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**Working Paper**

## Monetary transmission under competing corporate finance regimes

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# FinMaP-Working Paper No.52



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FINMAP –

**FINANCIAL DISTORTIONS AND MACROECONOMIC  
PERFORMANCE: EXPECTATIONS, CONSTRAINTS AND  
INTERACTION OF AGENTS**

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TITLE

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*JEL: E52, E44, E03, G21, G32*

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# Monetary Transmission Under Competing Corporate Finance Regimes

Paul De Grauwe and Eddie Gerba\*

December 23, 2015

## Abstract

The behavioural agent-based framework of De Grauwe and Gerba (2015) is extended to allow for a counterfactual exercise on the role of banks for monetary transmissions. A bank-based corporate financing friction is introduced and the relative contribution of that friction to the effectiveness of monetary policy is evaluated. We find convincing evidence that the monetary transmission channel is stronger in the bank-based system compared to the market-based. Impulse responses to a monetary expansion are around the double of those in the market-based framework. The (asymmetric) effectiveness of monetary policy in counteracting busts is, on the other hand, relatively higher in the market-based model. The statistical fit of the bank-based behavioural model is also improved compared to the benchmark model. Lastly, we find that a market-based (bank-based) financing friction in a general equilibrium produces highly asymmetric (symmetric) distributions and more (less) pronounced business cycles.

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# 1 Motivation

2 There is a long line of empirical research highlighting a strong link between firm char-  
3 acteristics, corporate finance structure and monetary policy transmission. Those  
4 studies show that the effectiveness of monetary policy and the asymmetric impact  
5 it will have on the economy over expansions vs recessions is dependent on the type  
6 of firms in the economy and their financing composition. Understanding this link  
7 has become even more timely in the current context of unconventional monetary  
8 policy since the interest rate is at the zero-lower bound and an enormous amount of  
9 liquidity has been injected into the banking system. Yet the willingness of banks to  
10 lend to firms, in particular the SMEs has been (in relative terms) very weak. This  
11 is true for both the Euro Area and the UK, but to a lesser extent also for the US.  
12 Therefore, the question of whether the composition of the firm sector matters for  
13 the effective transmission of monetary policy has re-emerged.

14 The current paper extends this analysis by casting the model in a behavioural  
15 framework. In particular, while we maintain the effects of monetary policy on exter-  
16 nal financing demand and bank loan supply, we believe that assuming that agents  
17 understand the entire structure of the economy and model decisions using the full  
18 information set is strong. We therefore relax it and assume that agents in the econ-  
19 omy are rational in the sense that they learn from the past and rationally optimise in  
20 their own sphere, but hold incomplete information regarding the aggregate structure  
21 of the economy. However, for reasons of tractability we separate the two competing  
22 corporate financing regimes into two and study the monetary transmission and its  
23 impact of firms in two separate models. In other words, we consider two extreme  
24 cases of the corporate finance structures considered in Bolton and Freixas (2006)  
25 assuming that only one dominates in each case. This is a reasonable approximation  
26 of the corporate financing regime in the Euro Area (US) where more than 80% of  
27 firm financing comes from banks (bond market). Only the very large and highly  
28 multinational firms have the luxury of mixed financing portfolio and can access the  
29 big market funds.<sup>1</sup>

30 We find strong evidence that the monetary transmission channel is stronger in  
31 the bank-based system. The impulse response analysis showed that the effects from  
32 a monetary expansion are approximately twice that of the MBF version. Moreover,

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<sup>1</sup>Even in the UK, the share of firm finances coming from banks is significantly higher than the share coming from the market. This is in particular true for SMEs, who have very limited access to (stock) market financing.

the confidence intervals are much narrower in the BBF version since the estimation of coefficients is much more precise and the variation in estimates for different initializations of the learning framework is much smaller. This implies a better convergence in the estimation of the bank-based model version.

The statistical analysis shows that while market-based financial systems generate high asymmetries over the business cycles and a high probability mass on the extremes, the bank based one produces the contrary. Also the second, third and fourth moments are considerably lower in that version. This results in a better empirical fit of the Euro Area model to the data.

Lastly, we (discriminately) evaluate the relative effectiveness of monetary policy in counteracting busts and find mixed evidence. In terms of generating higher and more sustained booms, a monetary easing in the market-based system is more effective. However, if we evaluate the effectiveness in terms of avoiding severe and costly busts, a monetary easing in a bank-based financing system is more successful.

To conclude, the business cycles in the US are heavily driven by the swings in (imperfect beliefs) and market sentiment. As a result, the distribution of model variables become asymmetric and a lot of the probability mass is to the right of the mean. In the bank-based system, on the other hand, the cycles are (proportionately) more driven by fundamentals and the probability of heavy boom and busts are negligible. This results in symmetric distribution of the model variables, and a smoother business cycle.

## 1.1 Literature Review

The current bulk of literature can be summarized into three strands. The first strand examines the mutual links between firm characteristics and monetary transmission via the loan supply channel. As an example of this, Bougheas, Mizen and Yalein (2006) show that small, young and risky firms are affected more by tight monetary conditions than large, old and secure ones. Kashyap and Stein (2000) go a level deeper and argue that when a central bank tightens policy, aggregate bank lending falls and a substitution towards non-bank financing, such as commercial paper takes place. As a result, aggregate investment falls by more than would be predicted simply by a rise in bank interest rates. This is because small firms that do not have significant buffer cash holdings are forced to reduce investment around periods of tight credit. Similarly, small banks seem more prone to reduce lending compared

1 to large ones due to a lower buffer of securities. Hoshi, Scharfstein and Singleton  
2 (1993) show that this is exactly what happens in Japan. Kashyap, Stein and Wilcox  
3 (1996) extend their initial study above and show that even when the level effect  
4 is accounted for so that large (small) firms increase (reduce) all types of financing  
5 during a monetary tightening, there is a considerable substitution away from bank  
6 loans towards commercial paper.<sup>2</sup>

7 The second strand has largely focused on the demand (and capital) channel  
8 of monetary policy. So, for instance, Ashcraft and Campello (2007) argue that  
9 the monetary transmission is demand rather than supply driven as in the previous  
10 studies. The mechanism works through firm balance sheet and is independent from  
11 the bank lending channel. Using a unique Euro Area survey and the US counterpart,  
12 Ciccarelli, Maddaloni and Peydro (2014) similarly find that the amplification of  
13 monetary policy shocks to output and prices is highest via the borrowers' balance  
14 sheet channel, but do also find some role for the loan supply channel. Gaiotti and  
15 Secchi (2006) go even further in this direction and find firm- and loan-level evidence  
16 in Italy in favour of the presence of a cost channel of monetary policy transmission  
17 proportional to the amount of working capital held by each firm.

18 Peersman and Smets (2005) find asymmetric (real) effects of monetary tighten-  
19 ing. They show that the negative effects of interest rate increases on output are  
20 significantly greater in recessions than in booms. However, a considerable degree of  
21 heterogeneity between industries exists in both the degree of asymmetry across the  
22 business cycle phases and the overall policy effects. While the second heterogeneity  
23 is related to the durability of the good produced in the sectors, the heterogeneity  
24 in asymmetry is strongly related to differences in financial structure of firms (i.e.  
25 maturity structure of debt, coverage ratio, firm size and financial leverage). Hence  
26 firm financial composition matters for the asymmetric effects of monetary policy.

27 The third strand has largely focused on the incentive structure of banks in order  
28 to understand the monetary transmission. In a pan-European study, Ehrmann et  
29 al (2001) show that monetary policy alters bank loan supply with the effects most  
30 dependent on the liquidity levels of individual banks. The size of banks, however,  
31 does not explain its lending reaction in contrast to the US. Looking more specifically  
32 at the incentive structure in Spain, Jimenez et al (2009) find that lower overnight  
33 rates prior to loan origination push banks to lend more to borrowers with a weaker

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<sup>2</sup>Calomiris, Himmelberg and Wachtel (1995) and Ludvigson (199821) also reach the same conclusion and find a strong loan supply effect of monetary policy.

credit history and to grant more loans with a higher probability of default. As a result, the lending portfolio of banks will be riskier during loose monetary policy conditions due to banks profit seeking incentives.

The theoretical contributions that particularly look at monetary transmissions under various corporate and banking structures have been, as far as we are aware, slimmer.<sup>3</sup> Recently Bhamra, Fisher and Kuehn (2011) have investigated the intertemporal corporate effects of monetary policy when firms issue debt with a fixed nominal coupon. Forward-looking corporate default decisions thus depend on monetary policy through its impact on future inflation. They find that under a passive peg, a negative productivity shock coupled with deflation produces strong incentives for corporate default, which under real costs of financial distress in turn triggers a debt-deflation spiral.

The framework closest to ours is Bolton and Freixas (2006). In it, bank lending is constrained by capital adequacy requirements. The financial sector is casted into a DSGE model and asymmetric information adds a cost to outside bank capital. Moreover, firms can substitute bank lending to corporate bonds. But, because bank debt is easier to restructure it is more attractive than corporate bonds. On the other hand, bank loans are in short supply (arising from a capital requirement regulation, a dilution cost for outside equity and a cost for running banks) which creates an endogenous cost of flexibility. Monetary policy operates through changes in the spread of bank loans over corporate bonds. In turn, this induces changes in the aggregate composition of financing by firms, and in banks equity-capital base.

## 2 European vs US corporate financing structure

To compare the monetary transmissions, we will analyze two versions of the model. In the baseline US version of corporate financing structure, firms basically raise funds on the (bond) market. More specifically, their access to external funds depends mainly on the value of internal funds firms hold, which in turn depends on the stock market value of their capital. In essence, the quantity they can borrow depends on the ability they have to raise funds on the market. This is the structure described in De Grauwe and Gerba (2015) or De Grauwe and Macchiarelli (2015).

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<sup>3</sup>There is a large literature incorporating the various financing regimes of firms in their general equilibrium modelings. However, models that specifically look at the various (and asymmetric) effects of monetary policy on firm financing under different regimes have been fewer.



1 In the second version of the model, on the other hand, the amount that firms  
 2 can borrow depends entirely on banks' willingness to lend. To be more specific, the  
 3 rate at which bank lend funds to firms depends on three factors: their market power  
 4 in the retail branch, the cost of managing bank capital in the wholesale branch,  
 5 and the adjustment costs faced in changing the lending rate by the retail branch.  
 6 The second component is moreover time-varying, which means that the rate will  
 7 fluctuate over the business cycle. This approach in modelling the financial sector  
 8 follows Gerali et al (2010) who model the Euro Area financial sector and corporate  
 9 financing in this way.

10 In the next subsection, we will proceed by briefly outlining the corporate financ-  
 11 ing regime used in De Grauwe and Gerba (2015). We will amend the model to fit  
 12 the Euro Area financing structure in the following subsection. In section 3 we will  
 13 discuss and compare the two transmissions, while section 4 concludes.

## 14 **2.1 Market funding structure**

15 To remind the reader about the corporate financing mechanism modeled in De  
 16 Grauwe and Gerba (2015) and De Grauwe and Macchiarelli (2015) models, we will  
 17 just briefly outline it here.

18 Firms borrow money from the market paying an interest rate which normally  
 19 exceeds the risk-free interest rate. Hence the cost of market funds  $eft_t$  is equal to  
 20 the risk free rate  $r_t$  plus a spread  $x_t$  as:

$$eft_t = r_t + x_t \tag{1}$$

21 The spread between the two rates depends on firms' equity:

$$x_t = eft_t - r_t = \psi n_t^f \tag{2}$$

22 Following the collateral constraint approach used in Bernanke, Gertler and Gilchrist  
 23 (1999), the quantity of funds that firms can access on the market depends on the  
 24 value of its internal funds, or collateral. Thus, an increase in the value of firms'  
 25 equity reduces the spread and vice versa. This spread arises because of asymmetric  
 26 information regarding the credit risk of borrowers that lenders lack. To compensate  
 27 for this credit risk, the market charges a spread. When the value of equity of the  
 28 firm rises (falls), the market perceives it as a reduction (rise) in credit risk and an

improvement (deterioration) in the solvency of firm. The market reacts by reducing (increasing) the spread. In other words, firms can borrow more (less) at the same *ex ante* cost.<sup>4</sup>

The value of equity of firms is determined by stock markets. When during a boom the asset prices (essentially equity) of good firms go up, the firm's collateral constraint relaxes and its creditworthiness improves. In contrast, during busts asset prices decline and firm's collateral constraint becomes more biting. In order to have asset price variability to contribute to the volatility in firms' equity, we connect firms' market capitalization to the number of time-varying shares  $\bar{n}_t$  multiplied by the current share price  $S_t$ , or:

$$n_t^f = S_t \bar{n}_t \quad (3)$$

Using the standard Gordon discounted dividend model, share prices in turn depend on the discounted value of all future dividends:

$$S_t = \frac{E_t[\Lambda_{t+1}^-]}{R_t^s} \quad (4)$$

where;

$$R_t^s = r_t + \xi \quad (5)$$

with  $E_t[\Lambda_{t+1}^-]$  denoting expected future dividends net of a discount rate  $R_t^s$ . The rate consists of a risk-free component  $r_t$  and a constant equity premium  $\xi$ . The stable growth Gordon model assumes that dividends grow at a constant rate. The forecasts made by agents about future dividends follow the logic of forecasts they make for the output and inflation gaps (which will be described further below). Agents assume the 1-period ahead forecast of dividends to be a fraction  $f$  of nominal GDP one period ahead.<sup>5</sup> Since nominal GDP consists of a real and an inflation component, agents make forecasts regarding future output gap as well as inflation. These forecasts are reevaluated sequentially in each period. Agents are willing to

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<sup>4</sup>In de Grauwe and Gerba (2015) and De Grauwe and Macchiarelli (2015) the counterpart to firms in lending are banks. However these banks operate under zero profit and act as *shadow lenders*. In reality what determines whether and what quantity firms can borrow is the value of their internal funds, or equity. The price of equity is determined by the stock market. Hence, the stock market determines if and how much firms can borrow. Therefore banks balance sheet is not necessary in this lending mechanism and can be directly reduced to market-type of lending.

<sup>5</sup>Just as in De Grauwe and Gerba (2015) dividends are supposed to be constant from  $t+1$  onwards.

1 switch to another forecasting rule if this performs better than the current rule.

2 If agents forecast a positive output gap in the future, then via the Gordon model,  
3 asset prices will also increase, relaxing firms' borrowing constraint. When all agents  
4 forecast a positive output gap (sentiment index=1), we say that agents are *opti-*  
5 *mists*. When the index is zero, or all agents forecast a negative output gap, agents  
6 become *pessimistic*. In that situation, asset prices will fall, reducing the value of firm  
7 collateral and thus their borrowing capacity. Following De Grauwe and Macchiarelli  
8 (2015), we call this type of swings in agents forecast (or market sentiment) *animal*  
9 *spirits*.

10 Now that we have connected firm equity to stock markets, we can rewrite the  
11 external finance spread as:

$$x_t = \psi_t n_t^f \equiv \psi \bar{n}_t S_t \quad (6)$$

12 As a result, stock prices directly influence the financing spread via firms' financial  
13 positions. Given this, we can write firms' leverage position as:

$$\tau_t = \frac{L_t^d}{\bar{n}_t S_t} \quad (7)$$

14 This leverage ratio is time-varying, and therefore endogenous to the business  
15 cycle. Remember that the more a firms is leveraged, the stronger the amplification  
16 effect of asset price movements on firm borrowing capacity. An increase in the value  
17 of stock prices increases a firm's collateral value and reduces its leverage. These two  
18 components combined lead to a more than proportional increase in its borrowing  
19 capacity. Conversely, when asset prices fall, the reduction in loans is more than  
20 proportional. That is why we should expect sharp swings in firm finances over the  
21 cycle as is typical of market-based corporate finance regimnes such as the US.<sup>6</sup>

22 This mechanism is embeded into the broader behavioural model as in De Grauwe  
23 and Gerba (2015). In it, interconnectedness between stock markets, firm finances  
24 and the supply side give rise to important propagation of shocks and amplification  
25 of market sentiments.

26 In the next section, we will amend the external finance spread and the general  
27 lending conditions to depend on banks' internal funding costs and their willingness  
28 to lend.

