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Monetary transmission under competing corporate finance regimes

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Monetary Transmission Under Competing Corporate Finance Regimes

by: Paul De Grauwe and Eddie Gerba
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Keywords: Monetary policy in the EA, monetary transmissions, banks, financial frictions, market based finance
JEL: E52, E44, E03, G21, G32

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Monetary Transmission Under Competing Corporate Finance Regimes

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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

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

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

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 a monetary expansion are approximately twice that of the MBF version. Moreover,¹

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

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

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

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

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²Calomiris, 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. 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).

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

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

2.1 Market funding structure

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

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

$$eft_t = r_t + x_t$$  \hspace{1cm} (1)

The spread between the two rates depends on firms’ equity:

$$x_t = eft_t - r_t = \psi_m f$$  \hspace{1cm} (2)

Following the collateral constraint approach used in Bernanke, Gertler and Gilchrist (1999), the quantity of funds that firms can access on the market depends on the value of its internal funds, or collateral. Thus, an increase in the value of firms’ equity reduces the spread and vice versa. This spread arises because of asymmetric information regarding the credit risk of borrowers that lenders lack. To compensate for this credit risk, the market charges a spread. When the value of equity of the 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
\textit{ex ante} cost.\textsuperscript{4}

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:

\[
n_t^f = S_t \bar{n}_t \quad ?? \tag{3}
\]

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

\[
S_t = \frac{E_t[\Lambda_{t+1}]}{R_t^s} \quad \tag{4}
\]

where;

\[
R_t^s = r_t + \xi \quad \tag{5}
\]

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.\textsuperscript{5} Since nominal GDP consists of a real and 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

\textsuperscript{4}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 \textit{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.

\textsuperscript{5}Just as in De Grauwe and Gerba (2015) dividends are supposed to be constant from \( t+1 \)
onwards.
switch to another forecasting rule if this performs better than the current rule.

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

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

\[ x_t = \psi_t n_f^t \equiv \psi n_t S_t \]  

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

\[ \tau_t = \frac{L_t}{\bar{n}_t S_t} \]  

This leverage ratio is time-varying, and therefore endogenous to the business cycle. Remember that the more a firms is leveraged, the stronger the amplification effect of asset price movements on firm borrowing capacity. An increase in the value of stock prices increases a firm’s collateral value and reduces its leverage. These two components combined lead to a more than proportional increase in its borrowing capacity. Conversely, when asset prices fall, the reduction in loans is more than proportional. That is why we should expect sharp swings in firm finances over the cycle as is typical of market-based corporate finance regimes such as the US.\(^6\)

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

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

\(^6\)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 $\epsilon^B_t$ and $\epsilon^D_t$ 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:

$$D_t = \pi^B_t n^B_t + B_t$$

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

$$\kappa_t = \frac{\pi^B_t n^B_t}{B_t}$$

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,

\(^7\)The price of stocks is exogenously determined.
which allows us to describe the lending \textit{wholesale} rate as:

\begin{equation}
R_t^B = R_t^D - \kappa^B \frac{n_t^B}{B_t} - \vartheta^B \left[ \frac{n_t^B}{B_t} \right]^2 \tag{10}
\end{equation}

The quadratic cost of deviating from the target has the functional form equal to

\begin{equation}
\kappa^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.
\end{equation}

\(\kappa^B\) is the leverage deviation cost, which is parametrized int his model. Assuming that banks have unlimited access to finance at the policy rate \(r_t\) from a central bank, via arbitrage condition we can rewrite the above expression as:

\begin{equation}
R_t^B - r_t = -\kappa^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 \tag{11}
\end{equation}

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

### 2.2.2 Loan retail branch

It obtains \textit{wholesale loans} \(B_t\) at rate \(R_t^B\), differentiates them and resells them to firms applying a markup. The markup is governed by a quadratic adjustment cost for changing the rate over time, and the adjustment cost in turn depends on the parameter determining the adjustment costs in loan rate setting, \(\kappa^B\). These are proportional to aggregate return on loans. The rate charged on loans can be expressed as:

\begin{equation}
r_t^B = \frac{1}{\epsilon_t^B - 1 + (1 + \beta) \kappa_t^B} \left( \kappa_t^B r_{t-1}^B + (\epsilon_t^B - 1) R_t^B - \epsilon_t^B \right) \tag{12}
\end{equation}

which in absence of inertias can be reduced to:

\begin{equation}
r_t^B = r_t + \frac{\kappa_t^B}{\epsilon_t^B - 1} (R_t^B - r_t) + \frac{1}{\epsilon_t^B - 1} r_t \tag{13}
\end{equation}

This is the external finance premium that firms face. The premium is proportional to the wholesale branch spread, which in turn is determined by the bank’s capital position. The degree of monopolistic competition also matters since an increase in market power (a fall in \(\epsilon_t^B\)) results in a higher premium.

