(A_{t-1}) + \varepsilon_t^a, \tag{53}$$

where ρ_a is an autoregressive coefficient and ε_t^a is a serially uncorrelated, normally distributed shock with zero mean and standard deviation σ^a. As in Smets and Wouters (2007), the parameter Θ represents fixed costs in production.

3 Data and estimation strategy

The two models, SWBGG and SWGK, are estimated with quarterly data for the period 1996Q1-2008Q3 using as observables real GDP, real investment, real private consumption, employment, GDP deflator inflation, wage and the spread. In the both models there are seven orthogonal structural shocks. The following shocks are common to both models: the monetary policy, ε_t^r; the technology, ε_t^a; the government, ε_t^g; the price mark-up, $\hat{u}_t^p$; and the wage mark-up, $\hat{u}_t^w$, shocks. Since the financial sectors differ across the two models, the two financial shocks differ as well. In the SWBGG model there are an investment-specific shock, ε_t^x, and a shock to borrowers' net worth, ε_t^{nb}. In the SWGK models there are a shock to the quality of capital, ε_t^ψ, and a shock to FI' net worth, ε_t^{nl}. Thus in both models there are shocks originating directly in the financial sector. This addition can be justified by the results of Jermann and Quadrini (2009), who find that the addition of financial shocks brings the model much closer to the data. In each model, the shocks follows a AR(1) process, but the shocks to the monetary policy rule and net worth.

The short sample is dictated by the availability of the data for the spread series. The final quarter corresponds to the pre-crisis period: the collapse of the Lehman Brothers in September 2008 has been used as characterizing the crisis period, e.g. Lenza et al. (2010) and Giannone et al. (2011). Data come from the Area Wide Model database (Fagan et al., 2005, see) but the spread, which is taken from the ECB database. The spread is computed as the difference between the yield on BBB corporate bond and government AAA bonds. A bank-based measure of the spread is considered since the Euro Area (EA) has been described as a bank-based financial system, differently from to the market-based financial system in the United States, e.g. Trichet (2009). Section 5 explores the robustness of the results to a different measure of the spread. Following Smets and Wouters (2003), all real variables are detrended by a linear trend. GDP, investment, consumption and wage are logged and first-differenced. The inflation rate is measured as a quarterly log-difference of GDP deflator and demeaned. Data on the spread are demeaned and then divided by 100 to make the units compatible with the log-first-differenced data. Data on employment are used since there are no data available for hours worked in the Euro Area. In particular, employment responds more sluggish to macroeconomic shocks than hours worked and the following Calvo-type of adjustment is assumed:

$$\hat{E}_t = \frac{1}{1+\beta}\hat{E}_{t-1} + \frac{\beta}{1+\beta}E_t\left[\hat{E}_{t+1}\right] - \frac{(1-\beta\sigma_E)(1-\sigma_E)}{(1+\beta)\sigma_E}\left(\hat{L}_t - \hat{E}_t\right)$$

where E_t is employment and $1-\sigma_E$ represents the fraction of firms that can adjust the level of employment to the preferred amount of total labor input. Data on employment are logged and detrended since there is an upward trend in the employment series for the Euro area and hours worked and employment are stationary variables in the model. Transformed data are shown in Figure 1.

The Bayesian estimation approach combines the prior distributions of the parameters and the likelihood function conditional on the observed data to obtain the posterior distributions for the parameters of interest.[4] The likelihood function for the data is computed through the state-space representation and the Kalman filter. Let θ be the model parameter to be estimated; then, the solution of the rational expectations system takes the form:

$$s_t = As_{t-1} + B\eta_t \tag{54}$$

$$o_t = Cs_t + Du_t \tag{55}$$

$$\eta_t \sim \mathbf{N}(0,\Omega) \quad \text{and} \quad u_t \sim \mathbf{N}(0,\Phi)$$

where s_t is a vector containing the model's variables expressed as log-deviation from their steady-state values. It includes not only endogenous variables but also the exogenous processes. Vector η_t contains white noise innovations to these shocks. Matrices A and B are functions of the structural parameters of the DSGE model; o_t is the vector of observables and u_t is a set of shocks to the observables (like measurement errors).

The prior distribution $p(\theta)$ capture the pre-sample beliefs about the value of the parameters. The

[4]Version 4.2.1 of the Dynare toolbox for Matlab is used for the computations.

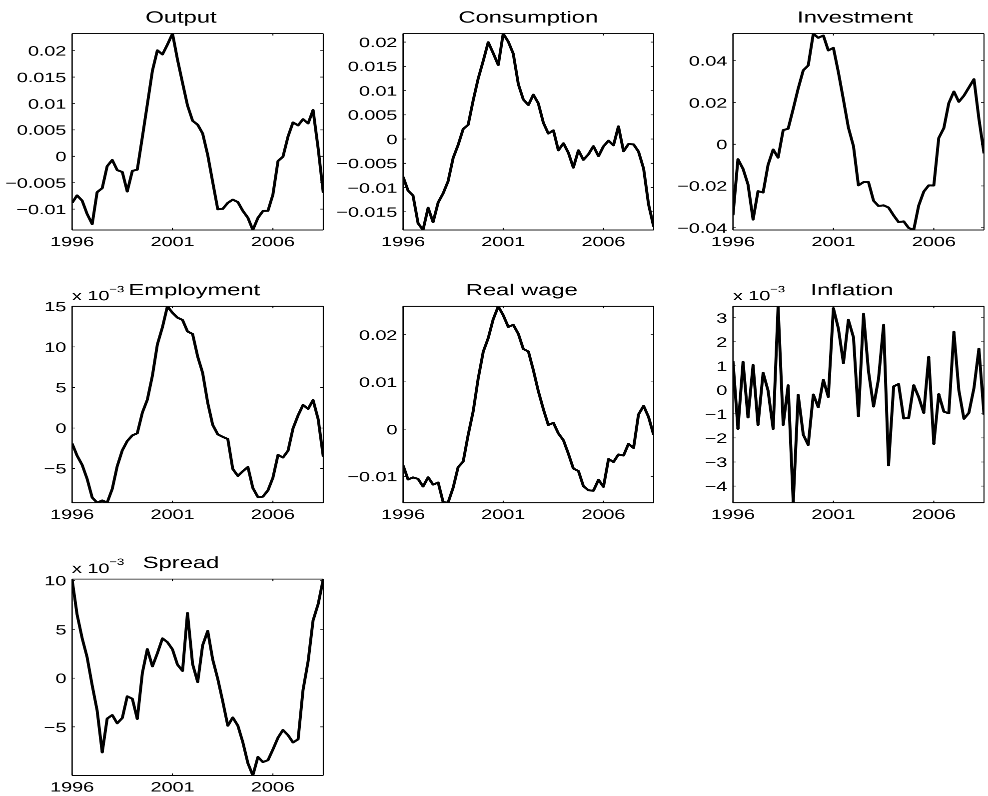

Figure 1: The dataset.

likelihood function, $p\left(o^T|\theta\right)$, tells the probability that the model assigns to each observation given some parameter value. According to the Bayes' theorem the posterior distribution of the parameters is:

$$p(\theta|o^T) = \frac{p\left(o^T|\theta\right)p(\theta)}{\int p\left(o^T|\theta\right)p(\theta)d\theta} \tag{56}$$

The likelihood and the priors are combined to approximate a posterior mode, which is used as the starting value of a Random Walk Metropolis algorithm (RWMA). This Markov Chain Monte Carlo (MCMC) method generates draws from the posterior density and updates the candidate parameter after each draw (see An and Schorfheide, 2007; Fernández-Villaverde, 2009, for details).

3.1 Calibration and priors

The parameters which cannot be identified in the dataset and/or are related to steady state values of the variables are calibrated, following a standard procedure (Smets and Wouters, 2003, 2007; Christiano et al., 2010, among others). The time period in the model corresponds to one quarter in the data.