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<sup>6</sup>Note that asset prices affect aggregate demand indirectly, via credit spread dynamics, and do not have wealth effects directly as in De Grauwe (2012) or De Grauwe and Macchiarelli (2015).

## 2.2 Financial sector

We modify De Grauwe and Gerba (2015) model to introduce (European style) bank-based corporate financing structure. Following Gerali et al (2010), we introduce an imperfect bank-driven credit production, where banks take deposits from savers, bundle these up into multiple credit lines, and give out loans to firms at a cost determined by the intrinsic (loan) production technology. At the same time, bank manages capital in a (dynamically) rational manner in order to cushion against future shocks to its balance sheet. To facilitate the exposition, we separate the bank capital management branch (*wholesale* sector) from the loan management (*retail* sector) activity as in Gerali et al (2010).

We can think of the banks as composed of two retail branches and one wholesale branch. The first retail branch is responsible for giving out differentiated loans to firms and the second for raising differentiated deposits. Banks operate in a competitive environment in the wholesale sector, but behave monopolistically competitive a la Dixit-Stiglitz in the retail one. Their ability to change rates in the *retail* sector depends on the market power they hold in that segment (determined by the parameters  $\epsilon_t^B$  and  $\epsilon_t^D$  for the loan and deposit segment) as well as the adjustment costs.

### 2.2.1 Wholesale branch

The balance sheet of the commercial bank can be defined as:

$$D_t = \pi_t^B n_t^B + B_t \quad (8)$$

$D_t$  are total deposits,  $B_t$  are total loans (given out to firms via the retail loan branch), and  $\pi_t^B n_t^B$  is the real value of bank equity, where  $n_t^B$  is the number of stocks of banks and  $\pi_t^B$  is the price.<sup>7</sup>The leverage is thus the ratio between its loans and equity. In this respect banks are subject to an explicit capital-to-asset ratio:

$$\kappa_t = \frac{\pi_t^B n_t^B}{B_t} \quad (9)$$

Whenever the bank moves away from the targeted capital-to-asset ratio  $\vartheta^B$ , the bank pays a quadratic cost (expressed in terms of additional capital requirement). This cost is internalized by the wholesale branch and carried over to the lender,

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<sup>7</sup>The price of stocks is exogenously determined.

1 which allows us to describe the lending *wholesale* rate as:

$$R_t^B = R_t^D - \kappa^{n^B} \left[ \frac{n_t^B}{B_t} - \vartheta^B \right] \left[ \frac{n_t^B}{B_t} \right]^2 \quad (10)$$

2 The quadratic cost of deviating from the target has the functional form equal to  
 3  $\kappa^{n^B} \left[ \frac{\pi_t^B n_t^B}{B_t} - \vartheta^B \right] \left[ \frac{\pi_t^B n_t^B}{B_t} \right]^2$ .  $\kappa^{n^B}$  is the leverage deviation cost, which is parametrized in  
 4 his model. Assuming that banks have unlimited access to finance at the policy rate  
 5  $r_t$  from a central bank, via arbitrage condition we can rewrite the above expression  
 6 as:

$$R_t^B - r_t = -\kappa^{n^B} \left[ \frac{\pi_t^B n_t^B}{B_t} - \vartheta^B \right] \left[ \frac{\pi_t^B n_t^B}{B_t} \right]^2 \quad (11)$$

7 The left-hand side represents marginal benefit from increasing lending since an  
 8 increase in profits is equal to the spread. Meanwhile, the right-hand side represents  
 9 the marginal cost from doing so in terms of the additional expenses arising for  
 10 deviating from the optimal capital-to-asset ratio. Therefore banks choose a level of  
 11 loans where marginal benefits and costs are equalized.

### 12 2.2.2 Loan retail branch

13 It obtains *wholesale loans*  $B_t$  at rate  $R_t^B$ , differentiates them and resells them to  
 14 firms applying a markup. The markup is governed by a quadratic adjustment cost  
 15 for changing the rate over time, and the adjustment cost in turn depends on the  
 16 parameter determining the adjustment costs in loan rate setting,  $\kappa^B$ . These are pro-  
 17 portional to aggregate return on loans. The rate charged on loans can be expressed  
 18 as:

$$r_t^B = \frac{1}{\epsilon_t^B - 1 + (1 + \beta)\kappa^B} (\kappa^B r_{t-1}^B + (\epsilon_t^B - 1)R_t^B - \epsilon_t^B) \quad (12)$$

19 , which in absence of inertias can be reduced to:

$$r_t^B = r_t + \frac{\epsilon_t^B}{\epsilon_t^B - 1} (R_t^B - r_t) + \frac{1}{\epsilon_t^B - 1} r_t \quad (13)$$

20 This is the external finance premium that firms face. The premium is propor-  
 21 tional to the wholesale branch spread, which in turn is determined by the bank's  
 22 capital position. The degree of monopolistic competition also matters since an in-  
 23 crease in market power (a fall in  $\epsilon_t^B$ ) results in a higher premium.

24 Following Gerali et al (2010) and Benes and Lees (2007), we assume that the

contracts that firms use to obtain loans are a composite constant elasticity of substitution basket of slightly differentiated financial products - each supplied by a branch of a bank  $j$  - and with elasticity  $\epsilon_t^B$ , as in Dixit and Stieglitz framework.<sup>8</sup>The elasticity is stochastic and exogenously determined. These innovations to elasticity can be seen as alterations independent from the monetary policy. Assuming symmetry amongst firms, their aggregate demand for loans at bank  $j$  can be expressed as:<sup>9</sup>

$$b_t(j) = \frac{r_t^B(j)^{-\epsilon^B}}{r_t^B} b_t \quad (14)$$

To interpret this expression, the loan that firm  $i$  gets depends on the overall volume of loans given to all firms, and on the interest rate charged on loans by bank  $j$  relative to the rate index for that kind of loans.

### 2.2.3 Deposit retail branch

In an analogous way, the retail unit collect deposits from savers and passes the funds funds on to the wholesale branch. They remunerate these funds at rate  $r_t$ . The quadratic adjustment costs for changing the deposit rate are determined by the parameter determining adjustment costs in deposit rate setting,  $\kappa^D$ , and are proportional to aggregate interest paid on deposits. Analogous to the retail borrowing rate, the deposit rate can be described as:

$$r_t^D = \frac{1}{\epsilon_t^D - 1 + (1 + \beta)\kappa^D} (\kappa^D r_{t-1}^D + (\epsilon_t^D - 1)R_t^D - \epsilon_t^D) \quad (15)$$

,which in absence of inertias, is simply a markdown over the policy rate:

$$r_t^D = \frac{\epsilon_t^D}{\epsilon_t^D - 1} r_t \quad (16)$$

The demand for deposits of saver  $i$  is symmetrically obtained to the case of loan rate determination in the previous subsection. Once again we assume that the contracts that savers use to deposit money are a composite constant elasticity of substitution basket of slightly differentiated financial products - each supplied

<sup>8</sup>The loan elasticity  $\epsilon_t^B$  is assumed to be above 1.

<sup>9</sup>In Gerali et al (2010) this expression is derived after minimizing over all firms  $B_t(i, j)$  the total repayment due to the continuum of banks  $j$ ,  $\int_0^1 r_t^B(j) b_t(i, j) dj$ , subject to  $[\int_0^1 b_t(i, j)^{(\epsilon_t^B - 1)/(\epsilon_t^B)} dj]^{\epsilon_t^B / (\epsilon_t^B - 1)} \geq b_t(i)$ .  $(\epsilon_t^B - 1)/(\epsilon_t^B)$  is the markup that banks apply on loans. Here we just take the derived first-order-condition and aggregate amongst firms. The micro-foundations are, however, straight forward.

1 by a branch of a bank  $j$  - and with elasticity  $\epsilon_t^D$ .<sup>10</sup>The elasticity is stochastic and  
2 exogenously determined. Once again, these innovations to elasticity can be seen as  
3 alterations independent from the monetary policy. Assuming symmetry amongst  
4 savers, their aggregate demand for deposits at bank  $j$  can by analogy to the above  
5 case be expressed as:<sup>11</sup>

$$d_t(j) = \frac{r_t^D(j)^{-\epsilon^D}}{r_t^D} d_t \quad (17)$$

6 ,where  $d_t$  are the aggregate deposits in the economy,  $r_t^D(j)$  is the return on  
7 deposits from bank  $j$ , and  $r_t^D$  is the rate index for that kind of deposits.

#### 8 **2.2.4 Bank finances**

9 Now that we have described the operations of each of the branches, we are in a  
10 position to describe the finances of the aggregate bank unit. Overall bank profits  
11 ( $p^B$ ) are the sum of net earnings from the two retail ( $r_t^B b_t - r_t^D d_t$ ) and one wholesale  
12 branch ( $\frac{\kappa^B}{2} [\frac{\pi_t^B n_t^B}{B_t} - \vartheta^B]^2 \pi_t^B n_t^B - Adj_t^B$ ):

$$p_t^B = r_t^B b_t - r_t^D d_t - \frac{\kappa^B}{2} [\frac{\pi_t^B n_t^B}{B_t} - \vartheta^B]^2 \pi_t^B n_t^B - Adj_t^B \quad (18)$$

13 Each period profits are accumulated in a standard fashion, and added on to the  
14 existing bank equity stock according to:

$$\pi_t^B n_t^B = (1 - \delta^B) \pi_{t-1}^B n_{t-1}^B + p_{t-1}^B \quad (19)$$

15 Banks' equity position has a core role in the functioning of the financial system  
16 since it (simultaneously) determines the quantity and the price of loans supplied.  
17 On one hand, it determines the external finance premium of firms (the cost of taking  
18 out credit with the bank) in 13, since the wholesale borrowing rate directly depends  
19 on banks' overall capital-to-asset position in 10. On the other hand, since banks pay  
20 a cost whenever they deviate from their targeted capital-to-asset ratio  $\vartheta^B$ , banks  
21 will choose a level of loans where the marginal benefit from extending the credit  
22 portfolio equals the marginal costs for deviating from the  $\vartheta^B$  target.

<sup>10</sup>The deposit elasticity  $\epsilon_t^D$  is assumed to be below -1.

<sup>11</sup>In Gerali et al (2010) this expression is derived after minimizing over all savers  $D_t(i, j)$  the total repayment due to the continuum of banks  $j$ ,  $\int_0^1 r_t^D(j) d_t(i, j) dj$ , subject to  $[\int_0^1 d_t(i, j)^{(\epsilon_t^D - 1)/(\epsilon_t^D)} dj]^{\epsilon_t^D / (\epsilon_t^D - 1)} \leq d_t(i)$ .  $(\epsilon_t^D - 1)/(\epsilon_t^D)$  is the markup that banks apply on deposits. Here we just take the derived first-order-condition and aggregate amongst savers. The micro-foundations are, however, direct.

## 2.3 Aggregate dynamics

For the American MBF system, we keep the equations as in the benchmark De Grauwe and Gerba (2015) model. In that framework, the aggregate demand equation can be expressed as:

$$y_t = a_1 \tilde{E}_t y_{t+1} + (1 - a_1) y_{t-1} + a_2 (r_t - \tilde{E}_t \pi_{t+1}) + (a_2 + a_3) x_t + (a_1 - a_2) \psi(u_t) k_t + Adj_t + \epsilon_t; \quad (a_1 - a_2) > 0 \quad (20)$$

Notice that apart from the standard terms derived in De Grauwe (2011, 2012) and De Grauwe and Macchiarelli (2015), aggregate demand depends on the usable capital in the production,  $u_t k_t$  discounted for the cost of financing ( $x_t$ ).

The reader will also notice that aggregate demand depends on the external finance (or risk) premium  $x_t$ . This is a reduced form expression for investment, since investment is governed directly by this premium, and therefore it is the dependent variable (see DeGrauwe and Macchiarelli (2015) for a derivation of this term).

For the European BBF case, we will need to make some amendments to the above expression.

First, we use expression 12 to redefine the external finance premium in I.1, and get:

$$y_t = a_1 \tilde{E}_t y_{t+1} + (1 - a_1) y_{t-1} + a_2' a_3' (r_t - \tilde{E}_t \pi_{t+1}) + a_4' R_t^B + (a_1 - a_2) \psi(u_t) k_t + Adj_t + \epsilon_t \quad (21)$$

, where  $a_2' = \frac{\epsilon_t^B (d_3 + e_2)}{1 - d_1}$ ,  $a_3' = \frac{1}{\epsilon_t^B - 1 + (1 + \beta) \kappa^B}$  and  $a_4' = (\epsilon^B - 1)$ . Hence we have redefined the external finance premium  $x_t$  in the aggregate demand equation. Second, banks accumulate capital and this is added to the resource constraint above. Following Gerali et al (2010) we add the *net* bank equity (net of equity depreciation rate  $\delta^B$ ) to the above expression:

$$y_t = a_1 \tilde{E}_t y_{t+1} + (1 - a_1) y_{t-1} + a_2' a_3' (r_t - \tilde{E}_t \pi_{t+1}) + a_4' R_t^B + (a_1 - a_2) \psi(u_t) k_t + \delta^B \pi_{t-1}^B n_{t-1}^B + Adj_t + \epsilon_t \quad (22)$$

Third, we include the adjustment costs from changing the (deposit and lending) rates into the term  $Adj_t$ .

As is standard, the aggregate supply (AS) equation is obtained from the price



1 discrimination problem of retailers (monopolistically competitive):

$$\pi_t = b_1 \tilde{E}_t \pi_{t+1} + (1 - b_1) \pi_{t-1} + b_2 y_t + \nu_t \quad (23)$$

2 As explained in DeGrauwe and Macchiarelli (2015),  $b_1 = 1$  corresponds to the  
3 New-Keynesian version of AS with Calvo-pricing (Woodford, 2003).

4 To complete the model, we will briefly outline the imperfect beliefs-setting and  
5 learning dynamics that we make use of in this framework.

## 6 2.4 Expectations formation and learning

7 Under rational expectations, the expectational term will equal its realized value  
8 in the next period, i.e.  $E_t X_{t+1} = X_{t+1}$ , denoting generically by  $X_t$  any variable  
9 in the model. However, as anticipated above, we depart from this assumption in  
10 this framework by considering bounded rationality as in DeGrauwe (2011, 2012).  
11 Expectations are replaced by a convex combination of heterogeneous expectation  
12 operators  $E_t y_{t+1} = \tilde{E}_t y_{t+1}$  and  $E_t \pi_{t+1} = \tilde{E}_t \pi_{t+1}$ . In particular, agents forecast  
13 output and inflation using two alternative forecasting rules: *fundamentalist rule* vs.  
14 *extrapolative rule*. Under the fundamentalist rule, agents are assumed to use the  
15 steady-state value of the output gap -  $y^*$ , here normalized to zero against a naive  
16 forecast based on the gap's latest available observation (extrapolative rule). Equally  
17 for inflation, *fundamentalist* agents are assumed to base their expectations on the  
18 central bank's target -  $\pi^*$  against the *extrapolatists* who naively base their forecast on  
19 a random walk approach.<sup>12</sup> We can formally express the fundamentalists in inflation  
20 and output forecasting as:

$$\tilde{E}_t^f \pi_{t+1} = \pi^* \quad (24)$$

$$\tilde{E}_t^f y_{t+1} = y_* \quad (25)$$

21 and the extrapolists in both cases as:

$$\tilde{E}_t^e \pi_{t+1} = \theta \pi_{t-1} \quad (26)$$

$$\tilde{E}_t^e y_{t+1} = \theta y_{t-1} \quad (27)$$

---

<sup>12</sup>The latest available observation is the best forecast of the future.

This particular form of adaptive expectations has previously been modelled by Pesaran (1987), and Brock and Hommes (1997, 1998), amongst others, in the literature. Setting  $\theta = 1$  captures the "naive" agents (as they have a strong belief in history dependence), while a  $\theta < 1$  or  $\theta > 1$  represents an "adaptive" or an "extrapolative" agent (Brock and Hommes, 1998). For reasons of tractability, we set  $\theta = 1$  in this model.