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 $\epsilon_B^t$, as in Dixit and Stieglitz framework.\textsuperscript{8} 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:\textsuperscript{9}

$$b_t(j) = \frac{r_B^t(j)^{-\epsilon_B^t}}{r_B^t} b_t$$  \hspace{1cm} (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 on to the wholesale branch. They remunerate these funds at rate $r_D$. 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:

$$r_D^t = \frac{\epsilon_D^t}{\epsilon_D^t - 1} r_D - \frac{1}{\epsilon_D^t - 1} (\kappa_D r_D^t - \epsilon_D^t)$$  \hspace{1cm} (15)

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

$$r_D^t = \frac{\epsilon_D^t}{\epsilon_D^t - 1} r_t$$  \hspace{1cm} (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 by a branch of a bank $j$.

\textsuperscript{8}The loan elasticity $\epsilon_B^t$ is assumed to be above 1.

\textsuperscript{9}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 $j$, $\int_0^1 r_B^t(j)b_t(i,j)\text{dj}$, subject to $[\int_0^1 b_t(i,j)(\epsilon_B^t - 1)/\epsilon_B^t)\text{dj}]^{\epsilon_B^t}/(\epsilon_B^t - 1) \geq b_t(i)$. $(\epsilon_B^t - 1)/\epsilon_B^t$ 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, straightforward.
by a branch of a bank $j$ - and with elasticity $\epsilon_D^t$. The elasticity is stochastic and exogenously determined. Once again, these innovations to elasticity can be seen as alterations independent from the monetary policy. Assuming symmetry amongst savers, their aggregate demand for deposits at bank $j$ can by analogy to the above case be expressed as:

$$d_t(j) = \frac{r_t^D(j)^{-\epsilon_D}}{r_t^D} d_t$$ \hspace{1cm} (17)

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

2.2.4 Bank finances

Now that we have described the operations of each of the branches, we are in a position to describe the finances of the aggregate bank unit. Overall bank profits ($p_B^t$) are the sum of net earnings from the two retail ($r_t^B b_t - r_t^D d_t$) and one wholesale branch ($\kappa^B \left[ \pi_t^B n_t^B - \vartheta^B \right]^{\pi^B} n_t^B - Adj^B$):

$$p_t^B = r_t^B b_t - r_t^D d_t - \frac{\kappa^B}{2} \left[ \pi_t^B n_t^B - \vartheta^B \right]^{\pi^B} n_t^B - Adj^B$$ \hspace{1cm} (18)

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

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

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

\textsuperscript{10}The deposit elasticity $\epsilon_D^t$ is assumed to be below -1.

\textsuperscript{11}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 $j$, $\int_0^1 r_t^P(j)d_t(i,j)uj$, subject to $[\int_0^1 d_t(i,j)(\epsilon^P(i,j)-1)/(\epsilon^P(i,j))^{\epsilon^P(i,j)-1} \leq d_t(i)]$. $(\epsilon^P(i,j)-1)/(\epsilon^P(i,j))$ 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:

\[ y_t = a_1 \tilde{E}_t y_{t+1} + (1-a_1)y_{t-1} + a_2' a_3' (r_t - \tilde{E}_t \pi_{t+1}) + a_4' R^B_t + (a_1 - a_2)\psi(u_t)k_t + Adj_t + \epsilon_t \]

(21)

where \( a_2' = \frac{\epsilon^B (d_3 + e_2)}{1 - d_1} \), \( a_3' = \frac{1}{\epsilon^B (1 + (1 + \beta)\pi^R)} \) 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:

\[ y_t = a_1 \tilde{E}_t y_{t+1} + (1-a_1)y_{t-1} + a_2' a_3' (r_t - \tilde{E}_t \pi_{t+1}) + a_4' R^B_t + (a_1 - a_2)\psi(u_t)k_t + \delta^B \pi^B_{t-1} n^B_{t-1} + Adj_t + \epsilon_t \]

(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...
discrimination problem of retailers (monopolistically competitive):

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

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

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

### 2.4 Expectations formation and learning

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

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

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

and the extrapolists in both cases as:

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

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

\textsuperscript{12}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 publicly available goodness-of-fit measure, the mean square forecasting error (MSFE). After the time ‘t’ realization is revealed, the two predictors are evaluated \textit{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:

\[
\tilde{E}_t \pi_{t+1} = \alpha^f_t \tilde{E}^f_t \pi_{t+1} + \alpha^e_t \tilde{E}^e_t \pi_{t+1}
\]  \hspace{1cm} (28)

\[
\tilde{E}_t y_{t+1} = \alpha^f_t \tilde{E}^f_t y_{t+1} + \alpha^e_t \tilde{E}^e_t y_{t+1}
\]  \hspace{1cm} (29)

where $\alpha^f_t$ is the weighted average of fundamentalists, and $\alpha^e_t$ that of the extrapolists. These shares are time-varying and based on the dynamic predictor se-
lection. The mechanism allows to switch between the two forecasting rules based on MSFE / utility of the two rules, and increase (decrease) the weight of one rule over the other at each $t$. Assuming that the utilities of the two alternative rules have a deterministic and a random component (with a log-normal distribution as in Manski and McFadden (1981) or Anderson et al (1992)), the two weights can be defined based on each period utility for each forecast $U_{i,t}^x$, $i = (y, \pi)$, $x = (f, e)$ according to:

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

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

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

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

, where the utilities are defined as:

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

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

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

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

and $w_k = (\rho^k(1-\rho))$ (with $0 < \rho < 1$) are geometrically declining weights adapted to include the degree of forgetfulness in the model (DeGrauwe, 2012). $\gamma$ is a parameter measuring the extent to which the deterministic component of utility determines actual choice. A value of 0 implies a perfectly stochastic utility. In that case, agents decide to be one type or the other simply by tossing a coin, implying a probability of each type equalizing to 0.5. On the other hand, $\gamma = \infty$ implies 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: \( \gamma = 0 \) imples 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 \( n^b \) is set to 1, which is sufficiently low in order to allow banks to operate in the initial period.
The parameters that were estimated in Gerali et al (2010) have been set in accordance to the results from their posterior distributions. In this way, the adjustment costs in leverage deviation, firms’ rate, and household rate (or \( \kappa_{nb}, \kappa_{b}, \) and \( \kappa_{d} \)) were calibrated to 11.07, 13 and 3.50 that is well within the 95% interval of the posterior. Moreover, those costs correctly reflect the varying costs that banks face in managing bank equity, producing loans and offering deposits.

All shocks, except to the capital utilization, are parametrized as white noise which means that their autoregressive component is set to 0. Likewise the standard deviations of shocks are set to 0.5 across the entire spectrum.\(^{13}\)

### 2.5.2 Model solution

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

\[
\begin{bmatrix}
1 & -b_2 & 0 & 0 & 0 \\
-a_2 c_1 & 1 - a_2 c_2 & -(a_2 + a_3) & 0 & (a_1 - a_2) \psi(u_t) \\
-\psi \tau^{-1} e_2 c_1 & -\psi \tau^{-1} e_2 c_1 & (1 - \psi \tau^{-1} e_2) & 0 & 0 \\
d_3 c_1 & -(1 - d_1 - d_3 c_2) & 0 & 1 & 0 \\
0 & 0 & e_2 & 0 & 1 \\
\end{bmatrix}
\begin{bmatrix}
\pi_t \\
y_t \\
x_t \\
s_t \\
k_t \\
\end{bmatrix}
= \begin{bmatrix}
b_1 & 0 & 0 & 0 & -e_2 \\
-a_2 & 1 - a_1 & 0 & 0 & \Psi(\frac{u_{t-1}}{u_t}) e_1 \\
-\psi \tau^{-1} e_2 & -\psi \tau^{-1} e_2 & 0 & 0 & 0 \\
d_3 & -d_2 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 \\
\end{bmatrix}
\begin{bmatrix}
\tilde{E}_t[\pi_{t+1}] \\
\tilde{E}_t[y_{t+1}] \\
\tilde{E}_t[x_{t+1}] \\
\tilde{E}_t[s_{t+1}] \\
\tilde{E}_t[k_{t+1}] \\
\end{bmatrix}
\]

\(^{13}\)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.
In the BBF version, the system of equations for the five variables looks instead like:

\[
\begin{bmatrix}
1 - b_2 & 0 & 0 & 0 & 0 \\
0 & 1 - a'_1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 \\
0 & -(1 - d_1 - d_2) & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & (1 - \delta \psi(u_t))
\end{bmatrix}
\begin{bmatrix}
\pi_{t-1} \\
y_{t-1} \\
x_{t-1} \\
s_{t-1} \\
k_{t-1}
\end{bmatrix}
+ \begin{bmatrix}
0 & 0 & 0 & 0 & 0 \\
a_2c_3 & 0 & 0 & 0 & 0 \\
-\psi^{-1}e_2c_3 & \psi^{-1} & \psi^{-1} & 0 & 0 \\
d_2c_3 & 0 & 0 & 0 & 0 \\
e_2 & 0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 \\
r_{t-1} & 0 & a_2 & 0 & 1 \\
(1 - d_1) & 0 & -d_3 & 0 & 0 \\
(1 - d_1) & 0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
\eta_t \\
y_t \\
x_t \\
s_t \\
k_t
\end{bmatrix}
\]