Table 1 shows the calibration of the parameters common to both models. The discount factor, β, is equal to 0.99, implying a quarterly steady state real interest rate of 1%; the capital income share, α, is equal to 0.33, implying a steady state labour income share of two third. The depreciation rate is equal to 0.025, corresponding to an annual depreciation rate of 10%. The ratio of government spending to GDP is equal to 0.22. The elasticities of substitution in goods and labour market are equal to 6 in order to target a gross steady state mark up of 1.20, as in Christiano et al. (2010) and Gelain (2010), among others. The parameter θ represents the survival rate of bankers in the SWGK model and of intermediate goods firms in the SWBGG model. This parameter is set equal to 0.9715 implying an expected working life for bankers and firms of almost a decade; this value is consistent with both Gertler and Karadi (2011) and BGG.

The calibration of the financial parameters is shown in Table 2. In the SWBGG model, the parameter pinning down the steady state spread, S, is set equal to 1.003125 to match the steady state spread in the dataset of 125 basis points. Following Bernanke et al. (1999) and Gelain (2010), the ratio of capital to net worth is set to 2, implying that 50% of firm's capital expenditures are externally financed. As long as the calibration of the SWGK model is concerned, the fraction of assets given to new bankers, χ, and the fraction of assets that can be diverted, λ, are equal to 0.0007 and 0.4255, respectively, to target the steady state spread in the dataset and a steady state leverage ratio of 5, a value comparable to that used by Gertler and Karadi (2011). Section 5 investigates the robustness of the main results to the calibration of the financial parameters.

Parameter	Value
β, discount factor	0.99
α, capital income share	0.3
δ, depreciation rate	0.025
$\frac{G}{Y}$, government spending to GDP ratio	0.22
ε, elasticity of substitution in good market	set to target $M = 1.20$
ε_w, elasticity of substitution in labour market	set to target $M^w = 1.20$
θ, survival rate	0.9715

Table 1: Calibration of parameters common to both models

Table 3 shows the assumptions for the prior distributions of the estimated parameters for both models. The choice of the functional forms of parameters and the location of the prior mean correspond to a large

Financial Parameters	SWBGG Model	SWGK Model
S, steady state spread	1.003125	–
$\frac{K}{N}$, leverage ratio	2	5 (implied by χ and λ)
χ, fraction of assets given to the new bankers	–	0.0007
λ, fraction of divertable assets	–	0.4255

Table 2: Calibration of model-specific parameters

extent to those in Smets and Wouters (2003, 2007) where applicable. In general, the Beta distribution is used for all parameters bounded between 0 and 1, the Normal distribution is used for the unbounded parameters and the Inverse Gamma distribution for the standard deviation of the shocks in order to guarantee a positive variance.

The Calvo coefficients for prices and wages are described by a Beta distribution with a prior mean of 0.75, corresponding to an average length of contracts of a year. The Calvo parameter for employment is assumed to follow a Beta distribution but with a lower prior mean, equal to 0.5, as in Smets and Wouters (2003). The parameters measuring the degree of indexation to past inflation in the good an labour markets have also a prior mean of 0.5, following a Beta distribution. The elasticity of the investment adjustment cost function and the elasticity of marginal depreciation with respect to capital utilization follows a Normal distribution with a prior mean of 4 and 0.25. The habit parameter has a prior mean of 0.7 and follows a Beta distribution. The parameter measuring the inverse of the Frisch elasticity of labour supply follows a Normal distribution with a prior mean of 0.33, the value used for the same utility function by Gertler and Karadi (2011). The distribution and the prior mean of the parameter measuring fixed costs in production are Normal and 1.25, respectively. Following De Graeve (2008), the elasticity of external finance premium with respect to leverage is assumed to follow a Uniform distribution, with values in the interval $(0, 0.3)$. The distribution and prior mean of Taylor rule parameters are taken from Smets and Wouters (2003). The effective prior of the parameter measuring the response to inflation in the Taylor rule is truncated at the boundary of the determinacy region. The parameters measuring the persistence of the shock processes are assumed to follow a Beta distribution with a prior mean of 0.85. The Inverse Gamma (IG) distribution is used for the standard deviation of the shocks with a loose prior with 2 degrees of freedom.

4 Model comparison

The comparison between the two models is made first by looking at the estimated parameters and the Bayes Factor. Second, business cycle moments of each model are compared to “real facts”. Third, relative forecasting performance is presented. Finally impulse response and variance decomposition are described.

4.1 Estimated parameters and the Bayes Factor

The mean of the estimated parameters for each model are computed with the Metropolis-Hastings algorithm with a sample of 250,000 draws (see Smets and Wouters, 2003 for further details). For each model Table 3 reports the posterior mean with 95% probability intervals in parentheses. In general, parameters are remarkably similar across the two models. As in Smets and Wouters (2005), the fact that in almost all the cases the posterior estimate of a parameter in one model falls in the estimated confidence band for the same parameter of the other model can be considered as a rough measure of similarity. Nevertheless, the posterior mean of few parameters differs.

Concerning the first set of parameters, i.e. those similar across the two models, the main findings are as follows. The degree of price stickiness reveals that firms adjust prices about every two-and-a-half years. This value is consistent with the evidence reported by Smets and Wouters (2003). The Calvo parameter for wage stickiness reveals that the average duration of wage contracts is almost a year, considerably lower than the degree of price stickiness, as in Smets and Wouters (2003). There is a moderate degree of wage and price indexation, similarly to Gerali et al. (2010). The elasticity of the cost of changing investment is in the region of the estimates by Smets and Wouters (2003), since a 1% increase in the price of installed capital leads to an increase of investment of about 2%. The mean of the habit parameter is close to the value found by Gelain (2010) for both models. The estimates of the parameter measuring fixed costs in production and the Taylor rule parameter to inflation are also similar to Smets and Wouters (2003). There is strong evidence of short-term reaction to the current change in inflation. The response to the output gap level is similar to Gerali et al. (2010), though lower in the SWGK model. There is also evidence of short-term reaction to the current change in the output gap. Turning to the exogenous shock processes, all shocks are quite persistent; not surprisingly the IRFs show a persistent response of the variables to the shocks.

Parameters	Prior distribution			Posterior mean	Posterior mean
	Distr	Mean	St. Dev./df	SWBGG model	SWGK model
σ_p, Calvo prices	Beta	0.75	0.05	0.913 [0.891:0.936]	0.897 [0.870:0.925]
σ_w, Calvo wages	Beta	0.75	0.05	0.746 [0.690:0.802]	0.708 [0.647:0.767]
σ_E, Calvo employment	Beta	0.5	0.2	0.772 [0.733:0.811]	0.836 [0.804:0.867]
σ_{pi}, price indexation	Beta	0.5	0.2	0.120 [0.014:0.218]	0.121 [0.012:0.223]
σ_{wi}, wage indexation	Beta	0.5	0.2	0.118 [0.018:0.215]	0.126 [0.017:0.233]
ξ, inv. adj. costs	Normal	4	1.5	5.468 [3.656:7.216]	6.898 [5.348: 8.369]
ζ, elasticity of capital util	Normal	0.25	0.1	0.779 [0.697:0.884]	0.288 [0.185:0.386]
h, habit parameter	Beta	0.7	0.1	0.621 [0.567:0.677]	0.638 [0.590:0.686]
Θ, fixed costs in production	Normal	1.25	0.125	1.396 [1.215:1.574]	1.289 [1.084:1.449]
ϕ, inverse of Frisch elast. of labour supply	Normal	0.33	0.1	0.208 [0.063:0.327]	0.330 [0.174:0.473]
$\varkappa$, elast. of external finance to leverage	Uniform	0	0.3	0.053 [0.045:0.061]	–
ρ_π, Taylor rule	Normal	1.7	0.1	1.668 [1.518:1.826]	1.730 [1.576:1.884]
ρ_{Δ_π}, Taylor rule changes in π	Normal	0.3	0.1	0.285 [0.136:0.446]	0.299 [0.153:0.458]
ρ_y, Taylor rule	Normal	0.125	0.05	0.247 [0.180:0.316]	0.188 [0.115:0.259]
ρ_{Δ_y}, Taylor rule changes in y	Normal	0.0625	0.05	0.106 [0.027:0.178]	0.152 [0.069:0.233]
ρ_i, Taylor rule smoothing	Beta	0.80	0.2	0.185 [0.056:0.306]	0.598 [0.520:0.677]
ρ_a, persist of tech shock	Beta	0.85	0.1	0.731 [0.654:0.806]	0.684 [0.605:0.759]
ρ_x, persistence of investment shock	Beta	0.85	0.1	0.954 [0.935:0.974]	–
ρ_k, persist of capital shock	Beta	0.85	0.1	–	0.492 [0.402:0.581]
ρ_g, persistence of gov shock	Beta	0.85	0.1	0.974 [0.957:0.991]	0.864 [0.764:0.972]
ρ_p, persistence of price mark-up shock	Beta	0.85	0.1	0.899 [0.813:0.978]	0.762 [0.601:0.919]
ρ_w, persistence of wage mark-up shock	Beta	0.85	0.1	0.447 [0.277:0.624]	0.585 [0.426:0.750]
σ_a, std of tech shock	IG	0.1	2	0.020 [0.016:0.024]	0.026 [0.018:0.034]
σ_x, std of investment shock	IG	0.1	2	0.054 [0.045:0.064]	–
σ_k, std of capital quality shock	IG	0.1	2	–	0.022 [0.018:0.025]
σ_i, std of monetary shock	IG	0.1	2	0.015 [0.013:0.018]	0.015 [0.012:0.017]
σ_n, std of FI capital shock	IG	0.1	2	0.022 [0.017:0.027]	0.083 [0.064:0.101]
σ_g, std of gov shock	IG	0.1	2	0.049 [0.038:0.060]	0.015 [0.013:0.018]
σ_{pm}, std of price mark-up shock	IG	0.1	2	0.079 [0.023:0.148]	0.058 [0.021:0.094]
σ_{wm}, std of wage mark-up shock	IG	0.1	2	0.051 [0.029:0.071]	0.049 [0.028: 0.070]