Note that for the sake of consistency with the DSGE model, all variables here are expressed in gaps. Focusing on their cyclical component makes the model symmetric with respect to the steady state (see Harvey and Jaeger, 1993). Therefore, as DeGrauwe and Macchiarelli (2015) show, it is not necessary to include a zero lower bound constraint in the model since a negative interest rate should be understood as a negative interest rate gap. In general terms, the equilibrium forecast/target for each variable will be equal to its' steady state value.

Next, selection of the forecasting rule depends on the (historical) performance of the various rules given by a publically available goodness-of-fit measure, the mean square forecasting error (MSFE). After the time 't' realization is revealed, the two predictors are evaluated *ex post* using MSFE and new fractions of agent types are determined. These updated fractions are used to determine the next period (aggregate) forecasts of output-and inflation gaps, and so on. Agents' rationality consists therefore in choosing the best-performing predictor using the updated fitness measure. There is a strong empirical motivation for inserting this type of switching mechanism amongst different forecasting rules (see DeGrauwe and Macchiarelli (2015) for a brief discussion of the empirical literature, Frankel and Froot (1990) for a discussion of *fundamentalist* behaviour, and Roos and Schmidt (2012), Cogley (2002), Cogley and Sargent (2007) and Cornea, Hommes and Massaro (2013) for evidence of *extrapolative* behaviour, in particular for inflation forecasts).

The aggregate market forecasts of output gap and inflation is obtained as a weighted average of each rule:

$$\tilde{E}_t \pi_{t+1} = \alpha_t^f \tilde{E}_t^f \pi_{t+1} + \alpha_t^e \tilde{E}_t^e \pi_{t+1} \quad (28)$$

$$\tilde{E}_t y_{t+1} = \alpha_t^f \tilde{E}_t^f y_{t+1} + \alpha_t^e \tilde{E}_t^e y_{t+1} \quad (29)$$

where  $\alpha_t^f$  is the weighted average of fundamentalists, and  $\alpha_t^e$  that of the extrapolists. These shares are time-varying and based on the dynamic predictor se-

1 lection. The mechanism allows to switch between the two forecasting rules based  
2 on MSFE / utility of the two rules, and increase (decrease) the weight of one rule  
3 over the other at each  $t$ . Assuming that the utilities of the two alternative rules  
4 have a deterministic and a random component (with a log-normal distribution as  
5 in Manski and McFadden (1981) or Anderson et al (1992)), the two weights can  
6 be defined based on each period utility for each forecast  $U_{i,t}^x$ ,  $i = (y, \pi)$ ,  $x = (f, e)$   
7 according to:

$$\alpha_{\pi,t}^f = \frac{\exp(\gamma U_{\pi,t}^f)}{\exp(\gamma U_{\pi,t}^f) + \exp(\gamma U_{\pi,t}^e)} \quad (30)$$

$$\alpha_{y,t}^f = \frac{\exp(\gamma U_{y,t}^f)}{\exp(\gamma U_{y,t}^f) + \exp(\gamma U_{y,t}^e)} \quad (31)$$

$$\alpha_{\pi,t}^e \equiv 1 - \alpha_{\pi,t}^f = \frac{\exp(\gamma U_{\pi,t}^e)}{\exp(\gamma U_{\pi,t}^f) + \exp(\gamma U_{\pi,t}^e)} \quad (32)$$

$$\alpha_{y,t}^e \equiv 1 - \alpha_{y,t}^f = \frac{\exp(\gamma U_{y,t}^e)}{\exp(\gamma U_{y,t}^f) + \exp(\gamma U_{y,t}^e)} \quad (33)$$

8 ,where the utilities are defined as:

$$U_{\pi,t}^f = - \sum_{k=0}^{\infty} w_k [\pi_{t-k-1} - \tilde{E}_{t-k-2}^f \pi_{t-k-1}]^2 \quad (34)$$

$$U_{y,t}^f = - \sum_{k=0}^{\infty} w_k [y_{t-k-1} - \tilde{E}_{t-k-2}^f y_{t-k-1}]^2 \quad (35)$$

$$U_{\pi,t}^e = - \sum_{k=0}^{\infty} w_k [\pi_{t-k-1} - \tilde{E}_{t-k-2}^e \pi_{t-k-1}]^2 \quad (36)$$

$$U_{y,t}^e = - \sum_{k=0}^{\infty} w_k [y_{t-k-1} - \tilde{E}_{t-k-2}^e y_{t-k-1}]^2 \quad (37)$$

9 and  $w_k = (\rho^k(1 - \rho))$  (with  $0 < \rho < 1$ ) are gemoetrically declining weights  
10 adapted to include the degree of forgetfulness in the model (DeGrauwe, 2012).  $\gamma$  is  
11 a parameter measuring the extent to which the deterministic component of utility  
12 determines actual choice. A value of 0 implies a perfectly stochastic utility. In that  
13 case, agents decide to be one type or the other simply by tossing a coin, implying a  
14 probability of each type equalizing to 0.5. On the other hand,  $\gamma = \infty$  implmes a fully

deterministic utility, and the probability of using the fundamentalist (extrapolative) rule is either 1 or 0. Another way of interpreting  $\gamma$  is in terms of learning from past performance:  $\gamma = 0$  implies zero willingness to learn, while it increases with the size of the parameter, i.e.  $0 < \gamma < \infty$ .

As mentioned above, agents will subject the performance of rules to a fit measure and choose the one that performs best. In that sense, agents are 'boundedly' rational and learn from their mistakes. More importantly, this discrete choice mechanism allows to endogenize the distribution of heterogeneous agents over time with the proportion of each agent using a certain rule (parameter  $\alpha$ ). The approach is consistent with the empirical studies (Cornea et al, 2012) who show that the distribution of heterogeneous agents varies in reaction to economic volatility (Carroll (2003), Mankiw et al (2004)).

## 2.5 Calibration and model solution

### 2.5.1 Calibration

To simplify and focus the discussion, we will only present the calibrations of the parameters that are new to this model. The remaining parameters, including the parameters specific to the MBF version of this paper, have the same values as in De Grauwe and Gerba (2015). We refer to that paper for a more detailed discussion, as well as to the parameter list in the Appendix.

The parameters specific to the banking sector and the loan-deposit production are parametrized to the values in Gerali et al (2010). This is because their model attempts to replicate the banking sector frictions present in the Euro Area, which is also our interest here. The parameters that are calibrated in their model have the same values in our BBF version. So, for instance, banks' capital-to-asset target ratio,  $\varsigma$  is set to 0.09 in order to reflect a low-and-stable leverage in the banking sector (which is optimal from the perspective of the macroprudential authority). Also, banks' market power in the loan-and deposit-rate setting ( $\epsilon^b$  and  $\epsilon^d$ ) are set to 3.12 and -1.46 in order to reflect the relative strength that banks have in assets with respect to their liabilities. Equally, banks' cost for managing its capital is parametrized to 0.1049 as in Gerali et al (2010) in order to induce a sufficiently high cost for banks for reducing its capital position. The intertemporal discount rate,  $\beta$  is standardly set to 0.9943. The initial bank capital  $\bar{n}^b$  is set to 1, which is sufficiently low in order to allow banks to operate in the initial period.

1 The parameters that were estimated in Gerali et al (2010) have been set in accor-  
2 dence to the results from their posterior distributions. In this way, the adjustment  
3 costs in leverage deviation, firms' rate, and household rate (or  $\kappa^{nb}$ ,  $\kappa^b$ , and  $\kappa^d$ ) were  
4 calibrated to 11.07, 13 and 3.50 that is well within the 95% interval of the posterior.  
5 Moreover, those costs correctly reflect the varying costs that banks face in managing  
6 bank equity, producing loans and offering deposits.

7 All shocks, except to the capital utilization, are parametrized as white noise  
8 which means that their autoregressive component is set to 0. Likewise the standard  
9 deviations of shocks are set to 0.5 across the entire spectrum.<sup>13</sup>

## 10 2.5.2 Model solution

11 We solve the model using recursive methods (see DeGrauwe (2012) for further de-  
12 tails). This allows for non-linear effects. The model has six endogenous variables,  
13 output gap, inflation, financing spread, savings, capital and interest rate. In the  
14 benchmark MBF version of the model, the first five are obtained after solving the  
15 following system:

$$\begin{bmatrix} 1 & -b_2 & 0 & 0 & 0 \\ -a_2c_1 & 1 - a_2c_2 & -(a_2 + a_3) & 0 & (a_1 - a_2)\psi(u_t) \\ -\psi\tau^{-1}e_2c_1 & -\psi\tau^{-1}e_2c_1 & (1 - \psi\tau^{-1}e_2) & 0 & 0 \\ d_3c_1 & -(1 - d_1 - d_3c_2) & 0 & 1 & 0 \\ 0 & 0 & e_2 & 0 & 1 \end{bmatrix} \begin{bmatrix} \pi_t \\ y_t \\ x_t \\ s_t \\ k_t \end{bmatrix} =$$

$$16 \quad = \begin{bmatrix} b_1 & 0 & 0 & 0 & -e_2 \\ -a_2 & 1 - a_1 & 0 & 0 & \Psi\left(\frac{i_t}{i_{t-1}}\right)e_1 \\ -\psi\tau^{-1}e_2 & -\psi\tau^{-1}e_2 & 0 & 0 & 0 \\ d_3 & -d_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \tilde{E}_t[\pi_{t+1}] \\ \tilde{E}_t[y_{t+1}] \\ \tilde{E}_t[x_{t+1}] \\ \tilde{E}_t[s_{t+1}] \\ \tilde{E}_t[k_{t+1}] \end{bmatrix} +$$

---

<sup>13</sup>The AR-component of the shock to capital utilization cost is set conservatively to 0.1, just enough to generate some persistence in the capital cost structure.

$$\begin{aligned}
& + \begin{bmatrix} 1 - b_2 & 0 & 0 & 0 & 0 \\ 0 & 1 - a'_1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & -(1 - d_1 - d_2) & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & (1 - \delta\psi(u_t)) \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ y_{t-1} \\ x_{t-1} \\ s_{t-1} \\ k_{t-1} \end{bmatrix} + \\
& + \begin{bmatrix} 0 & 0 & 0 \\ a_2 c_3 & 0 & 0 \\ -\psi\tau^{-1}e_2 c_3 & \psi\tau^{-1} & \psi\tau^{-1} \\ d_2 c_3 & 0 & 0 \\ e_2 & 0 & 0 \end{bmatrix} \begin{bmatrix} r_{t-1} \\ D_{t-1} \\ n_{t-1}^b \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & a_2 & 0 & 1 & (a_1 - a_2) \\ 0 & \psi^{-1}\tau e_2 & 1 & 0 & 0 \\ 0 & -d_3 & 0 & -(1 - d_1) & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \eta_t \\ u_t \\ \vartheta \\ \epsilon_t \\ uc f_t \end{bmatrix}
\end{aligned}$$

In the BBF version, the system of equations for the five variables looks instead like:

$$\begin{bmatrix} 1 & -b_2 & 0 & 0 & 0 \\ -a_2 c_1 & 1 - a_2 c_2 & -(a_2 + a_3) & 0 & (a_1 - a_2)\psi(u_t) \\ -\frac{\kappa^b * e_2 * c_1}{\epsilon^b - 1 + (1 + \beta)\kappa^b} & -\frac{\kappa^b * e_2 * c_1}{\epsilon^b - 1 + (1 + \beta)\kappa^b} & -\frac{\kappa^b * e_2}{\epsilon^b - 1 + (1 + \beta)\kappa^b} & 0 & 0 \\ d_3 c_1 & -(1 - d_1 - d_3 c_2) & 0 & 1 & 0 \\ 0 & 0 & e_2 & 0 & 1 \end{bmatrix} \begin{bmatrix} \pi_t \\ y_t \\ x_t \\ s_t \\ k_t \end{bmatrix} =$$

$$= \begin{bmatrix} b_1 & 0 & 0 & 0 & -e_2 \\ -a_2 & 1 - a_1 & 0 & 0 & \Psi\left(\frac{i_t}{i_{t-1}}\right)e_1 \\ \frac{-e_2 * c_1}{\epsilon^b - 1 + (1 + \beta)\kappa^b} & \frac{e_1}{\epsilon^b - 1 + (1 + \beta)\kappa^b} & 0 & 0 & 0 \\ d_3 & -d_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \tilde{E}_t[\pi_{t+1}] \\ \tilde{E}_t[y_{t+1}] \\ \tilde{E}_t[x_{t+1}] \\ \tilde{E}_t[s_{t+1}] \\ \tilde{E}_t[k_{t+1}] \end{bmatrix} +$$

$$+ \begin{bmatrix} 1 - b_2 & 0 & 0 & 0 & 0 \\ 0 & 1 - a'_1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & -(1 - d_1 - d_2) & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & (1 - \delta) \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ y_{t-1} \\ x_{t-1} \\ s_{t-1} \\ k_{t-1} \end{bmatrix} +$$

1

$$+ \begin{bmatrix} 0 & 0 & 0 \\ a_2 c_3 & 0 & 0 \\ \frac{(\epsilon^b - 1) * e_2 * c_3}{\epsilon^b - 1 + (1 + \beta) \kappa^b} & \frac{(\epsilon^b - 1)}{\epsilon^b - 1 + (1 + \beta) \kappa^b * (1 - \kappa)} & \frac{(\epsilon^b - 1) * e_2 * c_3}{\epsilon^b - 1 + (1 + \beta) \kappa^b} \\ d_3 c_3 & 0 & 0 \\ e_2 & 0 & 0 \end{bmatrix} \begin{bmatrix} r_{t-1} \\ D_{t-1} \\ n_{t-1}^b \end{bmatrix} +$$

2

$$+ \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & a_2 & 1 & (a_1 - a_2) \\ 0 & (\varsigma - \varsigma_{t-1}) * e_2 & 0 & 0 \\ 0 & -d_3 & -(1 - d_1) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \eta_t \\ u_t \\ \epsilon_t \\ u c f_t \end{bmatrix}$$

3

Using matrix notation, we can write this as:  $\mathbf{AZ}_t = \mathbf{B}\tilde{\mathbf{E}}_t \mathbf{Z}_{t+1} + \mathbf{CZ}_{t-1} + \mathbf{DX}_{t-1} + \mathbf{Ev}_t$ .

4

We can solve for  $\mathbf{Z}_t$  by inverting:  $\mathbf{Z}_t = \mathbf{A}^{-1}(\mathbf{B}\tilde{\mathbf{E}}_t \mathbf{Z}_{t+1} + \mathbf{CZ}_{t-1} + \mathbf{DX}_{t-1} + \mathbf{Ev}_t)$

5

and assuring  $\mathbf{A}$  to be non-singular.

6

The only difference is that the equation for financing spread (line 3 in matrices A, B D and E) looks different in the two versions of the model (since the spread depends on different variables respectively).

9

Solution for interest rate  $r_t$  is obtained by substituting  $y_t$  and  $\pi_t$  into the Taylor rule. Bank equities, credit, deposits, loan rate, deposit rate, bank profits, bank leverage, firm leverage, investment, utilization costs, labor, net worth of banks, and net worth of firms are determined by the model solutions for output gap, inflation, financing spread, savings and capital.<sup>14</sup>

Expectation terms with a tilde  $\tilde{\mathbf{E}}_t$  implies that we do not impose rational expectations. Using the system of equations above, if we substitute the law of motion consistent with heterogeneity of agents (fundamentalists and extrapolators), then we can show that the endogenous variables depend linearly on lagged endogenous variables, their equilibrium forecasts and current exogenous shocks.

Note that for the forecasts of output and inflation gap, the forward looking terms in equations I.1 and I.7 are substituted by the discrete choice mechanism in I.26. For a comparison of solutions in the 'bounded rationality' model and rational expectations framework, see section 2.4 in De Grauwe and Macchiarelli (2015).

<sup>14</sup>However, external financing spread, capital, and savings do not need to be forecasted as these do not affect the dynamics of the model (i.e. there is no structure of higher order beliefs as law of iterated expectations does not hold in the behavioural model). See section 3.1 in DeGrauwe and Macchiarelli (2015) for comparison of solutions under rational expectations and bounded rationality ("heuristics").