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

\[
= \begin{bmatrix}
b_1 & 0 & 0 & 0 & -e_2 \\
-a_2 & 1 - a_1 & 0 & 0 & \Psi(\frac{\pi}{\pi_{t-1}})e_1 \\
-d_3 & -d_2 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\tilde{E}_t[\pi_{t+1}] \\
\tilde{E}_t[y_{t+1}] \\
\tilde{E}_t[x_{t+1}] \\
\tilde{E}_t[s_{t+1}] \\
\tilde{E}_t[k_{t+1}]
\end{bmatrix}
+ \begin{bmatrix}
1 - b_2 & 0 & 0 & 0 & 0 \\
0 & 1 - a'_1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 \\
0 & -(1 - d_1 - d_2) & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & (1 - \delta)
\end{bmatrix}
\begin{bmatrix}
\pi_{t-1} \\
y_{t-1} \\
x_{t-1} \\
s_{t-1} \\
k_{t-1}
\end{bmatrix}
\]
Using matrix notation, we can write this as:

\[ A\mathbf{Z}_t = B\tilde{\mathbf{E}}_t\mathbf{Z}_{t+1} + C\mathbf{Z}_{t-1} + D\mathbf{X}_{t-1} + Ev_t. \]

We can solve for \( \mathbf{Z}_t \) by inverting:

\[ \mathbf{Z}_t = A^{-1}(B\tilde{\mathbf{E}}_t\mathbf{Z}_{t+1} + C\mathbf{Z}_{t-1} + D\mathbf{X}_{t-1} + Ev_t) \]

and assuring \( A \) to be non-singular.

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).

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.\(^{14}\)

Expectation terms with a tilde \( \tilde{E}_t \) 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).

\(^{14}\)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 ($\epsilon$):\(^{15}\)

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

(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.\(^{16}\)

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

\(^{15}\)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).

\(^{16}\)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.
to the same shock in the BBF version. Note that the size of the shock as well as the 
scale of the figures is kept the same in both versions. The numbers on the x-axis 
indicate number of quarters. The shock is introduced in $t=100$ and we observe the 
responses over a long period of 60 quarters (or 15 years). The figures depict the full 
impulse responses with the 95% confidence intervals. The blue line represents the 
median impulse response, and the red lines are the 95% interval.

### 3.1.1 Market-based-financing version

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

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

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

### 3.1.2 Bank-based-financing version

In the BBF version, the effects from a monetary policy expansion are approximately 
twice as strong as in the previous version. On the real side, Investment rises by 0.7%, 
capital by 0.4%, output by 0.4% and inflation by 0.08%. On the banking side, the 
expansion is even stronger. Deposit rate goes up by 0.5%, attracting more deposits
(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 marked-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.\(^{18}\)

Second and turning to the relative matching of the statistical moments in the
data, the volatilities of financial variables such as \(d_t, r_t, r^d_t, n^b_t, n^f_t, d_t\) 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 \((l^s_t, x_t)\) 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 correla-
tions 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 \(\psi(u_t), \vartheta, x_t, n^b_t, n^f_t\) 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

\(^{18}\)See also the histograms in Figures I.8 and I.9.
are \( k_t \) (going from a correlation with the business cycle of 0.45 to 0.78), \( d_t \) (from 0.17 to 0.70), \( r_t \) (from 0.39 to 0.53), \( l_t^* \) (from 0.11 to 0.16), or \( x_t \) (from -0.41 to -0.46). All this points towards a stronger inter-relation between most (endogenous) model variables and a more potent underlying (macroeconomic) mechanism in the bank-based version.

3.3 Monetary transmission in crises: US vs EU

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

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

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

On the other hand, the amplitude (or swings) of the cycles are more modest in the BBF version. If one interprets the aim of monetary policy as a tool to prevent heavy cyclical swings, that task is more effectively achieved in the latter version. This means that the monetary policy is more responsive to downturns, which prevents the economy from reaching severe and costly troughs. Therefore, if one evaluates the policy from that angle, the monetary transmission during recessions seems to 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.\(^\text{19}\)

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

\(^{19}\)See the histogram of animal spirits in figure I.8.
a monetary expansion are approximately twice that of the MBF version. Moreover, 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 the latter version. This results in a better empirical fit of the Euro Area model to the data.

Lastly, we (discriminatorately) 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.