Table 3: Prior and posterior distributions of structural parameters

The mean of the standard errors of the shocks is lower than the studies of Smets and Wouters (2003) and Gelain (2010) who use data over the period 1980Q2-1999Q4 and 1980Q1-2008Q3, respectively. The more recent period used here is characterised by lower volatility, similarly to the findings of Gerali et al. (2010), who use data over the period 1998Q1-2008Q4.

The second set of parameters includes those for which the posterior means differ. The mean of the parameter measuring the elasticity of capital utilisation is higher in the SWBGG model. This result is not surprising since the way in which this elasticity is computed differs among the two models. While in the SWGK model the cost of capital utilisation is directly related with the increased depreciation *à la* King and Rebelo (2000), in the SWBGG model the capital utilisation function is modelled as in Christiano et al. (2005) who use a more general function. Notwithstanding this, the mean of this parameter is higher than the corresponding estimates by Smets and Wouters (2003), suggesting a lower response of capital utilization. The degree of interest rate smoothing is considerably low compared to the similar studies for the Euro Area, since its mean is equal to 0.185 in the SWBGG model and to 0.598 in the SWGK model versus 0.956 in Smets and Wouters (2003) and 0.845 in Gelain (2010). This result is in line with Consolo and Favero (2009), who examined the problem of weak instruments to identify the degree of monetary policy inertia. According to Consolo and Favero (2009) and Rudebusch (2002), a high degree of interest rate smoothing hardly reconciles with the low predictability of monetary policy rates. These authors found that serially correlated or persistent shocks could explain monetary policy inertia. The difference in the mean of the parameter between the two models could be partly explained by the different size of the interest rate shock, analysed in Subsection 4.2. A closer inspection of Table 3 reveals that the AR coefficients of the shock processes are generally lower for the SWGK model. Moreover, in both models the government shock is most persistent, similarly to Smets and Wouters (2003). The same rationale applies to the standard deviation of the shocks, but for the standard deviation of the FI capital shock with a higher posterior mean in the SWGK model. Both models feature two “financial shocks”: the FI capital shock is common to both models and originate in the demand side of financial sector in the SWBGG model and in the supply-side in the SWGK model; the shock to the marginal efficiency of investment in the SWBGG model; and to the quality of capital in the SWGK model. The volatility of the FI capital shock is lower in the SWBGG model, which features a higher volatility of the other “financial shock”, contrary to what happens in the SWGK model, with the caveat of comparing different shock.

A third set of parameters includes those parameters which differ among the two models. For example, the shock to the marginal efficiency of investment in the SWBGG model and to the quality of capital in the SWGK model. The elasticity of external finance premium with respect to the leverage position of intermediate goods firms has a posterior mean of 0.053, higher than the value found by Gelain (2010), suggesting a more reactive external premium to the firms' leverage position.

Another dimension along which the two estimated models are compared is the Bayes Factor, as in An and Schorfheide (2007) and Levine et al. (2010), among many others. Such a comparison is based on the marginal likelihood of alternative models. Let m_i be a given model, with $m_i \in M$, θ the parameter vector and $p_i(\theta|m_i)$ the prior density for model m_i. The marginal likelihood for a given model m_i and common dataset Y is:

$$L(Y|m_i) = \int_\theta L(Y|\theta, m_i) p_i(\theta|m_i) d\theta$$

where $L(Y|\theta, m_i)$ is the likelihood function for the observed data Y conditional on the parameter vector and on the model; and $L(Y|m_i)$ is the marginal data density. The Bayes Factor between model i and model j is calculated as follows:

$$BF_{ij} = \frac{L(Y|m_i)}{L(Y|m_j)} = \frac{\exp(LL(Y|m_i))}{\exp(LL(Y|m_j))} \tag{57}$$

where LL stands for log-likelihood. The log data density of the two models is computed with the Geweke (1999)'s modified harmonic mean estimator. The Bayes Factor between the SWGK model and the SWBGG model is:

$$BF_{12} = \frac{\exp(LL(Y|m_{SWGK}))}{\exp(LL(Y|m_{SWBGG}))} = \frac{\exp(1440.27)}{\exp(1390.27)} = 5.2 \times 10^{21} \tag{58}$$

The positive and large value of the Bayes Factor provides clear evidence in favour of the SWGK model.

4.2 Model-implied shocks

Another dimension along which the two models are compared is the analysis of the estimated structural shocks implied by the Kalman smoother at the posterior mean, as in Kirchner and Rieth (2010). As shown in Figure 2, the SWBGG model generates much larger investment, interest rate and government shocks and also larger price mark-up and wage mark-up shocks. The sole exception is the shock to net worth, larger in the SWGK model. It should be noted that this shock affects the net worth of financial intermediaries in the SWGK model and the net worth of intermediate goods firms in the SWBGG model. In the former model this shock is more volatile because it captures both the supply and the demand of the credit market, while in the latter model it only captures the demand side of the credit market. Overall,

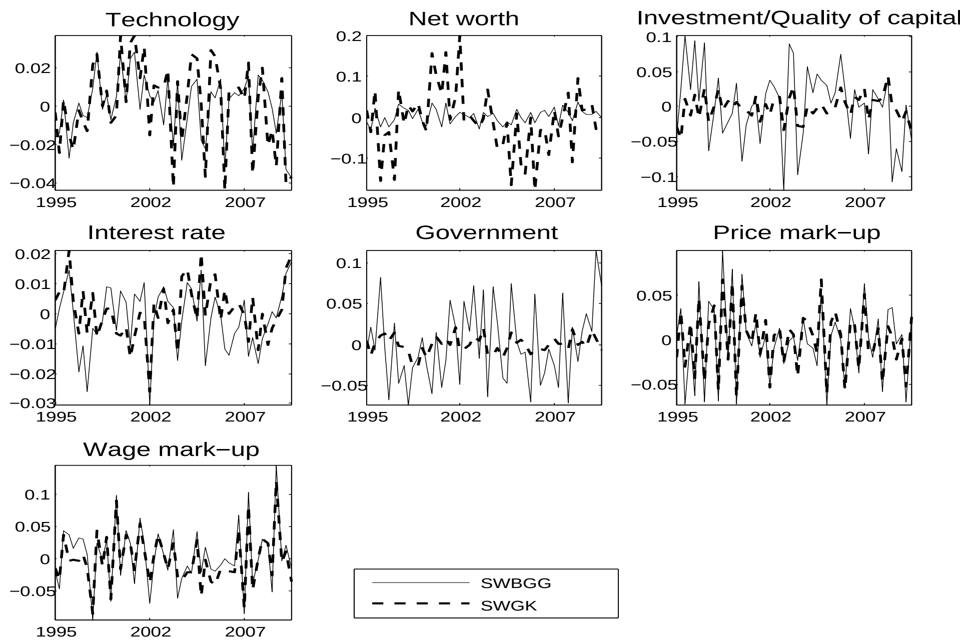

Figure 2: Estimated structural shocks in the SWBGG and SWGK models.

the SWGK model requires smaller shocks to describe the data.