### 2.5.3 Forcing variables

The shock we will examine in this paper is primarily a standard (negative) monetary policy shock ( $\epsilon$ ):<sup>15</sup>

$$r_t = r_{t-1} + \gamma\pi_t + (1 - \gamma)y_t + \epsilon \quad (38)$$

, where  $\epsilon$  is a white noise monetary policy shock which is calibrated to 0.5 in both versions of the model. Note in matrix E that the monetary policy shock is scaled by the leverage gap in the banking sector ( $\varsigma - \varsigma_t$ ). This gap measures how much the banking sector is away from its' targeted (or optimal) leverage ratio. The bigger the gap, the more leveraged the banking sector, and the stronger effect a monetary policy shock will have on the system. This is in order to capture the enhanced effects that leveraging has on flows, in particular when a de-leveraging spiral is triggered.<sup>16</sup>

## 3 Quantitative results

Our analysis consists of three parts. The first part is an analysis of (model consistent) impulse responses to a monetary policy shock. We are in particular interested in detecting differences between monetary transmissions in a market-based and bank-based corporate financing system. The second part is an examination of the (model generated) second-, and higher-order moments to contrast the statistical fit of the model. The final part consists of analyzing the monetary transmission during recessions. In particular, we wish to understand whether monetary policy is more effective in reviving the economy during recessions in the US or Euro Area.

### 3.1 Impulse responses to a monetary policy shock

Figure I.1 depicts the impulse responses to an expansionary monetary policy shock in the MBF version of the model, whereas Figures I.2 and I.3 depict the responses

---

<sup>15</sup>We also execute the other three shocks (technology, aggregate demand and capital utilization cost shocks) but in this study focus on the monetary transmission channel only. For the analysis of the other shocks, please refer to De Grauwe and Gerba (2015).

<sup>16</sup>Before we begin with the analysis, bear in mind that the behavioural model does not have one steady state that is time invariant for the same calibration (as is standard for the DSGE method). Therefore, following a white noise shock, the model will not necessarily return to a previous steady state. If not the same steady state, it can either reach a new steady state, or have a prolonged response to the initial shock. In other words, there is a possibility for the temporary shock to have permanent effects in the model (via the animal spirits channel). That is why we draw a full distribution of impulse responses to capture the entire spectrum of responses.



1 to the same shock in the BBF version. Note that the size of the shock as well as the  
2 scale of the figures is kept the same in both versions. The numbers on the x-axis  
3 indicate number of quarters. The shock is introduced in  $t=100$  and we observe the  
4 responses over a long period of 60 quarters (or 15 years). The figures depict the full  
5 impulse responses with the 95% confidence intervals. The blue line represents the  
6 median impulse response, and the red lines are the 95% interval.

### 7 **3.1.1 Market-based-financing version**

8 As is standard, an expansionary monetary policy (0.5% fall) leads to a fall in the ex-  
9 ternal finance premium, which relaxes the credit that firms can access and therefore  
10 pushes up investment (0.3%). This pushes up capital accumulation (0.4%). This  
11 expansion is perceived by agents as a period of positive outlook, which triggers the  
12 optimism (animal spirits up 0.2%). This optimism is translated into an increase in  
13 deposits (0.25%) and bank equity (0.3%). The expansion leads to an increase in  
14 output (0.20%) and a rise in inflation (0.01%), but with a lag of 1 quarter.<sup>17</sup>

15 However, this optimism is very brief as the monetary authority raises the interest  
16 rate (0.1%) to combat the rising inflation. By agents, this is perceived as the end of  
17 the expansionary phase, resulting in a reversal of the sentiment to pessimism (animal  
18 spirits fall by 0.05%). The consequence is a turn in the response of macroeconomic  
19 and financial aggregates, leading to return of these variables to the steady state.

20 Note that the confidence interval of all variables is relatively wide. This arises  
21 from the uncertainty regarding the coefficients of leverage ratio and net worth. Since  
22 leverage ratio of firms is estimated endogenously in each period and it depends on  
23 the very volatile stock market prices in this model version (see equation 7 and ??),  
24 the uncertainty from these two estimates is translated onto the other coefficients,  
25 since many of them are dependent on either of them. As a result, the confidence  
26 intervals for each estimated coefficient become wide.

### 27 **3.1.2 Bank-based-financing version**

28 In the BBF version, the effects from a monetary policy expansion are approximately  
29 twice as strong as in the previous version. On the real side, Investment rises by 0.7%,  
30 capital by 0,4%, output by 0.4% and inflation by 0.08%. On the banking side, the  
31 expansion is even stronger. Deposit rate goes up by 0.5%, attracting more deposits

---

<sup>17</sup>Initially, output falls by 0.25% as well as inflation by 0.05%, but this is reverted after 1 period. This finding is frequent in the literature and denominated as the price puzzle.

(0.2%), which also permits them to rise loans by 0.75%. The resulting effect is an increase in leverage by 0.1%, but also a substantial increase in bank profitability, since its profits rise considerably over time (accumulating up to 400% in 10 years after the shock).

The confidence intervals are also much narrower in this version of the model. Since firm leverage plays a less central role in the intermediation mechanism of the bank-based model version, the uncertainty arising from its estimated coefficients is not passed-on onto the model dynamics to the same extent. As a result, the variation around the median impulse response is now much smaller, and the IRF distribution is more tight.

### 3.2 Statistical evaluation of the models

Table I.2 depicts the correlations of model variables in both versions, table I.3 depicts the statistical moments in the MBF version, table I.4 in the BBF model, and table I.5 that of the US data.

First, the bank-based-financing version produces less asymmetric distributions compared to the market-based one. Many of the variables in BBF have skewness and kurtosis that are lower and also cycles that are similar to the overall business cycle. Moreover the volatilities of many variables are considerably lower.<sup>18</sup>

Second and turning to the relative matching of the statistical moments in the data, the volatilities of financial variables such as  $d_t$ ,  $r_t$ ,  $r_t^d$ ,  $n_t^b$ ,  $n_t^f$ ,  $d_t$  and  $i_t$  are better matched in the BBF version. On the other hand, the volatilities of real variables such as  $\pi_t$ ,  $k_t$ ,  $c_t$ ,  $s_t$  and of credit variables ( $l_t^s$ ,  $x_t$ ) are better matched in the MBF version.

Third, the BBF version improves significantly the matching of model correlations. For instance, the autocorrelations of  $k_t$ ,  $\pi_t$  and  $x_t$  are improved with respect to the benchmark market-based version. In the same way, the matching in correlations of financial market variables is also considerably improved.

To conclude we also notice a much clearer cyclical pattern in all model variables in the BBF version compared to the MBF. This means that variables which previously were (close to) acyclical such as  $\psi(u_t)$ ,  $\vartheta$ ,  $x_t$ ,  $n_t^b$ ,  $n_t^f$  now have a clearer (pro or counter) cyclical pattern. In addition, the cyclical nature of other variables has significantly increased in the banking amended version. Examples of those variables

<sup>18</sup>See also the histograms in Figures I.8 and I.9.

1 are  $k_t$  (going from a correlation with the business cycle of 0.45 to 0.78),  $d_t$  (from  
2 0.17 to 0.70),  $r_t$  (from 0.39 to 0.53),  $l_t^s$  (from 0.11 to 0.16), or  $x_t$  (from -0.41 to  
3 -0.46). All this points towards a stronger inter-relation between most (endogenous)  
4 model variables and a more potent underlying (macroeconomic) mechanism in the  
5 bank-based version.

### 6 **3.3 Monetary transmission in crises: US vs EU**

7 The final part of the comparison consists of examining the (asymmetric) impact of  
8 monetary expansions during recessions. More specifically, we are interested in un-  
9 derstanding whether a reduction in interest rates during recessions is more effective  
10 in bringing the economy back to its long-term trend in a market-based financial sys-  
11 tem such as US or in a bank-based such as the Euro Area. To do so, we will compare  
12 the simulated cycles depicted in Figures I.4 to I.6 and discriminately analyze the  
13 depth of the busts and the time it takes for the economy to recover from those using  
14 standard monetary measures.

15 Comparing the evolution of interest rates in the MBF and BBF model, monetary  
16 policy seems to be more easing during recessions in the latter version. The relaxation  
17 in interest rates are more frequent, and the drops are deeper in the BBF model. The  
18 sharpest drop of more than 5% around  $t=340$ , for instance, does not at all occur in  
19 the MBF model. On the contrary, the hikes in interest rates are instead sharper in  
20 the MBF version.

21 The effects on output from these drops, however, are more modest. Taking into  
22 account that the booms in output are weaker in BBF (by up to 1/3 compared to  
23 MBF), the more accomodative monetary policy in this version does not equally  
24 successfully translate into heavy booms. The reason, we believe, is the additional  
25 banking friction that we have added in the BBF model which prevents the (highly)  
26 accommodative monetary conditions to translate into a full-blasted boom.

27 On the other hand, the amplitude (or swings) of the cycles are more modest in the  
28 BBF version. If one interprets the aim of monetary policy as a tool to prevent heavy  
29 cyclical swings, that task is more effectively achieved in the latter version. This  
30 means that the monetary policy is more responsive to downturns, which prevents  
31 the economy from reaching severe and costly troughs. Therefore, if one evaluates  
32 the policy from that angle, the monetary transmission during recessions seems to  
33 be stronger in the Euro Area compared to the US.

### 3.4 Asymmetries over the business cycle

The last contrast we wish to make is the level of asymmetry that we find in the model. Looking at the histograms in Figures I.8 and I.9, we can say that most of the variables have a more asymmetric distribution in the MBF model. For output, capital, asset prices and utilization costs, there is a higher probability mass to the right than to the left of the mean. For inflation, the opposite is true. This means that a market-based financial system produces more sentiment-pronounced cyclical dynamics where heavy optimism results in a prolonged period of boom but also in a sharp subsequent bust. Those heavy sentiment swings, however, are not to the same extent present in the bank-based model. Instead there is symmetry between periods of boom and bust, and the dynamics in the economy is to a larger extent driven by fundamentals. This is confirmed by the (almost) symmetric distributions of output, capital and asset prices implying a relatively equal split between the left-and-right-end probability mass. What is more, there seems to be a heavier bias towards negative outlook on the future or pessimism in the BBF version.<sup>19</sup>

## 4 Discussion and concluding remarks

The effectiveness of monetary policy in reviving stagnating economies has once again become a key priority for policy makers during the Euro Area debt crisis. The extent to which monetary easing could restore confidence on financial markets as well as in bringing the key inflation rate close to its 2% target level has been the key concern of the ECB for the past five years. The relative success of it, however, is still very unclear.

In the current paper we look at one aspect of this problematic. In particular, we study the relative effectiveness of monetary policy in a bank-based and in a market-based (corporate) financing system. Our aim is to understand whether the monetary transmission mechanism is more effective when banks or markets provide the majority of liquidity in the economy. As an approximation, we characterize the Euro Area financial system as a banking friction, and the US one to the (stock) market friction.

We find strong evidence that the monetary transmission channel is stronger in the bank-based system. The impulse response analysis showed that the effects from

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<sup>19</sup>See the histogram of animal spirits in figure I.8.

1 a monetary expansion are approximately twice that of the MBF version. Moreover,  
2 the confidence intervals are much narrower in the BBF version since the estima-  
3 tion of coefficients is much more precise and the variation in estimates for different  
4 initializations of the learning framework is much smaller. This implies a better  
5 convergence in the estimation of the bank-based model version.

6 The statistical analysis shows that while market-based financial systems gener-  
7 ate high asymmetries over the business cycles and a high probability mass on the  
8 extremes, the bank based one produces the contrary. Also the second, third and  
9 fourth moments are considerably lower in the latter version. This results in a better  
10 empirical fit of the Euro Area model to the data.

11 Lastly, we (discriminately) evaluate the relative effectiveness of monetary policy  
12 in counteracting busts and find mixed evidence. In terms of generating higher  
13 and more sustained booms, a monetary easing in the market-based system is more  
14 effective. However, if we evaluate the effectiveness in terms of avoiding severe and  
15 costly busts, a monetary easing in a bank-based financing system is more successful.

16 There are several ways in which the current work can be extended. First, the  
17 framework can be extended to an open-economy setting. Considering that the US  
18 and Euro Area are highly open economies, the interaction between monetary policy  
19 and the external sector is an important mechanism. This is ignored in the cur-  
20 rent paper, and therefore the sensitivity of monetary policy to external shocks is  
21 completely overlooked.

22 Second and possibly more interesting would be to include a mixture model of  
23 financing in our framework. Instead of studying separately a pure bank based and  
24 market based system, a more realistic approach is to include both but with different  
25 weights depending on the economy at study. That would bring this framework  
26 closer to the one of Bolton and Freixas (2006), but again different to theirs, allow  
27 us to additionally study the important interaction between imperfect beliefs and  
28 the financial system. It would also represent a more general version of the current  
29 theoretical set-up.

30 Lastly, we calibrate our parameters in the model. An interesting exercise would  
31 be to estimate the parameters of the model in order to get a more accurate repre-  
32 sentation of the business cycles.

## References

- [1] Anderson S.P., De Palma A., and Thisse J.F. (1992), *Discrete Choice Theory of Product Differentiation*, MIT Press, pages 13–62.
- [2] Ashcraft, A. B., and Campello, M. (2007). Firm balance sheets and monetary policy transmission. *Journal of Monetary Economics*, 54(6), 1515-1528.
- [3] Bene, J., and Lees, K. (2007). Monopolistic Banks and Fixed Rate Contracts: Implications for Open Economy Inflation Targeting.
- [4] Bhamra, H. S., Fisher, A. J., and Kuehn, L. A. (2011). Monetary policy and corporate default. *Journal of Monetary Economics*, 58(5), 480-494.
- [5] Bolton, P., and Freixas, X. (2006). Corporate finance and the monetary transmission mechanism. *Review of financial Studies*, 19(3), 829-870.
- [6] Bougheas, S., Mizen, P., and Yalcin, C. (2006). Access to external finance: Theory and evidence on the impact of monetary policy and firm-specific characteristics. *Journal of Banking and Finance*, 30(1), 199-227.
- [7] Brock W.A., and Hommes C.H. (1997), "A Rational Route to Randomness", *Econometrica*, 65(5): pp. 1059–96
- [8] Brock W.A., and Hommes C.H. (1998), "Heterogeneous Beliefs and Routes to Chaos in a Simple Asset Pricing Model", *Journal of Economic Dynamics and Control*, 22(8-9): pp. 1235–74
- [9] Calomiris, C. W., Himmelberg, C. P., and Wachtel, P. (1995, June). Commercial paper, corporate finance, and the business cycle: a microeconomic perspective. In *Carnegie-Rochester Conference Series on Public Policy* (Vol. 42, pp. 203-250). North-Holland.
- [10] Carroll C.D. (2003), "Macroeconomic Expectations of Households and Professional Forecasters", *The Quarterly Journal of Economics*, 118(1): pp. 269–98
- [11] Champ B. and Freeman S. (1990), "Money, Output and the Nominal National Debt", *American Economic Review*, June: pp. 390–97
- [12] Champ B. and Freeman S. (1994), *Modelling Monetary Economics*, John Wiley & Sons, New York.