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

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

Lastly, we calibrate our parameters in the model. An interesting exercise would be to estimate the parameters of the model in order to get a more accurate representation of the business cycles.
References


Appendices

I Equations, Tables and Figures

I.1 Equations in the MBF and BBF models

Aggregate Demand:

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

Investment

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

External Finance Premium

\[ efp_t = \phi \tilde{n}_t S_t \]
(I.3)

Consumption

\[ c_t = 1 - s_t \]
(I.4)

Aggregate Supply:

Cobb-Douglas Production Function

\[ y_t = a_t (k_t \psi(u_t))^{\alpha} h_t^{1-\alpha} \]
(I.5)

Utilization cost function

\[ \psi(u_t) = \xi_0 + \xi_1 (u_t - 1) + \frac{\xi_2}{2} (u_t - 1)^2 \]
(I.6)
Approximated Philips Curve:

\[ \pi_t = b_1 \hat{E}_t \pi_{t+1} + (1 - b_1) \pi_{t-1} + b_2 y_t + \nu_t \]  
(I.7)

Capital evolution

\[ k_t = (1 - \delta) \psi(u_t) k_{t-1} + \Psi \nu_t \]  
(I.8)

Cash-in-advance constraint

\[ \vartheta_t = S_{t+1} k_{t+1} - n^f_t \]  
(I.9)

Labour market

\[ y_t = \frac{l_t w_t}{1 - \alpha} \]  
(I.10)

Monetary policy

\[ r^n_t = \rho r^n_{t-1} + \zeta \pi_t + \gamma_y y_t + \sigma_r \]  
(I.11)

Financial market:

Bank net worth

\[ n^b_t = \kappa (l^* + \bar{n} S_t) \]  
(I.12)

Evolution of bank leverage

\[ \tau_t = \tau_{t-1} + \frac{l^d_t}{n^d_t} \]  
(I.13)

Stock market price

\[ S_t = \frac{E_t[\Lambda_{t+1}^-]}{R^s_t} = \frac{\hat{E}_t y_{t+1} - \hat{E}_t \pi_{t+1}}{R^s_t} \]  
(I.14)

Firm net worth

\[ n^f_t = S_t \bar{n}_t = \frac{1}{\tau} (L^D_{t-1} + e_1 \hat{E}_t y_{t+1} + e_2 (r_t + e f p_t - \hat{E}_t \pi_{t+1})) \]  
(I.15)
Deposits
\[ d_t = d_{t-1} + s_t \]  
(I.16)

Loan demand
\[ l_t^d = l_{t-1}^d + i_t \]  
(I.17)

Credit market equilibrium
\[ l_t^d = l_t^s \]  
(I.18)

Bank-based financing system:
\[ r_b^t = \frac{\kappa^b r_b^t + (\epsilon^b - 1)R_b^t - \epsilon^b}{\epsilon^b - 1 + (1 + \beta)\kappa^b} \]  
(I.19)
\[ r_d^t = \frac{\kappa^d r_d^t - (\epsilon^d - 1)R_d^t + \epsilon^d}{-\epsilon^d + 1 - (1 + \beta)\kappa^d} \]  
(I.20)
\[ x_t \equiv r_b^t - r_d^t = r_b^t - r_t \]  
(I.21)
\[ R_b^t = r_t - \kappa^{nb} \left[ \frac{n_t^b}{l_t^s} - \zeta \left[ \frac{n_t^b}{l_t^s} \right]^2 \right] \]  
(I.22)
\[ s_t = \zeta - \left[ \frac{l_t^s}{n_b^t} \right] \]  
(I.23)
\[ pib_t = r_b^t l_t^s - r_d^d d_t - \frac{\kappa^{nb}}{2} \left[ \frac{n_t^b}{l_t^s} - \zeta \right]^2 n_t^b - adj_t \]  
(I.24)
\[ n_t^b = \bar{n}^b + (1 - \delta^b)n_{t-1}^b + pib_t \]  
(I.25)

Learning environment:

Inflation learning
\[ \tilde{E}_t \pi_{t+1} = \alpha_t^f \tilde{E}_t^f \pi_{t+1} + \alpha_t^e \tilde{E}_t^e \pi_{t+1} \]  
(I.26)

Output learning
\[ \tilde{E}_t y_{t+1} = \alpha_t^f \tilde{E}_t^f y_{t+1} + \alpha_t^e \tilde{E}_t^e y_{t+1} \]  
(I.27)

Learning rules:
\[ \tilde{E}_t^f \pi_{t+1} = \pi^* \]  
(I.28)
\[ \tilde{E}_t^f y_{t+1} = y^* \] (I.29)