4.3 Business cycle moments

As standard, especially in the RBC literature, the moments generated by the models are compared to those in the data to further assess the conformity between the data and the models. This analysis makes also it possible to compare alternative models. In this section the autocorrelation in the data are compared to those in the models computed at the posterior means, as in Gabriel et al. (2010). Figure 3 shows the autocorrelation of output, investment, inflation and the spread. These series are positively correlated over short horizons. Both models match reasonably well the correlation of output, inflation and the spread. Investment is more autocorrelated in the models than in the data. Both models are able to reproduce the autocorrelation of output, though the SWGK model fits the data better. Both models generate a more autocorrelated series of investment, but the SWGK model gets slightly closer to the data. The SWGK models also reproduce the autocorrelation of inflation, while the SWBGG model generated a more autocorrelated series. As far as the spread is concerned, both models generate a more autocorrelated series of investment, but the SWGK model gets slightly closer to the data. Overall, the SWGK model fits the observed autocorrelation better compared to the SWBGG model for all the series.

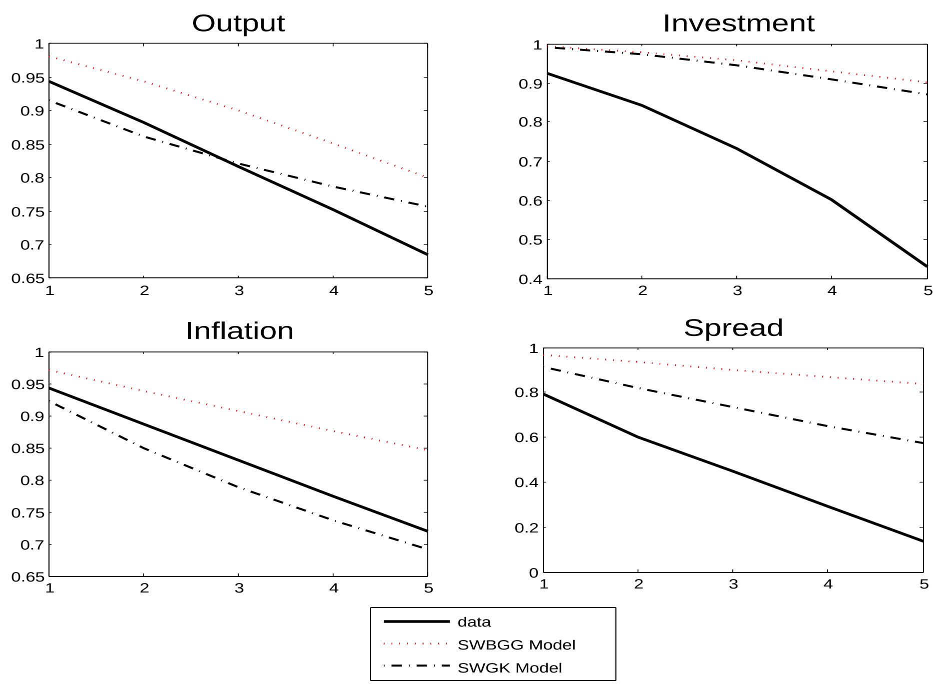

Figure 3: Business cycle moments: autocorrleations in the data versus the models.

4.4 Forecasting performance

One-step ahead forecasts are computed in order to evaluate the forecasting performance of alternative models, as in Kirchner and Rieth (2010) and Adolfson et al. (2007). Following Kirchner and Rieth (2010), Table 4 reports the root mean squared forecast error (RMSFE) computed with one-sided Kalman filtered estimates of the observed variables, at the posterior mean of the estimated parameters in each model.[5]

Table 4 shows that RMSFE for output and investment are larger than RMSFE for the other variables in both models. The lowest value is recorded for inflation, with a RMSFE of 0.0002 in the SWBGG model and of 0.0004 in the SWGK model; then the spread has a RMSFE of 0.0003 in the SWGK model and of 0.0024 in the SWBGG model. The comparison between the two models reveals that RMSFE for output, consumption, investment, wage and the spread are lower in the SWGK model. RMSFE for employment and inflation are lower in the SWBGG model compared to those of the SWGK model, though quantitatively speaking the difference between the two models is negligible.

The relatively inferior forecasting performance for output and investment in both models is not surprising, since both models do not include factors such as the external sector, which might contribute to provide a better forecast for these variables. The introduction of financial frictions shows reasonable empirical properties in forecasting the financial variable included in the dataset.

Overall, the SWGK model performs better in terms of forecasting some selected variables of the Euro Area.

	Root mean squared forecast error	
Variable	Model SWBGG	Model SWGK
Output	0.0046	0.0022
Consumption	0.0021	0.0017
Investment	0.0075	0.0070
Employment	0.0012	0.0013
Wage	0.0020	0.0017
Inflation	0.0002	0.0004
Spread	0.0024	0.0003

Table 4: Forecasting performance

4.5 Impulse response function

This section presents the impulse response functions analysis. Figures 4, 5 and 6 examine three shocks, the two "financial" and the monetary policy shocks, since they highlight the different transmission mechanisms among the two models. All the shocks are set to produce a downturn. The first four charts of each figure show the responses of output, investment, inflation and the spread in the SWBGG model, while the other four charts show the responses of the same variables in the SWGK model. In all the figures, the solid lines represent the estimated median and the dotted lines represent the 95% highest posterior density

[5] The formula is: RMSE = $\sqrt{T^{-1}\sum_{t=1}^{T}(y_t - \hat{y_t}^f)^2}$, where y_t stands for the observable and $\hat{y_t}^f$ is the one-step ahead forecast.

confidence intervals.

Figure 4 shows the consequences of a shock to net worth. In the SWBGG model this shock affects net worth of intermediate goods firms, while in the SWGK model it affects net worth of FI. In the former model, a reduction in net worth of firms has two direct effects: (i) the amount of borrowing should increase since firms have less internal funds to acquire *the same amount* capital, equation (33); and (ii) the leverage ratio increases, as evident from equation (35). This last effect implies an increase in the agency costs and loans become riskier. As a result, the spread rises, as evident from the chart. The higher costs of purchasing capital depress the demand for it and investment falls. Output increases on impact, although not significantly, due to the first effect which is then more than offset by the second effect, implying a significant reduction in output. The contraction in aggregate demand leads to a decline in inflation. In the SWGK model, the shock to FI net worth shown in Figure 4 leads to an immediate increase in the leverage, as evident from equation (40). Since the endogenous balance sheet constraint is always binding, financial intermediaries are obliged to curtail their supply of lending. As a result, investment is falling as well as output. The reduction in loans causes a fall in bank profits. As explained in Villa and Yang (2011), three factors affect the profits of financial intermediaries: the amount of loans, the lending rate and the leverage. The fall in profits caused by a reduction of loans makes financial intermediaries willing to increase the lending rate more than the increase in the policy rate, in order to restore profits. The rise in the spread is shown in Figure 4. The increase in financing costs makes lending more expensive and firms reduce the demand for loans, further squeezing investment. It should also be noted that in this model there is an identity between loans and capital, equation (49). The reduction of loans, i.e. capital, also immediately affect the production function. As a result, in addition to the change in the aggregate demand, the aggregate supply is also clearly affected. As a result, on the nominal side the contraction in output implies higher marginal costs and, therefore, inflation rises.