- 1 [13] Christiano, L., Motto, L., Rostagno, R. (2010), "Financial factors in business  
2 cycles", ECB Working Paper Series No. 1192, May
- 3 [14] Ciccarelli, M., Maddaloni, A., and Peydr, J. L. (2014). Trusting the bankers:  
4 A new look at the credit channel of monetary policy. *Review of Economic  
5 Dynamics*.
- 6 [15] Cogley T. (2002), "A Simple Adaptive Measure of Core Inflation", *Journal of  
7 Money, Credit and Banking*, 34(1): pp. 94–113
- 8 [16] Cogley T., and Sargent T. (2007), "Inflation-Gap Persistence in the US",  
9 mimeo, Northwestern University
- 10 [17] Cornea A., Hommes C.H. and Massaro D. (2012), *Behavioral Heterogeneity in  
11 U.S. Inflation Dynamics*, CeNDEF Working Papers, 12–03.
- 12 [18] De Grauwe P., and Gerba, E. (2015), "Stock Market Cycles and Supply Side  
13 Dynamics: Two Worlds, One Vision?", CES Ifo Working Paper No. 5573.
- 14 [19] De Grauwe, P. and Macchiarelli C. (2015), "Animal Spritis and Credit Cycles",  
15 *Forthcoming in Journal of Economic Dynamics and Control*
- 16 [20] De Grauwe, P. (2012), *Lectures on Behavioural Macroeconomics*, Princetone  
17 University Press
- 18 [21] De Grauwe, P. (2011), "Animal Spirits and Monetary Policy", *Economic The-  
19 ory*, 47(2-3), pp. 423–57
- 20 [22] Ehrmann, M., Gambacorta, L., Martnez-Pags, J., Sevestre, P., and Worms, A.  
21 (2001). Financial systems and the role of banks in monetary policy transmission  
22 in the euro area.
- 23 [23] Frankel J., and Froot K., (1990), "Charists, Fundamentalists, and Trading in  
24 the Foreign Exchange Market", *American Economic Review*, 80(2), pp.181–85
- 25 [24] Gaiotti, E., and Secchi, A. (2006). Is there a cost channel of monetary policy  
26 transmission? An investigation into the pricing behavior of 2,000 firms. *Journal  
27 of Money, Credit, and Banking*, 38(8), 2013-2037.
- 28 [25] Gerali A., Neri S., Sessa L., and Signoretti F.M. (2010), "Credit and Banking  
29 in a DSGE Model of the Euro Area", *Journal of money, Credit and Banking*,  
30 42 (Sep): pp. 107–41

- [26] Harvey A.C. and Jaeger A. (1993), "Detrending, Stylised Facts and the Business Cycle", *Journal of Applied Econometrics*, 8: pp.231–47
- [27] Hoshi, T., Scharfstein, D. S., and Singleton, K. J. (1993). Japanese corporate investment and bank of Japan guidance of commercial bank lending. In Japanese monetary policy (pp. 63-94). University of Chicago Press.
- [28] Jimnez, G., Ongena, S., Peydr, J. L., and Saurina Salas, J. (2009). Hazardous times for monetary policy: what do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking?.
- [29] Kashyap, A. K., and Stein, J. C. (2000). What do a million observations on banks say about the transmission of monetary policy?. *American Economic Review*, 407-428.
- [30] Kashyap, A. K., Stein, J. C., and Wilcox, D. W. (1996). Monetary policy and credit conditions: Evidence from the composition of external finance: Reply. *The American Economic Review*, 310-314.
- [31] Ludvigson, S. (1998). The channel of monetary transmission to demand: evidence from the market for automobile credit. *Journal of Money, Credit and Banking*, 365-383.
- [32] Mankiw N.G., Reis R. and Wolfers J. (2004), "Disagreement About Inflation Expectations", *NBER Macroeconomics Annual 2003*, 18: pp. 209–70
- [33] Manski C.F., McFadden D.L., (1981), "Alternative Estimators and Sample Designs for Discrete Choice Analysis" in *Structural Analysis of Discrete Data and Econometric Applications*, Manski C.F. and McFadden D.L. (ed.), Cambridge: The MIT Press
- [34] Milani F., (2007), "Expectations, Learning and Macroeconomic Persistence", *Journal of Monetary Economics*, 54(7), pp.2065–82
- [35] Peersman, G., and Smets, F. (2005). The Industry Effects of Monetary Policy in the Euro Area\*. *The Economic Journal*, 115(503), 319-342.
- [36] Pesaran H.M., (1987), *The Limits of Rational Expectations*, Blackwell, Oxford



1 [37] Roos M.W.M. and Schmidt U. (2012), "The Importance of Time-Series Extrapolation for Macroeconomic Expectations" *German Economic Review*, 13(2): pp. 196–210

## 4 Appendices

### 5 I Equations, Tables and Figures

#### 6 I.1 Equations in the MBF and BBF models

7 **Aggregate Demand:**

8 Aggregate Demand:

$$y_t = a_1 \tilde{E}_t y_{t+1} + (1 - a_1) y_{t-1} + a_2 (r_t - \tilde{E}_t \pi_{t+1}) + (a_2 + a_3) efp_t + (a_1 - a_2) \psi(u_t) k_t + Adj_t + \epsilon_t \quad (\text{I.1})$$

9

10 Investment

$$i_t = e_1 \tilde{E}_t [y_{t+1}] + e_2 [r_t + efp_t - \tilde{E}_t [\pi_{t+1}]] \quad (\text{I.2})$$

11

12 External Finance Premium

$$efp_t = \phi \bar{n}_t S_t \quad (\text{I.3})$$

13

14 Consumption

$$c_t = 1 - s_t \quad (\text{I.4})$$

15 **Aggregate Supply:**

16 Cobb-Douglas Production Function

$$y_t = a_t (k_t \psi(u_t))^\alpha h_t^{\omega(1-\alpha)} \quad (\text{I.5})$$

17

18 Utilization cost function

$$\psi(u_t) = \xi_0 + \xi_1 (u_t - 1) + \frac{\xi_2}{2} (u_t - 1)^2 \quad (\text{I.6})$$

Approximated Philips Curve:

$$\pi_t = b_1 \tilde{E}_t \pi_{t+1} + (1 - b_1) \pi_{t-1} + b_2 y_t + \nu_t \quad (\text{I.7})$$

Capital evolution

$$k_t = (1 - \delta) \psi(u_t) k_{t-1} + \Psi i_t \quad (\text{I.8})$$

Cash-in-advance constraint

$$\vartheta_t = S_{t+1} k_{t+1} - n_t^f \quad (\text{I.9})$$

Labour market

$$y_t = \frac{l_t w_t}{1 - \alpha} \quad (\text{I.10})$$

Monetary policy

$$r_t^n = \rho r_{t-1}^n + \zeta \pi_t + \gamma_y y_t + \sigma_r \quad (\text{I.11})$$

**Financial market:**

Bank net worth

$$n_t^b = \kappa (l_t^s + \bar{n} S_t) \quad (\text{I.12})$$

Evolution of bank leverage

$$\tau_t = \tau_{t-1} + \frac{l_t^d}{n_t^f} \quad (\text{I.13})$$

Stock market price

$$S_t = \frac{E_t[\Lambda_{t+1}^-]}{R_t^s} \equiv \frac{\tilde{E}_t y_{t+1} - \tilde{E}_t \pi_{t+1}}{R_t^s} \quad (\text{I.14})$$

Firm net worth

$$n_t^f = S_t \bar{n}_t = \frac{1}{\tau} (L_{t-1}^D + e_1 \tilde{E}_t y_{t+1} + e_2 (r_t + efp_t - \tilde{E}_t \pi_{t+1})) \quad (\text{I.15})$$

1

2 Deposits

$$d_t = d_{t-1} + s_t \quad (\text{I.16})$$

3

4 Loan demand

$$l_t^d = l_{t-1}^d + i_t \quad (\text{I.17})$$

5

6 Credit market equilibrium

$$l_t^d = l_t^s \quad (\text{I.18})$$

7 **Bank-based financing system:**

$$r_t^b = \frac{\kappa^b r_t^b + (\epsilon^b - 1)R_t^b - \epsilon^b}{\epsilon^b - 1 + (1 + \beta)\kappa^b} \quad (\text{I.19})$$

8

$$r_t^d = \frac{\kappa^d r_t^d - (\epsilon^d - 1)R_t^d + \epsilon^d}{-\epsilon^d + 1 - (1 + \beta)\kappa^d} \quad (\text{I.20})$$

9

$$x_t \equiv r_t^b - r_t^d = r_t^b - r_t \quad (\text{I.21})$$

10

$$R_t^b = r_t - \kappa^{nb} \left[ \frac{n_t^b}{l_t^s} - \varsigma \right] \left[ \frac{n_t^b}{l_t^s} \right]^2 \quad (\text{I.22})$$

11

$$\varsigma_t = \varsigma - \left[ \frac{l_t^s}{nb_t} \right] \quad (\text{I.23})$$

12

$$pib_t = r_t^b l_t^s - r_t^d d_t - \frac{\kappa^{nb}}{2} \left[ \frac{n_t^b}{l_t^s} - \varsigma \right]^2 n_t^b - adj_t \quad (\text{I.24})$$

13

$$n_t^b = \bar{n}^b + (1 - \delta^b) n_{t-1}^b + pib_t \quad (\text{I.25})$$

14 **Learning environment:**

15 Inflation learning

$$\tilde{E}_t \pi_{t+1} = \alpha_t^f \tilde{E}_t^f \pi_{t+1} + \alpha_t^e \tilde{E}_t^e \pi_{t+1} \quad (\text{I.26})$$

16

17 Output learning

$$\tilde{E}_t y_{t+1} = \alpha_t^f \tilde{E}_t^f y_{t+1} + \alpha_t^e \tilde{E}_t^e y_{t+1} \quad (\text{I.27})$$

18

19 Learning rules:

$$\tilde{E}_t^f \pi_{t+1} = \pi^* \quad (\text{I.28})$$

$$\tilde{E}_t^f y_{t+1} = y^* \quad (I.29)$$

$$\tilde{E}_t^e \pi_{t+1} = \theta \pi_{t-1} \quad (I.30)$$

$$\tilde{E}_t^e y_{t+1} = \theta y_{t-1} \quad (I.31)$$

Weights

$$\alpha_{\pi,t}^f = \frac{\exp(\gamma U_{\pi,t}^f)}{\exp(\gamma U_{\pi,t}^f) + \exp(\gamma U_{\pi,t}^e)} \quad (I.32)$$

$$\alpha_{y,t}^f = \frac{\exp(\gamma U_{y,t}^f)}{\exp(\gamma U_{y,t}^f) + \exp(\gamma U_{y,t}^e)} \quad (I.33)$$

$$\alpha_{\pi,t}^e \equiv 1 - \alpha_{\pi,t}^f = \frac{\exp(\gamma U_{\pi,t}^e)}{\exp(\gamma U_{\pi,t}^f) + \exp(\gamma U_{\pi,t}^e)} \quad (I.34)$$

$$\alpha_{y,t}^e \equiv 1 - \alpha_{y,t}^f = \frac{\exp(\gamma U_{y,t}^e)}{\exp(\gamma U_{y,t}^f) + \exp(\gamma U_{y,t}^e)} \quad (I.35)$$

Utilities:

$$U_{\pi,t}^f = - \sum_{k=0}^{\infty} w_k [\pi_{t-k-1} - \tilde{E}_{t-k-2}^f \pi_{t-k-1}]^2 \quad (I.36)$$

$$U_{y,t}^f = - \sum_{k=0}^{\infty} w_k [y_{t-k-1} - \tilde{E}_{t-k-2}^f y_{t-k-1}]^2 \quad (I.37)$$

$$U_{\pi,t}^e = - \sum_{k=0}^{\infty} w_k [\pi_{t-k-1} - \tilde{E}_{t-k-2}^e \pi_{t-k-1}]^2 \quad (I.38)$$

$$U_{y,t}^e = - \sum_{k=0}^{\infty} w_k [y_{t-k-1} - \tilde{E}_{t-k-2}^e y_{t-k-1}]^2 \quad (I.39)$$

**Shocks**

Monetary policy shock:

$$r_t = r_{t-1} + \gamma \pi_t + (1 - \gamma) y_t + \epsilon \quad (I.40)$$

## I.2 Tables and Figures

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Table I.1: Parameters of the behavioural model and descriptions

Parameter	Description	Value
<b>Calibrated</b>		<b>Calibration</b>
$\pi^*$	The central bank's inflation target	0
$d_1$	Marginal propensity of consumption out of income	0.5
$e_1$	Coefficient on expected output in investment eq.	0.1
$d_2$	Coefficient on expected output in consumption eq. to match $a_1 = 0.5$	$0.5 * (1 - d_1) - e_2$
$d_3$	Coefficient on real rate in consumption eq.	-0.01
$e_2$	Coefficient on real rate in investment eq. to match $a_2 = -0.5$	$(-0.5) * (1 - d_1) - d_3$
$a_1$	Coefficient of expected output in output eq.	$(e_1 + d_2)/(1 - d_1)$
$a_1'$	Coefficient of lagged output in output eq.	$d_2/(1 - d_1)$
$a_2$	Interest rate elasticity of output demand	$(d_3 + e_2)/(1 - d_1)$
$a_3$	Coefficient on spread term in output eq.	$-d_3/(1 - d_1)$
$b_1$	Coefficient of expected inflation in inflation eq.	0.5
$b_2$	Coefficient of output in inflation eq.	0.05
$c_1$	Coefficient of inflation in Taylor rule eq.	1.5
$\psi$	Parameter of firm equity	-0.02
$\tau$	Firms' leverage	1.43
$\alpha^d$	Fraction of nominal GDP forecast in expected future dividends	0.2
$\beta$	Bubble convergence parameter	0.98
$c_2$	Coefficient of output in Taylor equation	0.5
$c_3$	Interest smoothing parameter in Taylor equation	0.5
$\delta$	Depreciation rate of capital	0.025
$\alpha$	Share of capital in production	0.3
$\Psi$	Adjustment cost function in investment	0.5
$\gamma$	Switching parameter in Brock-Hommes (or intensity of choice parameter)	1
$\rho$	Speed of declining weights in memory (mean square errors)	0.5
$z$	Technological development parameter	0.5
$\xi$	Parameter 1 in the utilization cost function	0.8
$\xi_1$	Parameter 2 in the utilization cost function	0.3
$\xi_2$	Parameter 3 in the utilization cost function	0.25
$\epsilon_z$	Std. deviation of nom. Interest rate shock	0.5
$\rho^k$	AR process of shock to utilization cost function	0.1
<b>Parameters specific to the MBF model</b>		
$\bar{n}$	Number of shares in banks' balance sheets	40
$\tilde{n}$	Initial value for number of firms' shares	60
$\kappa$	Banks' inverse leverage ratio	0.09
$e$	Equity premium	0.05
<b>Parameters specific to the BBF model</b>		
$\delta^b$	Depreciation rate of bank capital	0.1049
$\kappa^{nb}$	Leverage deviation cost	11.07
$\kappa^b$	Adjustment costs in loan rate setting	13
$\kappa^d$	Adjustment costs in deposit rate setting	3.50
$\varsigma$	Banks' capital-to-asset ratio	0.09
$adj$	Other adjustment costs	0.5
$\epsilon^b$	Bank's market power in loan rate setting	3.12
$\epsilon^d$	Bank's market power in deposit rate setting	-1.46
$\beta$	Intertemporal discount rate	0.9943
$\bar{n}^b$	Initial (period t=0) bank capital	1

Table I.2: Model correlations - comparisons

Correlations	MBF behavioural model	BBF behavioural model	US data
$\rho(y_t, y_{t-1})$	0.86	0.89	0.85
$\rho(y_t, k_t)$	0.45	0.78	0.15
$\rho(y_t, \pi_t)$	-0.42	-0.40	-0.43
$\rho(y_t, as_t)$	0.84	0.83	-
$\rho(y_t, \psi(u_t))$	-0.01	-0.58	-
$\rho(y_t, d_t)$	0.17	0.70	0.32
$\rho(y_t, l_t^s)$	0.11	0.16	0.18
$\rho(y_t, r_t)$	0.39	0.53	0.45
$\rho(y_t, i_t)$	0.23	0.26	0.90
$\rho(y_t, c_t)$	0.21	0.20	0.32
$\rho(y_t, s_t)$	0.26	0.23	-0.28
$\rho(y_t, x_t)$	-0.41	-0.46	-0.49
$\rho(y_t, \vartheta_t)$	0.02	0.03	-
$\rho(k_t, k_{t-1})$	0.96	0.92	0.88
$\rho(k_t, as_t)$	0.32	0.63	-
$\rho(k_t, \vartheta_t)$	0.02	0.02	-
$\rho(k_t, r_t)$	0.08	0.54	0.31
$\rho(l_t^s, as_t)$	0.12	0.06	-
$\rho(l_t^s, k_t)$	0.28	0.21	0.38
$\rho(l_t^s, x_t)$	-0.09	-0.17	0.26
$\rho(\pi_t, \pi_{t-1})$	0.74	0.82	0.93
$\rho(\pi_t, as_t)$	-0.38	-0.30	-
$\rho(\pi_t, r_t)$	0.57	0.47	0.34
$\rho(\pi_t, r_{t-1})$	0.49	0.48	0.34
$\rho(x_t, x_{t-1})$	0.01	0.13	0.68
$\rho(x_t, as_t)$	-0.12	-0.32	-
$\rho(x_t, k_t)$	-0.24	-0.47	0.09
$\rho(x_t, \vartheta_t)$	0.01	0.005	-
$\rho(\vartheta_t, as_t)$	0.007	0.05	-
$\rho(y_t, n_t^b)$	-0.01	-0.07	0.45
$\rho(y_t, n_t^f)$	-0.02	-0.03	0.22
$\rho(n_t^b, n_{t-1}^b)$		0.99	
$\rho(r_t^b, r_{t-1}^b)$		0.93	
$\rho(r_t^d, r_{t-1}^d)$		0.74	
$\rho(y_t, r_t^b)$		0.02	
$\rho(k_t, \psi(u_t))$		0.27	
$\rho(pib_t, n_t^b)$		0.15	
$\rho(r_t^b, r_t^d)$		-0.04	
$\rho(pib_t, y_t)$		0.04	

Note: GDP deflator was used as the inflation indicator, 3-month T-bill for the risk-free interest rate, the deposit rate as the savings indicator and the Corporate lending risk spread (Moody's 30-year BAA-AAA corporate bond rate) as the counterpart for the firm borrowing spread in the models. The variables that are left blank do not have a direct counterpart in the data sample. These are also called 'deep variables'. The only way is to estimate a structural model (using for instance Bayesian techniques) and to derive a value based on a (theoretical) structure. Alternatively, one could also approximate values using micro data. However, this is outside the scope of this paper.