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

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

**Weights**

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

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

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

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

**Utilities:**

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

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

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

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

**Shocks**

Monetary policy shock:

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

1.2 Tables and Figures

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi^*$</td>
<td>The central bank’s inflation target</td>
<td>0</td>
</tr>
<tr>
<td>$d_1$</td>
<td>Marginal propensity of consumption out of income</td>
<td>0.5</td>
</tr>
<tr>
<td>$e_1$</td>
<td>Coefficient on expected output in investment eq.</td>
<td>0.1</td>
</tr>
<tr>
<td>$d_2$</td>
<td>Coefficient on expected output in consumption eq. to match $a_1 = 0.5$</td>
<td>$0.5 \times (1 - d_1) - e_2$</td>
</tr>
<tr>
<td>$d_3$</td>
<td>Coefficient on real rate in consumption eq.</td>
<td>$-0.01$</td>
</tr>
<tr>
<td>$\epsilon_2$</td>
<td>Coefficient on real rate in investment eq. to match $a_2 = -0.5$</td>
<td>$(-0.5) \times (1 - d_1) - d_3$</td>
</tr>
<tr>
<td>$a_1$</td>
<td>Coefficient of expected output in output eq.</td>
<td>$\frac{e_1 + d_2}{(1 - d_1)}$</td>
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<tr>
<td>$a_2$</td>
<td>Coefficient of lagged output in output eq.</td>
<td>$d_2/(1 - d_1)$</td>
</tr>
<tr>
<td>$a_2$</td>
<td>Interest rate elasticity of output demand</td>
<td>$\frac{d_3 + e_2}{(1 - d_1)}$</td>
</tr>
<tr>
<td>$a_3$</td>
<td>Coefficient on spread term in output eq.</td>
<td>$-d_3/(1 - d_1)$</td>
</tr>
<tr>
<td>$b_1$</td>
<td>Coefficient of expected inflation in inflation eq.</td>
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</tr>
<tr>
<td>$b_2$</td>
<td>Coefficient of output in inflation eq.</td>
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<tr>
<td>$c_1$</td>
<td>Coefficient of inflation in Taylor rule eq.</td>
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<td>$\psi$</td>
<td>Parameter of firm equity</td>
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<tr>
<td>$\tau$</td>
<td>Firms’ leverage</td>
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<tr>
<td>$\alpha^d$</td>
<td>Fraction of nominal GDP forecast in expected future dividends</td>
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<tr>
<td>$\beta$</td>
<td>Bubble convergence parameter</td>
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<tr>
<td>$c_2$</td>
<td>Coefficient of output in Taylor equation</td>
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<tr>
<td>$c_3$</td>
<td>Interest smoothing parameter in Taylor equation</td>
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<td>$\delta$</td>
<td>Depreciation rate of capital</td>
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<tr>
<td>$\alpha$</td>
<td>Share of capital in production</td>
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<td>$\Psi$</td>
<td>Adjustment cost function in investment</td>
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<tr>
<td>$\gamma$</td>
<td>Switching parameter in Brock-Hommes (or intensity of choice parameter)</td>
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<td>$\rho$</td>
<td>Speed of declining weights in memory (mean square errors)</td>
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<tr>
<td>$z$</td>
<td>Technological development parameter</td>
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<td>$\xi$</td>
<td>Parameter 1 in the utilization cost function</td>
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<td>$\xi_1$</td>
<td>Parameter 2 in the utilization cost function</td>
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<td>Parameter 3 in the utilization cost function</td>
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<td>$\epsilon_{b}$</td>
<td>Std. deviation of nom. Interest rate shock</td>
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<td>AR process of shock to utilization cost function</td>
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**Parameters specific to the MBF model**

<table>
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<tr>
<th>Parameter</th>
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<tr>
<td>$\bar{n}$</td>
<td>Number of shares in banks’ balance sheets</td>
</tr>
<tr>
<td>$\tilde{n}$</td>
<td>Initial value for number of firms’ shares</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Banks’ inverse leverage ratio</td>
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<td>$e$</td>
<td>Equity premium</td>
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**Parameters specific to the BBF model**