Figure 5 shows the effects of the investment-efficiency shock in the SWBGG model and of the shock to the quality of capital in the SWGK model. In the former case, the shock implies a rise in the price of capital, Q_t. This leads to two effects: (i) investment falls as well as output; and (ii) net worth of firms increases due to the higher return on capital, equation (38). The latter effect explains the fall in the spread shown in the chart. This should cause an increase in investment. However, the first effect dominates and investment decreases. The presence of the financial friction, therefore, attenuates the fall in investment and output, as also shown by Christensen and Dib (2008) and Gelain (2010). In the SWGK model, the shock to the quality of capital, also present in the model by Gertler and Kiyotaki (2009), is meant to capture economic obsolescence. If capital is good-specific, when the shock hits the economy, a random fraction of goods become obsolete and the capital used to produce the obsolete goods becomes worthless. Therefore, given a standard production function in capital and labour, this shock implies a contraction in output. However, this is only part of the story. The shock to the quality of capital directly translates into a shock to the bank balance sheet because of the identity between capital and assets. The loans provided by the financial intermediaries to firms are used by the latter to fully finance their acquisition of capital. Therefore, this shock implies a reduction in the "quality of intermediary assets". The reduction in total assets leads to a fall in banks profits. The same mechanism of the shock to FI net worth is at work. Financial intermediaries increase the lending rate to increase profits and this causes a rise in the spread and a further decline in lending and investment, as shown in the chart. Both aggregate demand and aggregate supply are affected; the change in aggregate demand is stronger, leading to a fall in inflation similarly to Gertler and Karadi (2011), though not significant.

Contractionary monetary policy shock is shown in Figure 6. While the impact responses are similar between the two models, the dynamics slightly changes. In both models an increase in the nominal interest rate reduces investment and, therefore, output. Demand downward pressures feed through changes in the output gap to inflation. This causes a downward shift in aggregate demand, which reduces inflation on impact. This is the standard interest rate channel of monetary policy transmission. In the models, the transmission mechanism of the policy shock is enhanced through its impact on the financial market. In the SWBGG model the tightening of monetary policy leads to a decline in the return to capital, as evident from equation (35). This causes a fall in net worth of intermediate goods firms, and the spread rises, as shown in the chart. This mechanism further reinforces the contraction in capital and investment. In the SWGK model, due to the retrenchment in investment, the demand for loans decreases as well. As a result, bank profits fall and FI net worth decreases. At this point, the FI balance sheet constraint comes into play: financial intermediaries cannot be over-leveraged because of the incentive compatibility constraint arising from the presence of asymmetric information. Therefore, FI increase the lending rate more than the increase in the policy rate. As a result, the spread increases; this causes a further decline in loans and investment as shown in Figure 6. In both models, the presence of financial frictions exacerbate the simulated contraction.

4.6 Variance decomposition

Movements in GDP, investment, inflation and spread are now decomposed into parts caused by each shock at different time horizon, based on the mode of the model's posterior distribution. The model economy is driven by seven shocks: productivity, monetary policy, government spending, net worth, shock to the investment/quality of capital, price mark-up and wage mark-up shocks. In Figure 8 the two "financial" shocks have been merged and are represented by the gray bar; the two mark-ups shocks are also merged and represented by the white bar.

Figure 7 shows that in the SWBGG model short run fluctuations in output are mainly driven the by "demand shocks", in this model interest rate (dark gray bar) and government (the white gray bar) shocks. Similarly to the results of Smets and Wouters (2007) for the US economy, the contribution of the monetary policy shock declines as the time horizon increases. Differently from SW, the contribution of productivity shock (the black bar) declines as well, while financial shocks (the gray bar) account for an increasing proportion of long-run movements in real GDP. This result is consistent with the findings of other models featuring imperfect financial markets, such as Jermann and Quadrini (2009) and Brzoza-Brzezina et al. (2011). Fiscal policy shocks explain almost a third of both short and long-run fluctuations in output. In the long run the mark-ups shocks play the major contribution in explaining output fluctuations compared to the contribution of the other shocks. Not surprisingly, "financial" shocks account for most movements of investment; the role of monetary policy shocks is decreasing over time. Similarly to Smets and Wouters (2007), mark-up shocks are the most important drivers of inflation. Productivity and monetary policy shocks account for a small fraction of inflation variability at every horizon. In the long-run "financial" and government shocks play an increasing role. The final chart shows the variance decomposition for the spread. In this case the contribution of each shock is not substantially different between the short run and medium- and long run. Not surprisingly financial shocks are the main drivers of this variable. The two financial shocks contribute to more than 70 percent of fluctuations in the spread. Interest rate shock plays a minor role.

As Figure 8 shows, in the SWGK model, the contribution of the monetary policy shock in explaining output variations also declines over time, even if its impact is greater. The contribution of financial shocks increases over time, while the role of productivity shocks is negligible. The introduction of a banking sector playing an active role in the transmission mechanism of the shocks alters the standard results of a SW economy. As far as investment is concerned, short and long-run fluctuations are mainly driven by monetary and financial shocks. Not surprisingly, results are similar for the spread, defined as the difference between lending rate and risk free rate. The latter component is mainly explained by interest rate shocks, while the two financial shocks contribute in the explanations in the movements of the lending rate, which originates within the banking sector. Inflation is mainly driven by mark-up shocks with financial shocks explaining an increasing fraction over time.

As a term of comparison, the contributions of the structural shocks in explaining business cycle fluctuations differ among the two models, in particular for output. The SWGK model tends to emphasize the role of the financial sector in explaining business cycle fluctuations compared to the SWBGG model.

5 Robustness analysis

This section illustrates a series of modifications in: (i) the calibration of the steady state leverage ratio of the two models; (ii) the series of the spread used as observable; and (ii) the models' specification.

The importance of the values of the leverage ratio is stressed by several studies, such as Peersman and Smets (2005) and Carlstrom et al. (2011). In the SWBGG model a change in the steady state leverage ratio has a direct impact on equation describing the evolution of net worth of intermediate goods firms: any change in the leverage ratio clearly influences the financial accelerator effect. In the SWGK model a change in the steady state leverage ratio influences the evolution of net worth of financial intermediaries. Similarly to the SWBGG model, a change in the steady state leverage ratio of banks affects the spread, and therefore total output, as explained in Subsection 4.5.

The leverage ratio is equal to 2 in the SWBGG model and 5 in the SWGK model in the baseline calibration shown in Table 2. Table 5 shows how the Bayes Factor is affected by changes in the leverage ratio of the two models.[6] For each models, estimations are run for the different values of the steady state leverage ratio and the marginal data densities of the model whose steady state leverage changes are kept to compute the Bayes Factor. For sake of brevity, parameters estimates are not reported. In the first two columns of the table the leverage ratio of firms in the SWBGG model changes from 1.2 to 3, implying that from 16% to 66% of firms' capital expenditure are externally financed. All the parameters of the SWGK model are the same as in Table 2. The Bayes Factor shows clear evidence in favour of the SWGK model, for any value of the leverage ratio in the SWBGG model. The last two columns of Table 5 shows the sensitivity of the Bayes Factor to different steady state leverage of the SWGK model, while all the

[6] Two methods can be used to evaluate the log data density: the modified harmonic mean and the Laplace approximation. As in Smets and Wouters (2007), the results of both approximations are very close in the baseline specification of Subsection 4.1: 1390.3 with the modified harmonic mean and 1389.1 with the Laplace approximation in the SWBGG model; and 1440.3 with the modified harmonic mean and 1439.5 with the Laplace approximation in the SWGK model. Since the former method is computationally costly, the latter method is used in these experiments.

parameters of the SWBGG model are unchanged. Financial intermediaries are generally more leveraged than firms; in this experiment the leverage ratio changes from a value of 4 to a value of 7. The conclusion of Section 4 are unchanged: there is clear evidence in favour of the SWGK model for different values of the steady state leverage ratio of FI.