Table I.3: Second and higher moments - MBF behavioural model

Variable	(Rel.) Standard deviation	(Rel.) Skewness	(Rel.) Kurtosis
$y_t$	2.17	0.21	10.91
$\pi_t$	0.35	-1.81	0.36
$k_t$	0.42	1.24	0.37
$x_t$	1	20.9	27.9
$as_t$	0.15	0.19	0.18
$d_t$	3.72	-0.52	0.17
$l_t^s$	5.07	1.90	0.17
$r_t$	0.95	-4.29	1.1
$i_t$	0.24	-7.81	9.54
$\psi(u_t)$	0.24	-0.05	0.05
$\vartheta_t$	73.89	3.89	53.5
$c_t$	0.24	7.05	9.79
$s_t$	0.24	-7.1	9.82
$n_t^b$	4.45	-4.43	52.66
$n_t^f$	73.9	-3.86	53.52
$S_t$	1.23	-3.33	53.75

Note: The moments are calculated taking output as the denominator. Following a standard approach in the DSGE literature, this is in order to examine the moments with respect to the general business cycle.

Table I.4: Second and higher moments - BBF behavioural model

Variable	(Rel.) Standard deviation	(Rel.) Skewness	(Rel.) Kurtosis
$y_t$	3.34	-0.21	3.25
$\pi_t$	0.26	1.81	1.05
$k_t$	0.35	0.81	0.96
$x_t$	1.11	-0.52	1.67
$as_t$	0.11	-2.62	0.54
$d_t$	0.92	-1.24	0.76
$l_t^s$	6.62	1.10	0.47
$r_t$	0.84	2.29	1.15
$i_t$	0.27	-0.91	1.51
$\psi(u_t)$	0.15	-0.01	0.16
$\vartheta_t$	58.49	-146.5	323.7
$c_t$	0.23	1.14	1.56
$s_t$	0.23	-1.2	1.56
$n_t^b$	0.14	66.3	67.5
$n_t^f$	58.48	-146	323.7
$S_t$	0.97	-147	327.4
$r_t^b$	0.002	-169.1	397.2
$r_t^d$	0.28	-1.81	1.08

Note: The moments are calculated taking output as the denominator. Following a standard approach in the DSGE literature, this is in order to examine the moments with respect to the general business cycle.

Table I.5: Second and higher moments - US data

Variable	(Rel.) Standard deviation	(Rel.) Skewness	(Rel.) Kurtosis
$\pi_t$	0.50	-0.66	3.54
$k_t$	1.50	0.82	1.66
$x_t$	0.18	-5.8	58.6
$as_t$	-	-	-
$d_t$	1.36	1.36	4.54
$l_t^s$	3.55	-0.61	3.75
$r_t$	0.76	-1.27	2.38
$i_t$	3.08	1.18	0.71
$\psi(u_t)$	-	-	-
$\vartheta_t$	-	-	-
$c_t$	0.81	0.37	0.14
$s_t$	8	0.49	8.39
$n_t^b$	1.32	-2.34	9.39
$n_t^f$	2.21	-0.34	16.37

Note: The moments are calculated taking real GDP as the denominator. These are calculated using the full sample of US data stretching from 1953:I - 2014:IV. During this period, the US economy experienced 10 cycles (using NBER business cycle dates), and the average GDP increase per quarter during expansions was 1.05% while it was -0.036% during recessions. The data were de-trended using a standard two-sided HP filter before the moments were calculated in order to facilitate comparison with the model generated (cyclical) moments. The variables that are left blank do not have a direct counterpart in the data sample. These are also called 'deep variables'. The only way is to estimate a structural model (using for instance Bayesian techniques) and to derive a value based on a (theoretical) structure. Alternatively, one could also approximate values using micro data. However, this is outside the scope of this paper.



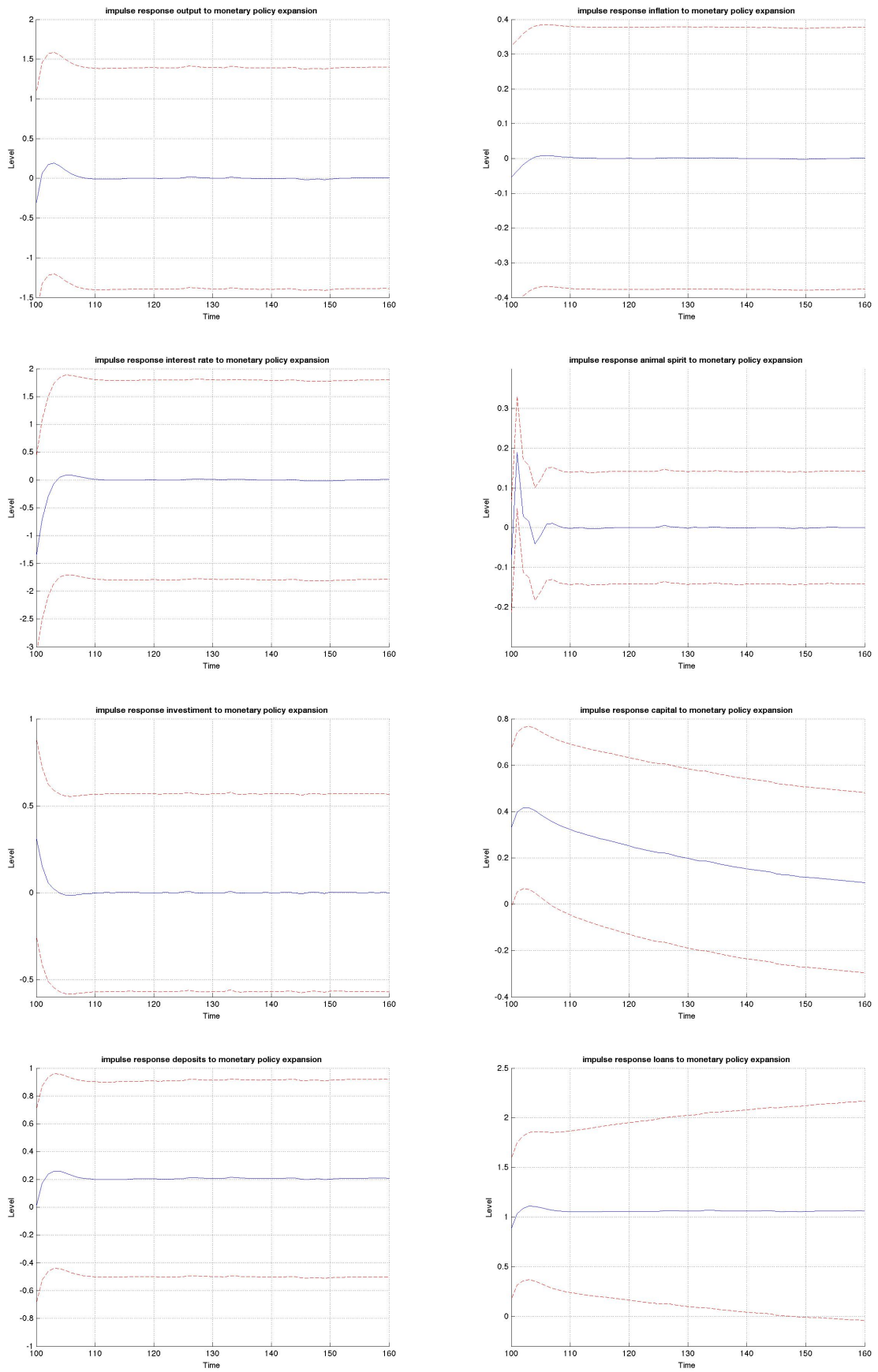


Figure I.1: Full impulse responses to an expansionary monetary policy shock with 95% confidence interval in MBF model

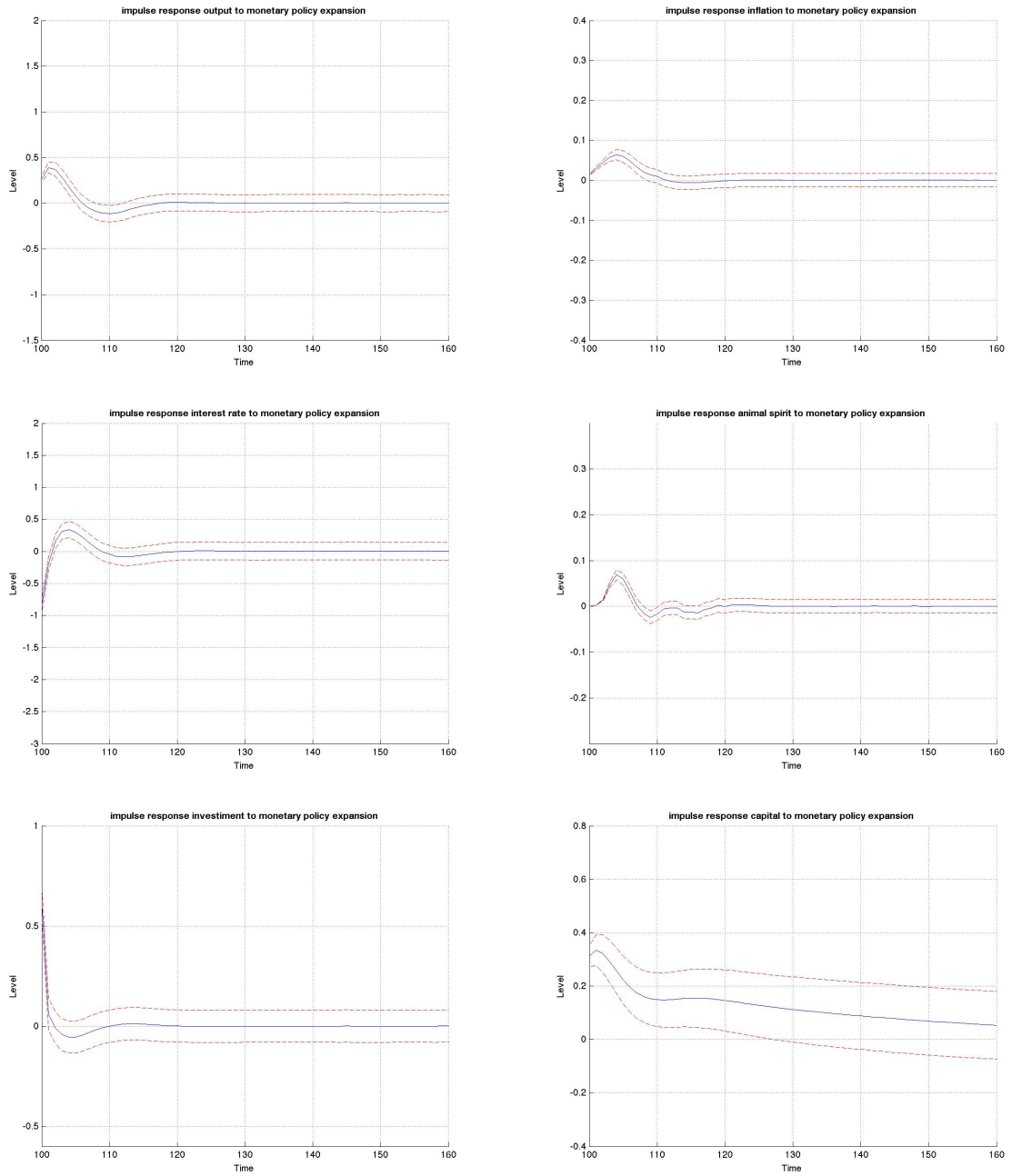


Figure I.2: Full impulse responses to an expansionary monetary policy shock with 95% confidence interval in BBF model

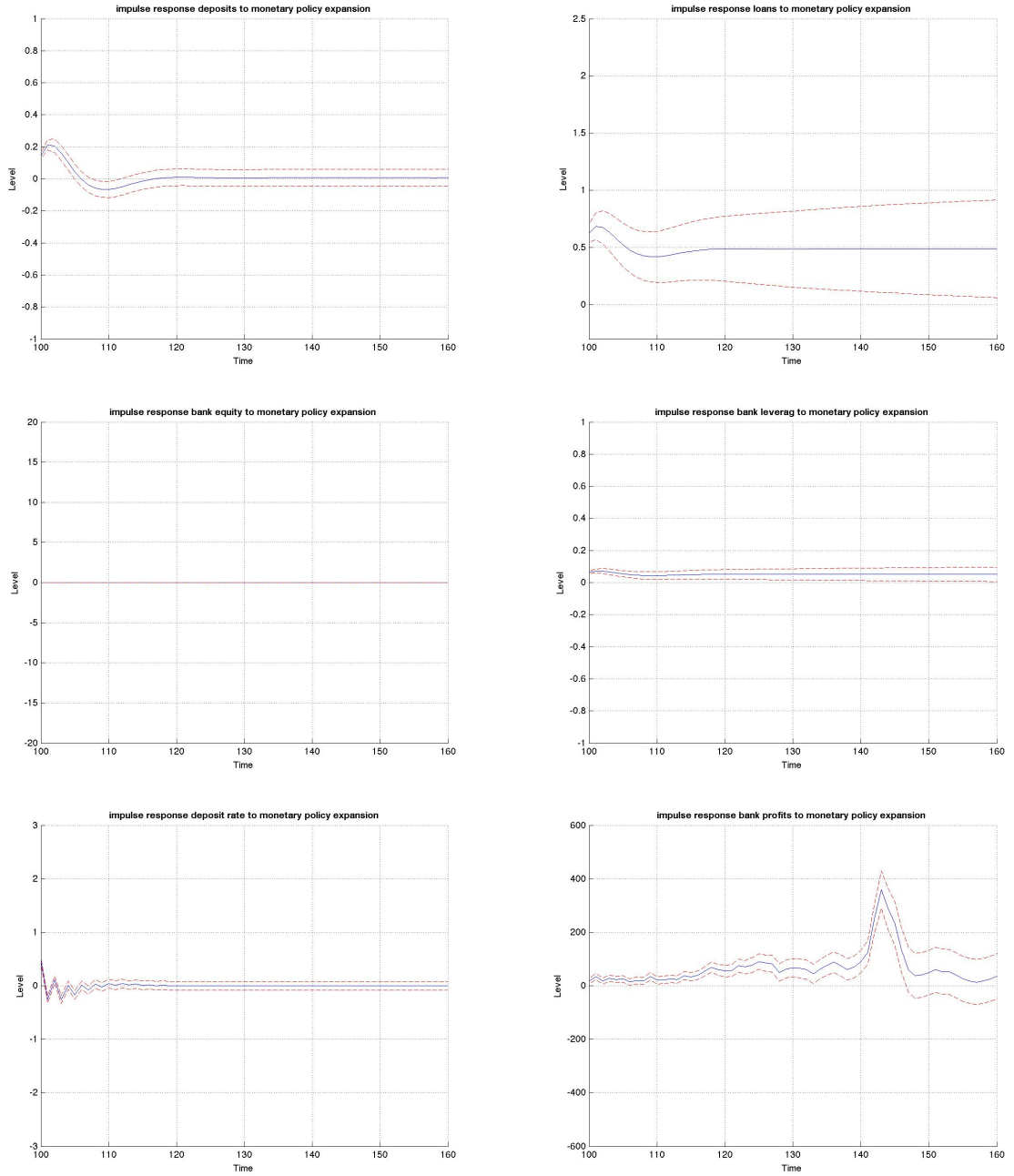


Figure I.3: Full impulse responses to an expansionary monetary policy shock with 95% confidence interval in BBF model 2