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<td>$\delta^b$</td>
<td>Depreciation rate of bank capital</td>
</tr>
<tr>
<td>$\kappa^{lb}$</td>
<td>Leverage deviation cost</td>
</tr>
<tr>
<td>$\kappa^b$</td>
<td>Adjustment costs in loan rate setting</td>
</tr>
<tr>
<td>$\kappa^d$</td>
<td>Adjustment costs in deposit rate setting</td>
</tr>
<tr>
<td>$\varsigma$</td>
<td>Banks’ capital-to-asset ratio</td>
</tr>
<tr>
<td>$\text{adj}^b$</td>
<td>Other adjustment costs</td>
</tr>
<tr>
<td>$\epsilon^b$</td>
<td>Bank’s market power in loan rate setting</td>
</tr>
<tr>
<td>$\epsilon^d$</td>
<td>Bank’s market power in deposit rate setting</td>
</tr>
<tr>
<td>$\beta^b$</td>
<td>Intertemporal discount rate</td>
</tr>
<tr>
<td>$\tilde{n}^b$</td>
<td>Initial (period t=0) bank capital</td>
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## Table I.2: Model correlations - comparisons

<table>
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<tr>
<th>Correlations</th>
<th>MBF behavioural model</th>
<th>BBF behavioural model</th>
<th>US data</th>
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<tbody>
<tr>
<td>$\rho(y_t, y_{t-1})$</td>
<td>0.86</td>
<td>0.89</td>
<td>0.85</td>
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<td>$\rho(y_t, k_t)$</td>
<td>0.45</td>
<td>0.78</td>
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<td>$\rho(y_t, \pi_t)$</td>
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<td>-0.40</td>
<td>-0.43</td>
</tr>
<tr>
<td>$\rho(y_t, a_{si})$</td>
<td>0.84</td>
<td>0.83</td>
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<tr>
<td>$\rho(y_t, \psi(u_t))$</td>
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<td>-0.58</td>
<td>-</td>
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<td>0.70</td>
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<tr>
<td>$\rho(y_t, l_t^b)$</td>
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<td>0.16</td>
<td>0.18</td>
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<tr>
<td>$\rho(y_t, r_t)$</td>
<td>0.39</td>
<td>0.53</td>
<td>0.45</td>
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<tr>
<td>$\rho(y_t, i_t)$</td>
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<td>0.26</td>
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<td>$\rho(y_t, c_t)$</td>
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<td>$\rho(y_t, s_t)$</td>
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<td>$\rho(y_t, x_t)$</td>
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<td>$\rho(y_t, \vartheta_t)$</td>
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<td>0.03</td>
<td>-</td>
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<tr>
<td>$\rho(k_t, k_{t-1})$</td>
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<tr>
<td>$\rho(k_t, a_{si})$</td>
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<td>0.63</td>
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</tr>
<tr>
<td>$\rho(k_t, \vartheta_t)$</td>
<td>0.02</td>
<td>0.02</td>
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</tr>
<tr>
<td>$\rho(k_t, r_t)$</td>
<td>0.08</td>
<td>0.54</td>
<td>0.31</td>
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<tr>
<td>$\rho(l_t^b, a_{si})$</td>
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<td>0.06</td>
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<tr>
<td>$\rho(l_t^b, k_t)$</td>
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<td>$\rho(l_t^b, x_t)$</td>
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<td>$\rho(\pi_t, \pi_{t-1})$</td>
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<td>0.82</td>
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<tr>
<td>$\rho(\pi_t, a_{si})$</td>
<td>-0.38</td>
<td>-0.30</td>
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<td>$\rho(\pi_t, r_t)$</td>
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<td>0.47</td>
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<td>$\rho(\pi_t, r_{t-1})$</td>
<td>0.49</td>
<td>0.48</td>
<td>0.34</td>
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<td>$\rho(x_t, x_{t-1})$</td>
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<tr>
<td>$\rho(x_t, a_{si})$</td>
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<td>-0.32</td>
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<tr>
<td>$\rho(x_t, k_t)$</td>
<td>-0.24</td>
<td>-0.47</td>
<td>0.09</td>
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<tr>
<td>$\rho(x_t, i_t)$</td>
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<td>0.005</td>
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<td>$\rho(\vartheta_t, a_{si})$</td>
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<td>0.05</td>
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<td>$\rho(y_t, n_{tb}^b)$</td>
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<td>-0.07</td>
<td>0.45</td>
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<tr>
<td>$\rho(y_t, n_{tb}^p)$</td>
<td>-0.02</td>
<td>-0.03</td>
<td>0.22</td>
</tr>
<tr>
<td>$\rho(n_{tb}^b, n_{tb}^{b-1})$</td>
<td>0.99</td>
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<td></td>
</tr>
<tr>
<td>$\rho(r_t^b, r_t^{b-1})$</td>
<td>0.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho(r_t^d, r_t^{d-1})$</td>
<td>0.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho(y_t, r_t^d)$</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho(k_t, \psi(u_t))$</td>
<td>0.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho(pibt, n_{tb}^b)$</td>
<td>0.15</td>
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<tr>
<td>$\rho(r_t^b, r_t^d)$</td>