SWBGG model		SWGK model	
Leverage = $\frac{K}{N}$	Bayes Factor = $\frac{\exp(LL(Y\|\bar{m}_{SWGK}))}{\exp(LL(Y\|m_{i,SWBGG}))}$	Leverage = $\frac{K}{N}$	Bayes Factor = $\frac{\exp(LL(Y\|m_{i,SWGK}))}{\exp(LL(Y\|\bar{m}_{SWBGG}))}$
1.2	3.6×10^{29}	4	9.9×10^{22}
1.5	8.4×10^{25}	4.5	1.1×10^{22}
1.8	1.5×10^{24}	4.8	1.1×10^{22}
2	7.8×10^{21}	5	7.8×10^{21}
2.2	6.5×10^{21}	5.4	5.6×10^{21}
2.4	6.0×10^{23}	5.8	6.7×10^{21}
2.6	1.6×10^{22}	6	4.9×10^{21}
2.8	1.6×10^{56}	6.5	3.1×10^{20}
3	3.1×10^{45}	7	1.4×10^{20}

Table 5: Sensitivity of the Bayes Factor to the steady state leverage ratio. In the first two columns the parameters of the SWGK model are calibrated as in Table 2 while the leverage ratio of the SWBGG model changes. In the last two columns the parameters of the SWBGG model are calibrated as in Table 2 while the leverage ratio of the SWGK model changes.

As an additional sensitivity check, a different series of the spread is used as observable. The series is computed as the difference between a yield on A corporate bonds and government AAA bonds. The average spread is now 82 basis points, lower than the baseline calibration. The parameter S in the SWBGG model and the parameter χ in the SWGK model are now changed to match the different value of the steady state spread; the other calibrated parameters are unchanged.[7] The Bayes Factor is then:

$$BF_{12} = \frac{\exp(LL(Y|m_{SWGK}))}{\exp(LL(Y|m_{SWBGG}))} = \frac{\exp(1437.28)}{\exp(1395.10)} = 2.1 \times 10^{18} \tag{59}$$

The comparison between the two models is again in favour of the SWGK model, even with a different series of the spread.

The two models embed the following same types of frictions: price stickiness, price indexation, wage stickiness, wage indexation, investment adjustment costs, habit in consumption, variable capital utilization and fixed costs in production. And the frictions originating in the financial sector are different. As a further robustness check, each of the common frictions are turned off one at a time in the spirit of SW. Then, the Bayes Factor is computed and reported in Table 6. This experiment makes also it possible to

[7] It would be interesting to use a series with a higher steady state average spread; however, this experiment is not possible due to data limitations.

compare the marginal data densities in order to analyse which frictions are important to account for the dynamics of each model. It is evident that the Bayes Factor is always in favour of the SWGK model, no matter which friction is turned off. In the SWBGG model on the side of nominal frictions, removing price stickiness implies a considerable deterioration in terms of log data density. Similarly to SW, price or wage indexation does not play an important role in explaining the model dynamics. On the side of real frictions, the most important in terms of log data density is investment adjustment costs. A larger value of the capital utilization elasticity implies higher marginal depreciation cost, and therefore less variation in capital utilization. Removing this friction does not imply a deterioration of the log-likelihood; its value is even higher. Similarly to SW, shutting this friction comes at no cost in terms of model's performance. The analysis of the importance of different frictions in the SWGK model yields similar result but for capital utilization, which plays a role in explaining model's performance.[8]

Friction	Bayes Factor
Baseline	$\frac{\exp(1439.52)}{\exp(1389.11)} = 7.8 \times 10^{21}$
$\sigma_p = 0.1$, Calvo prices	$\frac{\exp(1344.59)}{\exp(1188.19)} = 8.4 \times 10^{67}$
$\sigma_w = 0.1$, Calvo wages	$\frac{\exp(1370.96)}{\exp(1307.48)} = 3.7 \times 10^{27}$
$\sigma_{pi} = 0$, price indexation	$\frac{\exp(1438.12)}{\exp(1377.53)} = 2.1 \times 10^{26}$
$\sigma_{wi} = 0$, wage indexation	$\frac{\exp(1438.12)}{\exp(1377.50)} = 2.1 \times 10^{26}$
$\xi = 0.1$, inv. adj. costs	$\frac{\exp(1354.78)}{\exp(1117.13)} = 1.6 \times 10^{103}$
$\zeta = 2$, elasticity of capital util	$\frac{\exp(1417.30)}{\exp(1394.41)} = 8.7 \times 10^{9}$
$h = 0.1$, habit parameter	$\frac{\exp(1395.23)}{\exp(1340.51)} = 5.8 \times 10^{23}$
$\Theta = 1.1$, fixed costs in production	$\frac{\exp(1432.75)}{\exp(1378.76)} = 2.8 \times 10^{23}$

Table 6: Bayes Factor for different models' specifications

6 Conclusion

This paper builds and compares two DSGE models featuring different types of financial frictions: (i) the SWBGG model incorporates frictions originating in the demand side of the credit market; and (ii) the SWGK model incorporates frictions embedded in the supply side of the credit market. The two models are estimated with Bayesian techniques for the period 1996Q1-2008Q3 with Euro area data. The SWGK model provides better results according to the following criteria: the comparison of estimated parameters and the analysis of the Bayes Factor; the comparison between the simulated versus actual moments; the

[8]This apparent conflicting result is not surprising since the way capital utilization is modelled differs among the two models.

forecasting performance. This result is robust to a series of models' calibration and specification. Both models delivers reasonable impulse responses. The internal propagation mechanism and the financial accelerator effect of the shocks differ between the two models.

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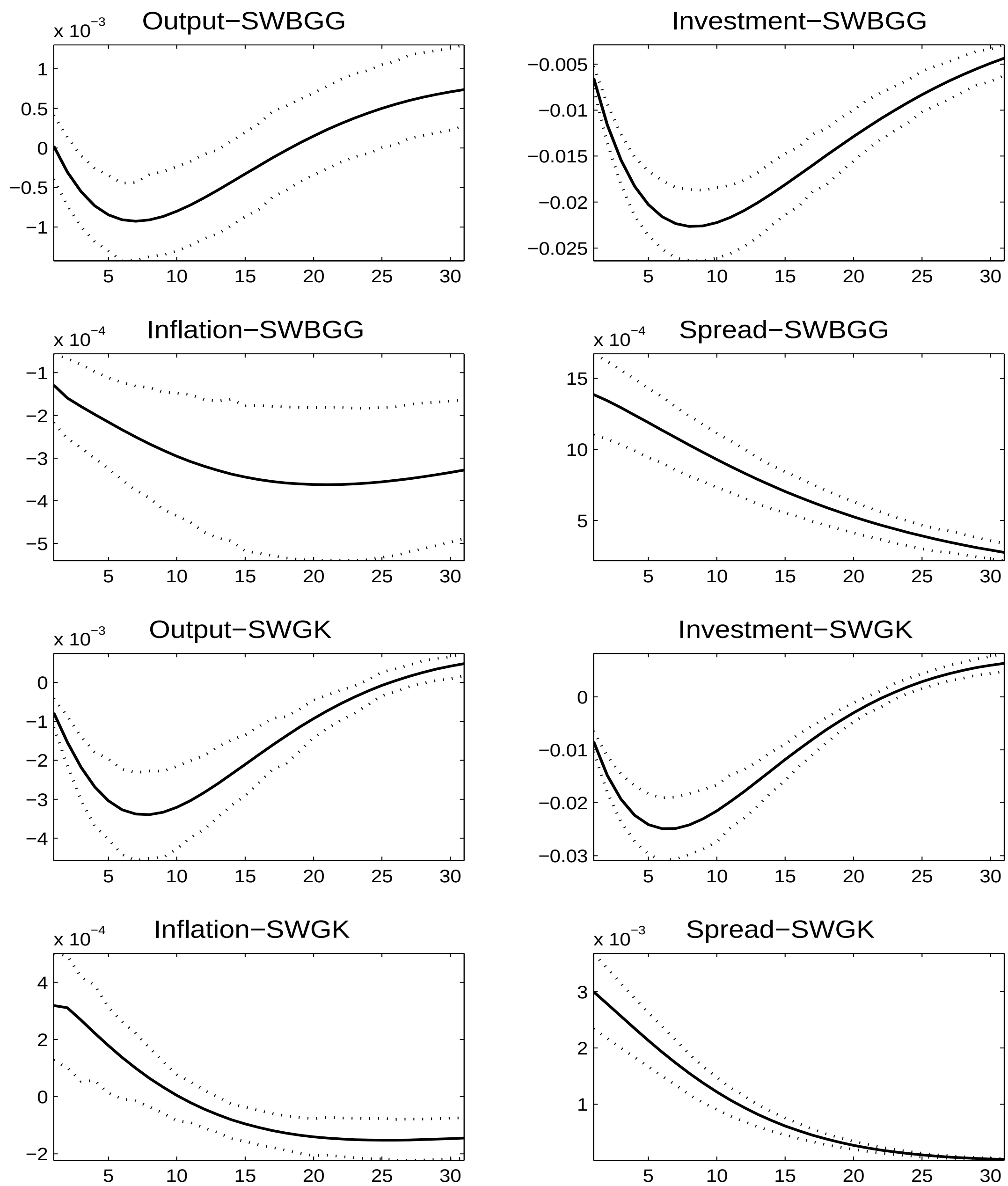

Figure 4: Net worth shock. Solid lines represent mean IRF and dashed line represent the 95% highest posterior density confidence intervals.