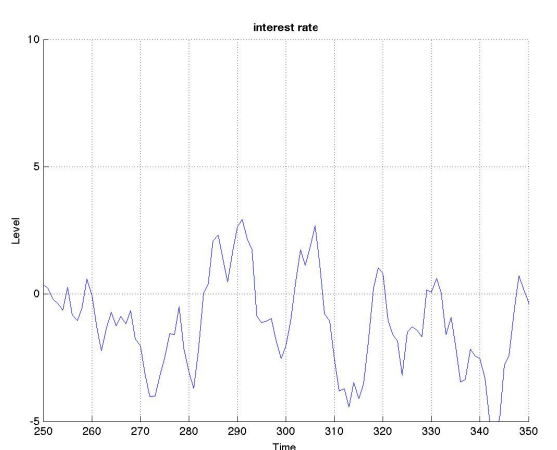
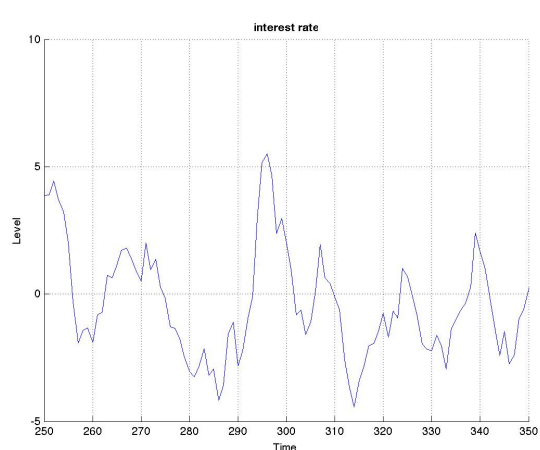
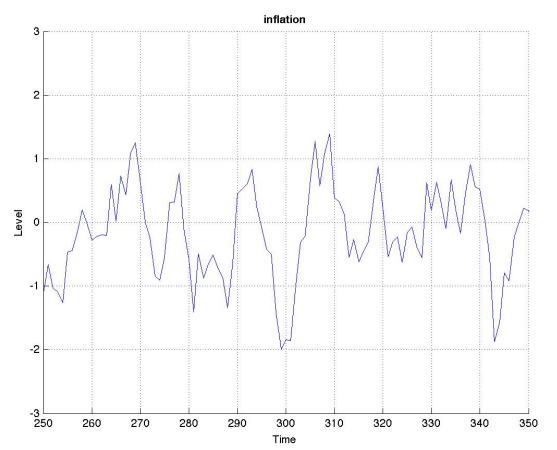
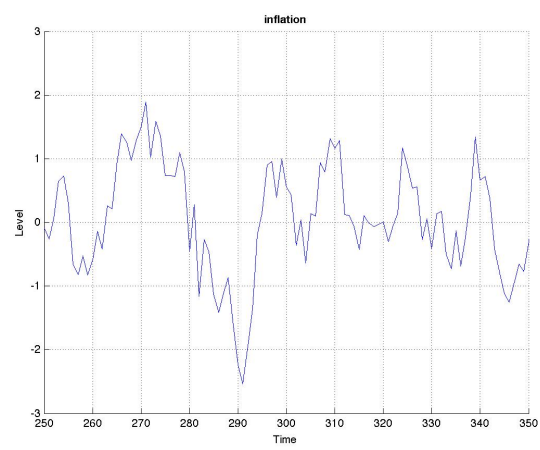
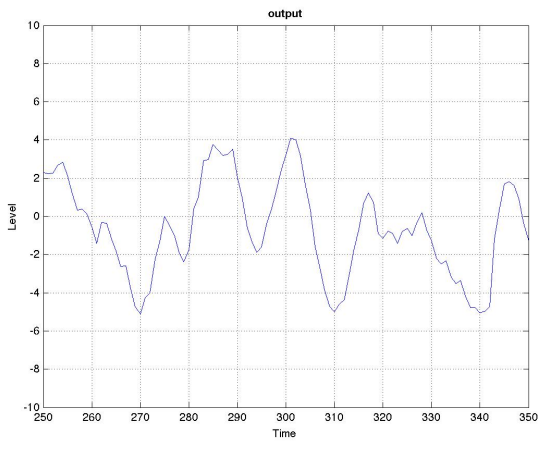
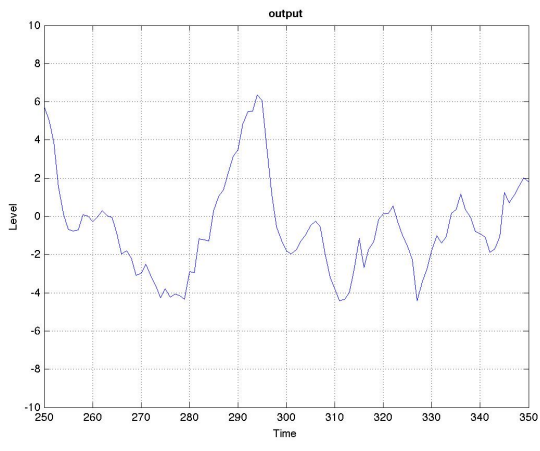


Figure I.4: Evolution of the key aggregate variables MBF vs BBF models

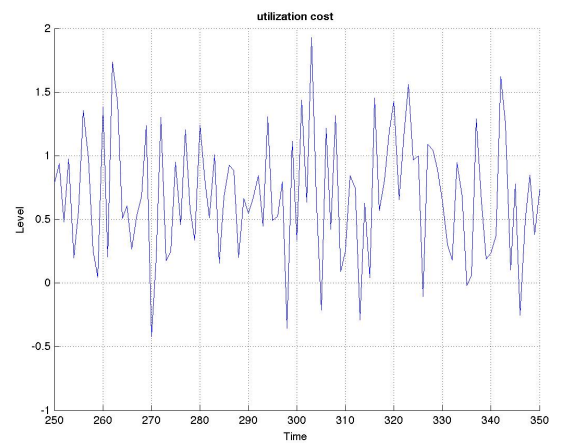
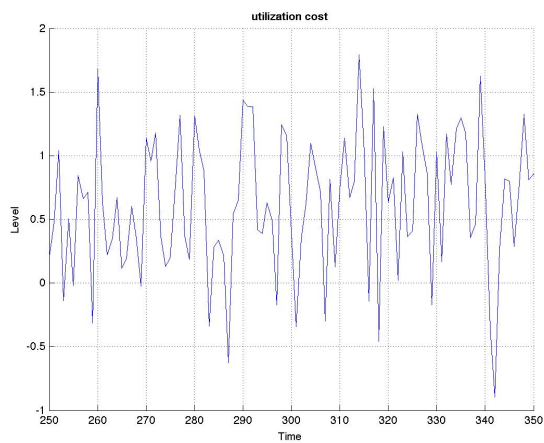
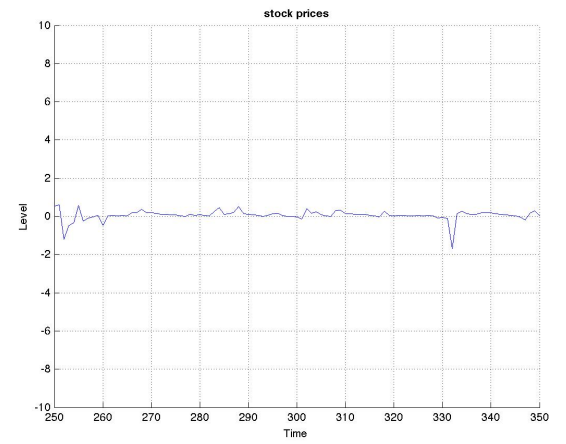
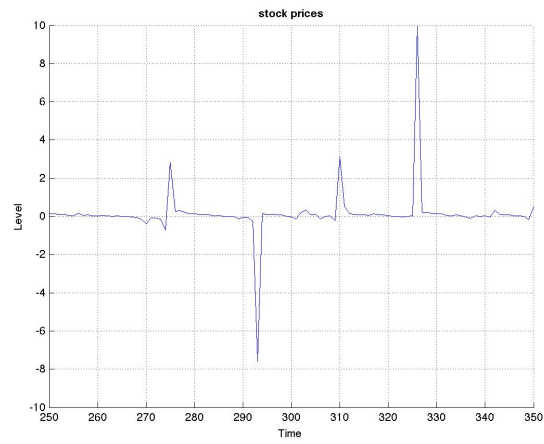
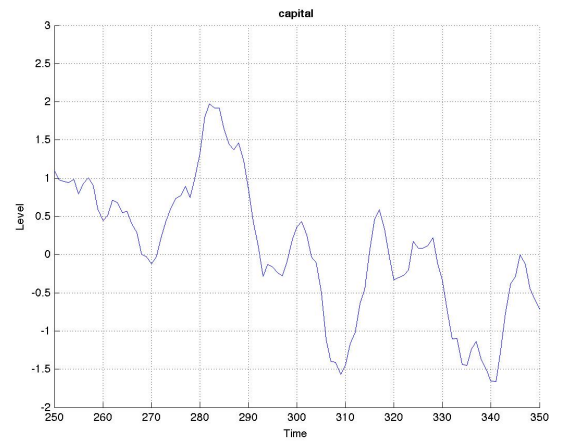
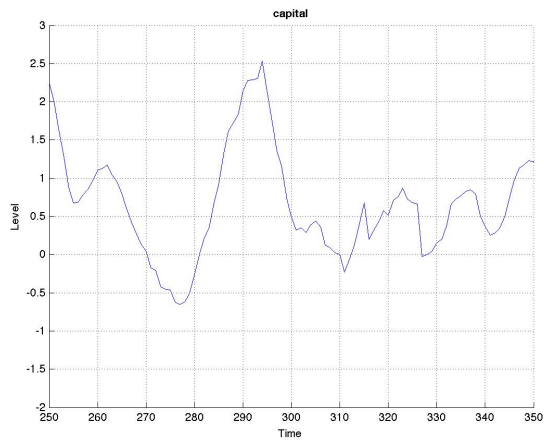


Figure I.5: Evolution of the key aggregate variables MBF vs BBF models 2

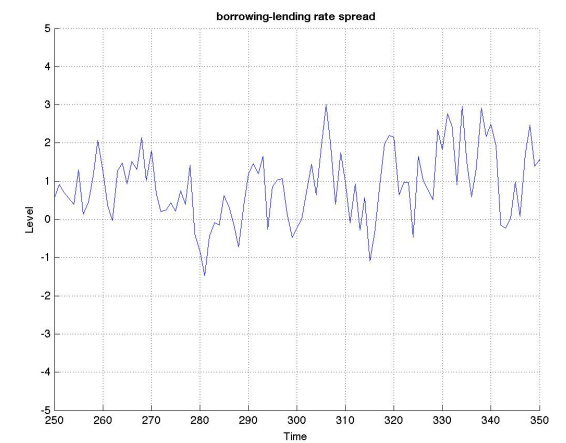
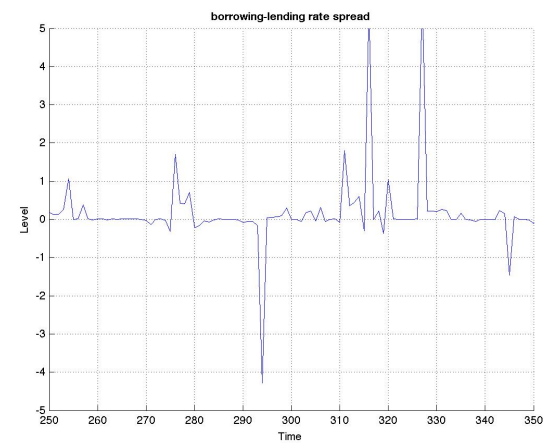
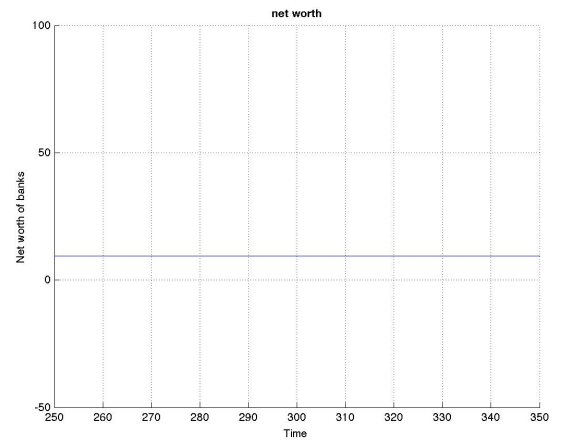
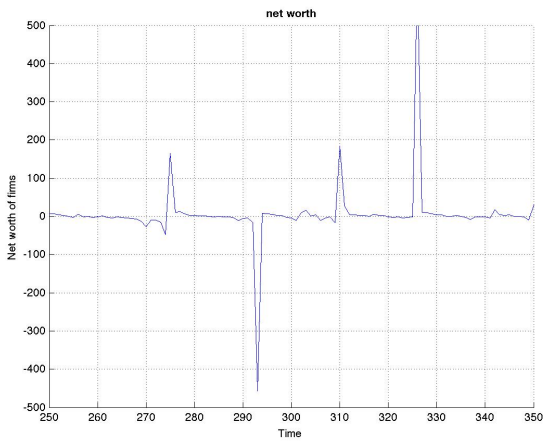
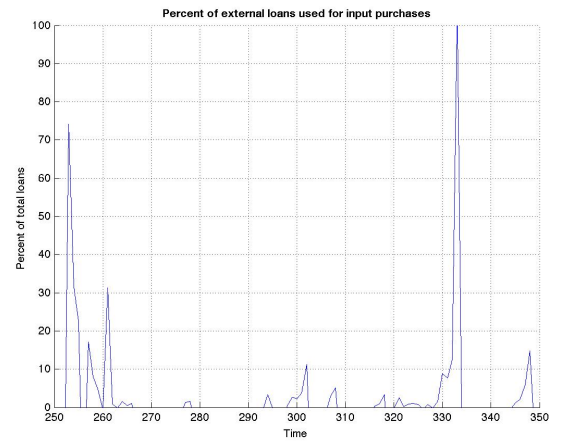
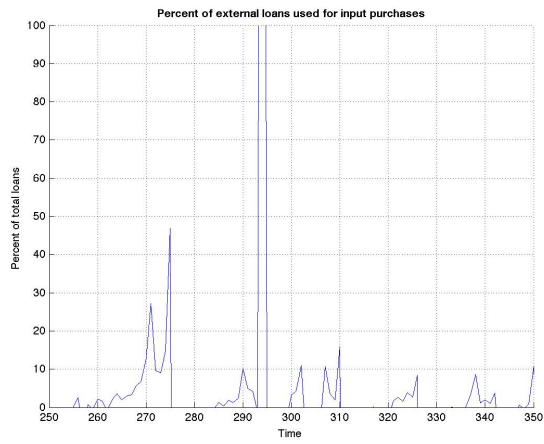