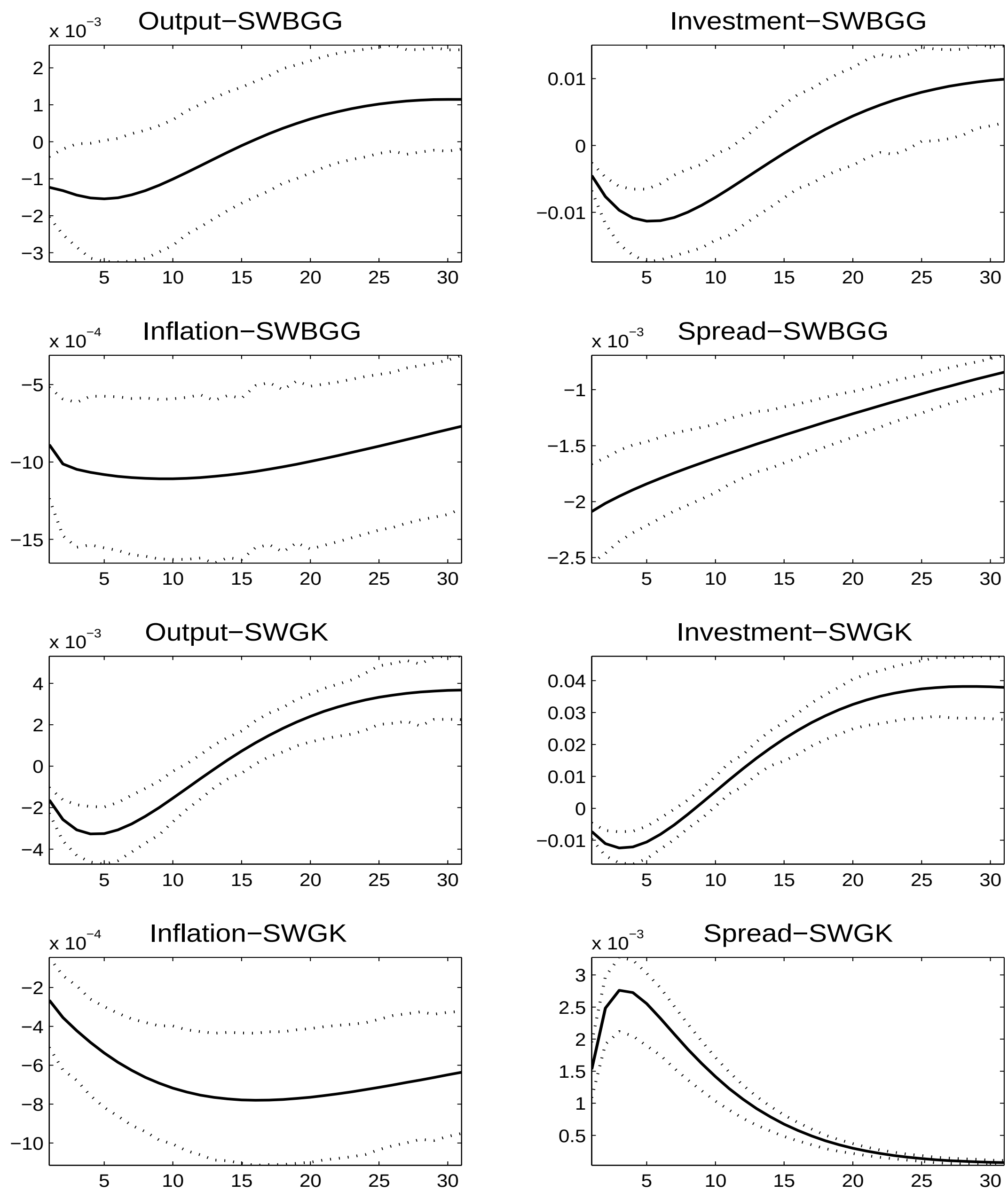

Figure 5: Investment-efficiency/quality of capital shock shock. Solid lines represent mean IRF and dashed line represent the 95% highest posterior density confidence intervals.

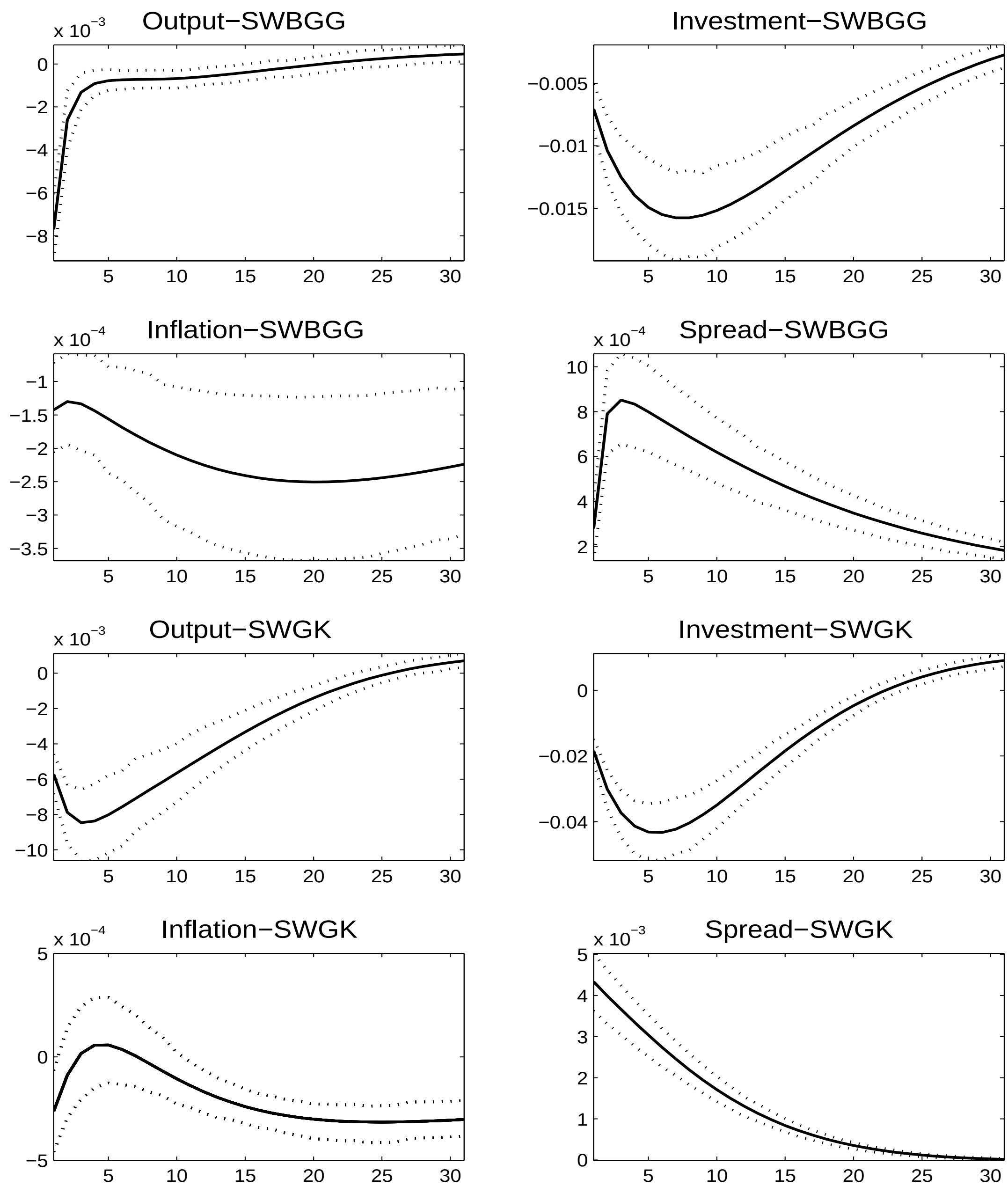

Figure 6: Monetary policy shock. Solid lines represent mean IRF and dashed line represent the 95% highest posterior density confidence intervals.

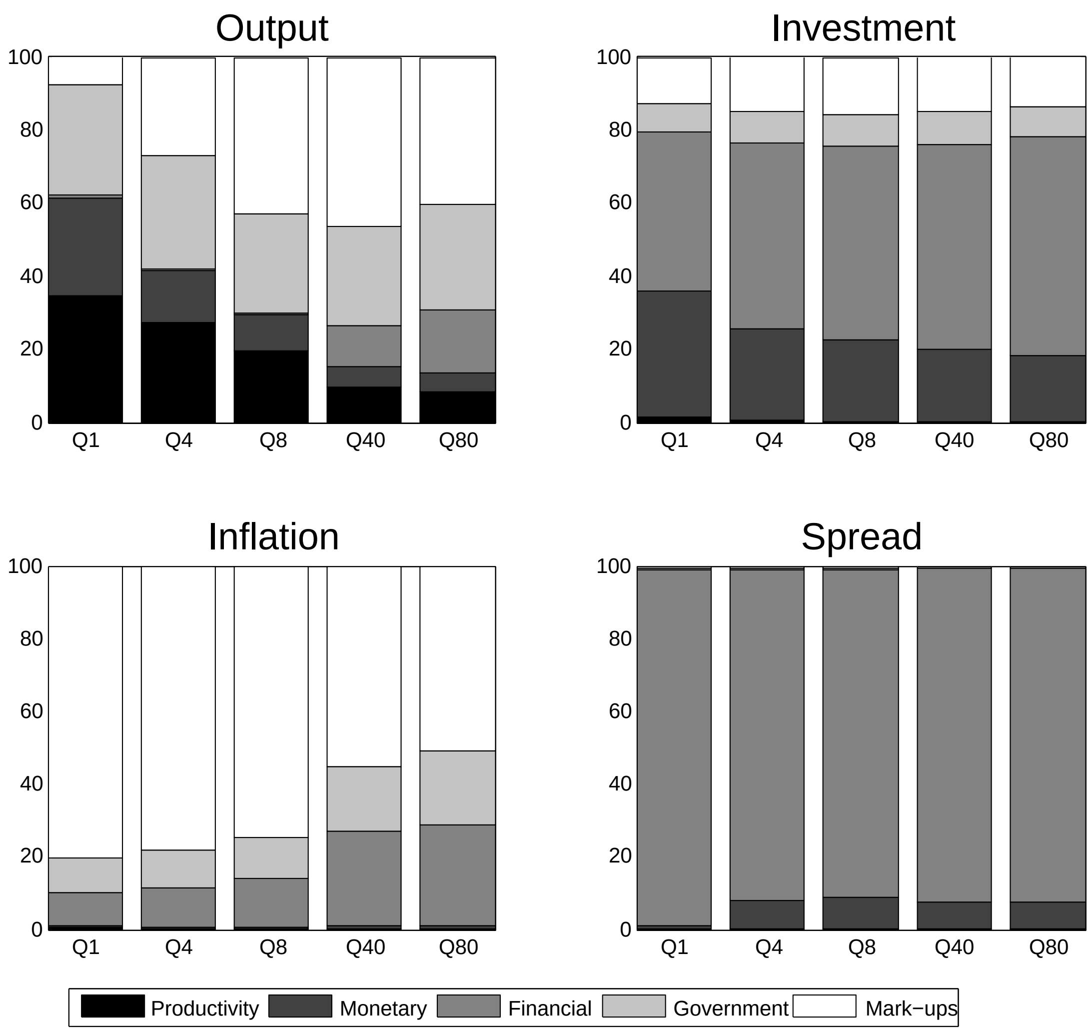

Figure 7: Forecast error variance decomposition computed at the mode of the posterior distribution in the SWBGG model.

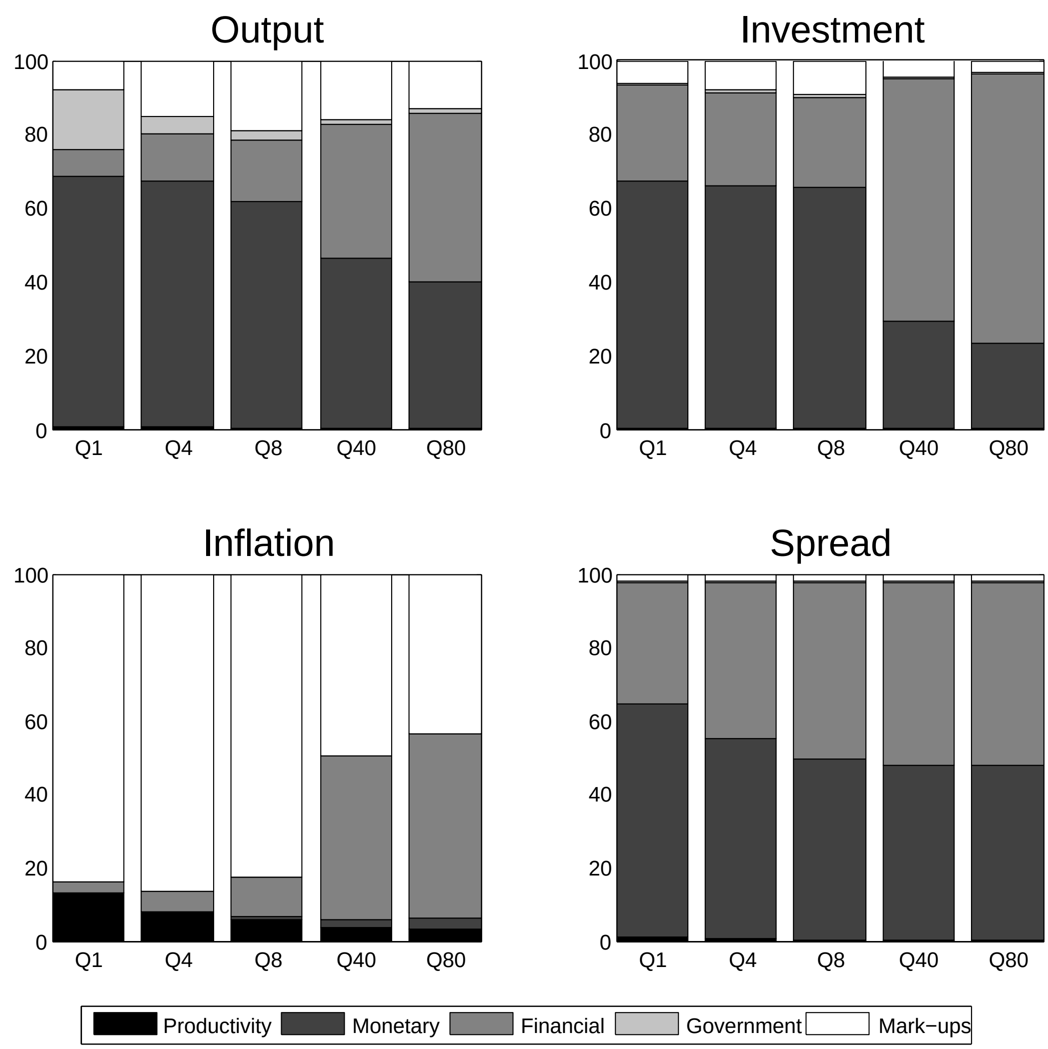

Figure 8: Forecast error variance decomposition computed at the mode of the posterior distribution in the SWGK model.