Figure I.6: Evolution of the key aggregate variables MBF vs BBF models 3

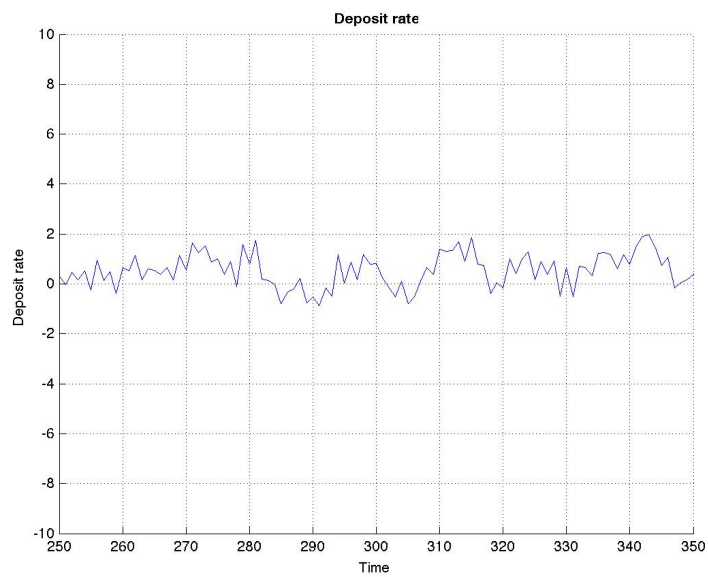
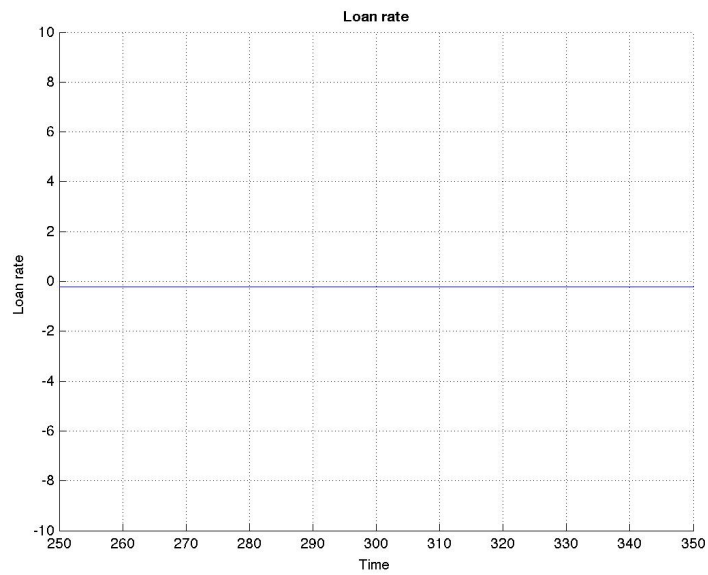
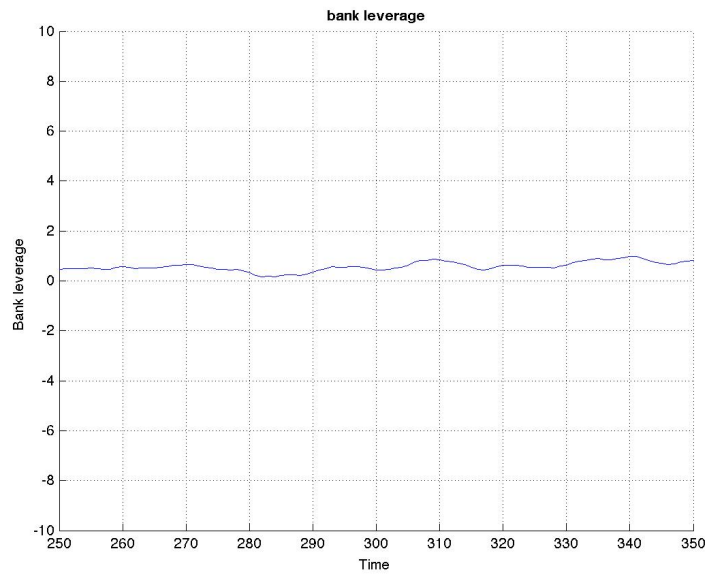


Figure I.7: Evolution of the key financial variables BBF model only

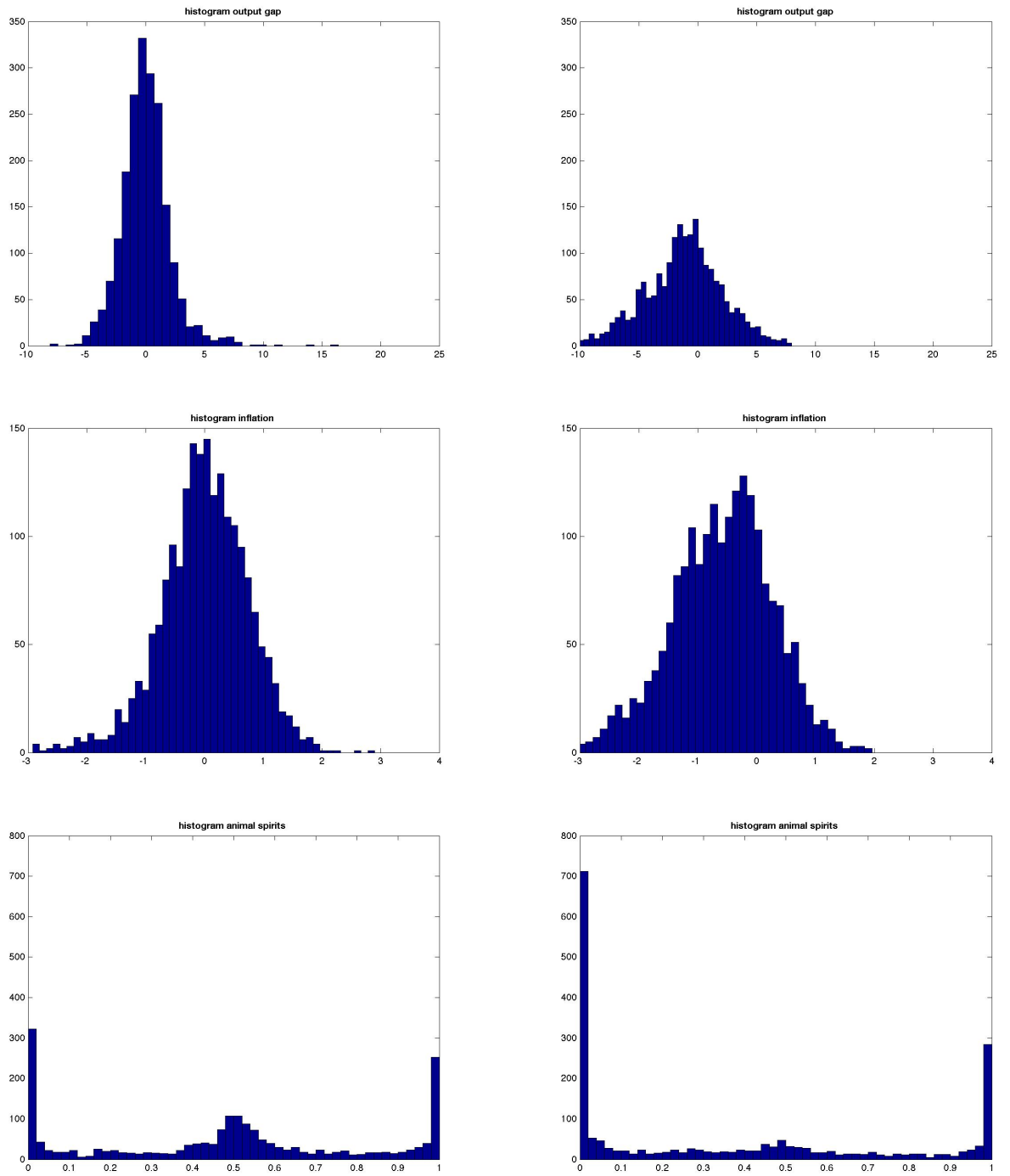


Figure I.8: Histograms MBF vs BBF



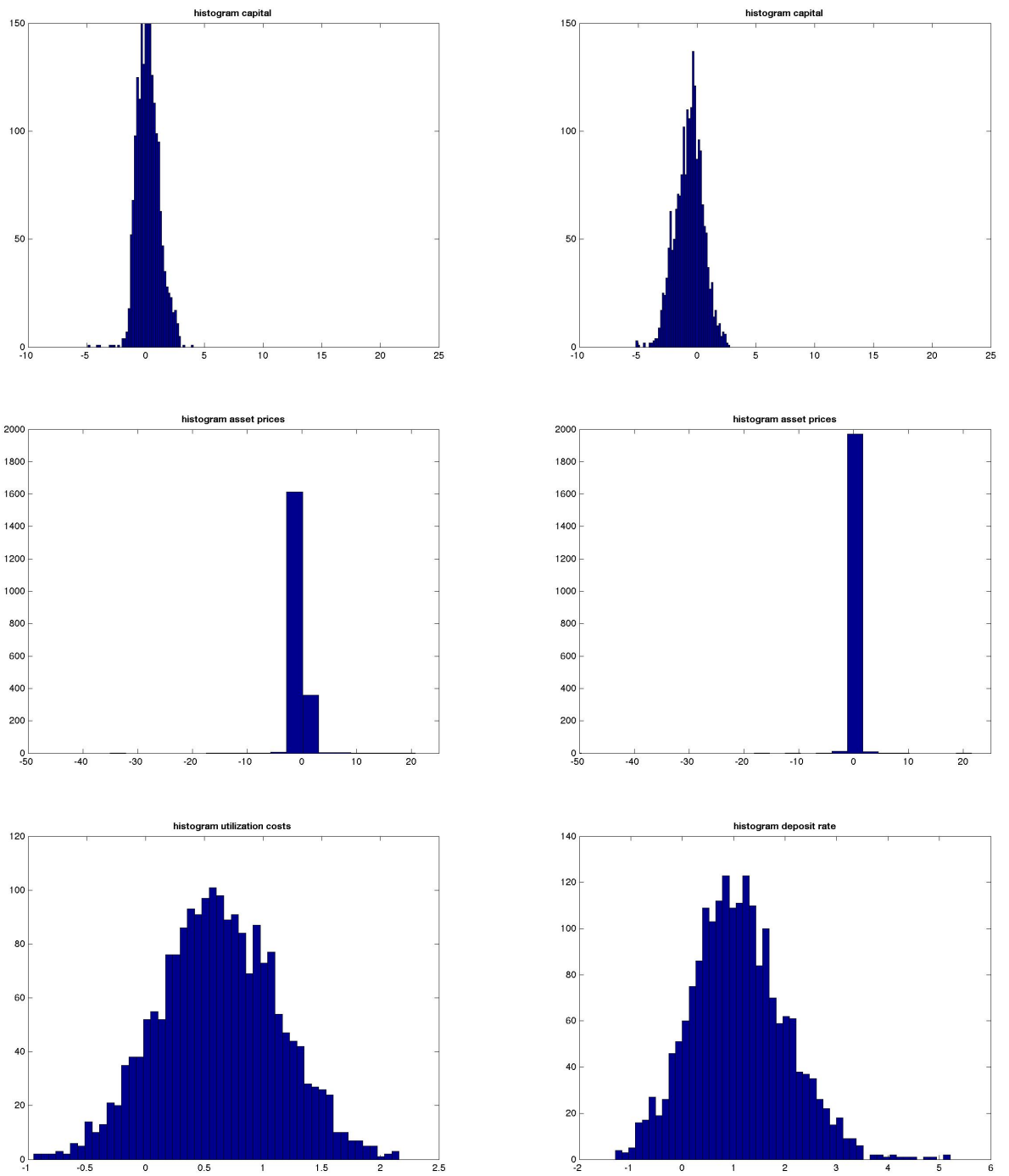


Figure I.9: Histograms MBF vs BBF 2

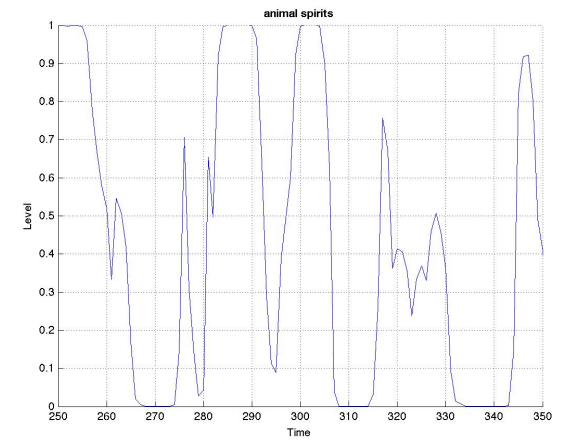
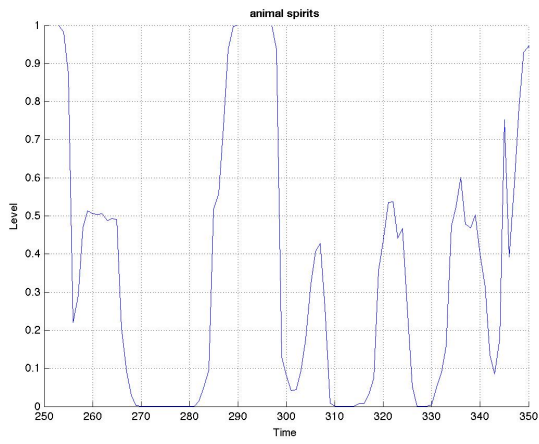
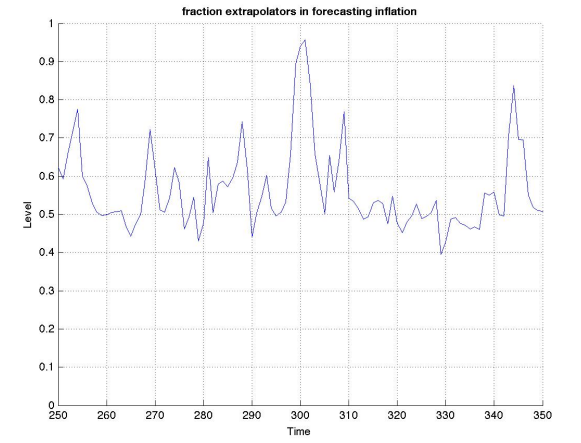
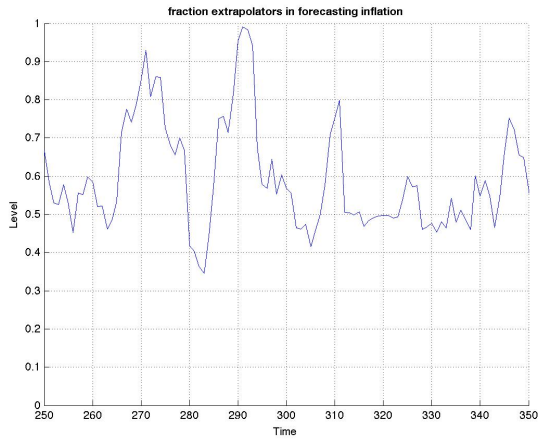
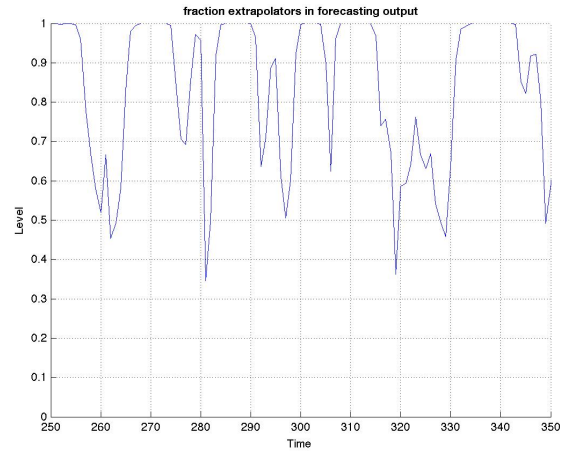
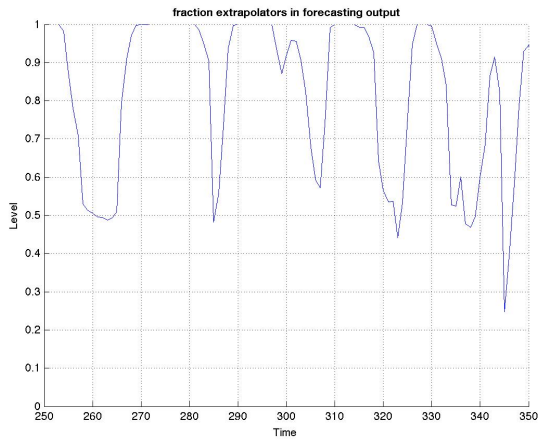


Figure I.10: Agent behaviour and animal spirits