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<tr>
<td>$\rho(pibt, y_t)$</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable (Rel.)</th>
<th>Standard deviation (Rel.)</th>
<th>Skewness (Rel.)</th>
<th>Kurtosis</th>
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</thead>
<tbody>
<tr>
<td>$y_t$</td>
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<td>0.21</td>
<td>10.91</td>
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<tr>
<td>$\pi_t$</td>
<td>0.35</td>
<td>-1.81</td>
<td>0.36</td>
</tr>
<tr>
<td>$k_t$</td>
<td>0.42</td>
<td>1.24</td>
<td>0.37</td>
</tr>
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<td>$x_t$</td>
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<td>27.9</td>
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<tr>
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<td>0.19</td>
<td>0.18</td>
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<tr>
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<td>0.17</td>
</tr>
<tr>
<td>$l_t^b$</td>
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<td>1.90</td>
<td>0.17</td>
</tr>
<tr>
<td>$r_t$</td>
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<td>-4.29</td>
<td>1.1</td>
</tr>
<tr>
<td>$i_t$</td>
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<td>-7.81</td>
<td>9.54</td>
</tr>
<tr>
<td>$\psi(u_t)$</td>
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<td>-0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>$\vartheta_t$</td>
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<td>3.89</td>
<td>53.5</td>
</tr>
<tr>
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<td>7.05</td>
<td>9.79</td>
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<tr>
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<td>0.24</td>
<td>-7.1</td>
<td>9.82</td>
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<td>-4.43</td>
<td>52.66</td>
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<td>-3.86</td>
<td>53.52</td>
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<tr>
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<td>1.23</td>
<td>-3.33</td>
<td>53.75</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable (Rel.)</th>
<th>Standard deviation (Rel.)</th>
<th>Skewness (Rel.)</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_t$</td>
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<td>-0.21</td>
<td>3.25</td>
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<tr>
<td>$\pi_t$</td>
<td>0.26</td>
<td>1.81</td>
<td>1.05</td>
</tr>
<tr>
<td>$k_t$</td>
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<td>0.81</td>
<td>0.96</td>
</tr>
<tr>
<td>$x_t$</td>
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<td>1.67</td>
</tr>
<tr>
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<td>0.54</td>
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<tr>
<td>$d_t$</td>
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<td>0.76</td>
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<tr>
<td>$l_t^b$</td>
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<td>1.10</td>
<td>0.47</td>
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<td>2.29</td>
<td>1.15</td>
</tr>
<tr>
<td>$i_t$</td>
<td>0.27</td>
<td>-0.91</td>
<td>1.51</td>
</tr>
<tr>
<td>$\psi(u_t)$</td>
<td>0.15</td>
<td>-0.01</td>
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</tr>
<tr>
<td>$\vartheta_t$</td>
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<td>-146.5</td>
<td>323.7</td>
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<tr>
<td>$c_t$</td>
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<td>1.14</td>
<td>1.56</td>
</tr>
<tr>
<td>$s_t$</td>
<td>0.23</td>
<td>-1.2</td>
<td>1.56</td>
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<tr>
<td>$n_t^b$</td>
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<td>66.3</td>
<td>67.5</td>
</tr>
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<td>$n_t^f$</td>
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<td>-146</td>
<td>323.7</td>
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<tr>
<td>$S_t$</td>
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<tr>
<td>$r_t^d$</td>
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<td>-1.81</td>
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</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable (Rel.)</th>
<th>Standard deviation (Rel.)</th>
<th>Skewness (Rel.)</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_t$</td>
<td>0.50</td>
<td>-0.66</td>
<td>3.54</td>
</tr>
<tr>
<td>$k_t$</td>
<td>1.50</td>
<td>0.82</td>
<td>1.66</td>
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<tr>
<td>$x_t$</td>
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<td>-5.8</td>
<td>58.6</td>
</tr>
<tr>
<td>$a_{st}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$d_t$</td>
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<td>1.36</td>
<td>4.54</td>
</tr>
<tr>
<td>$l^s_t$</td>
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<td>-0.61</td>
<td>3.75</td>
</tr>
<tr>
<td>$r_t$</td>
<td>0.76</td>
<td>-1.27</td>
<td>2.38</td>
</tr>
<tr>
<td>$i_t$</td>
<td>3.08</td>
<td>1.18</td>
<td>0.71</td>
</tr>
<tr>
<td>$\psi(u_t)$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\theta_t$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$c_t$</td>
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<td>0.37</td>
<td>0.14</td>
</tr>
<tr>
<td>$s_t$</td>
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<td>0.49</td>
<td>8.39</td>
</tr>
<tr>
<td>$n^b_t$</td>
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<td>-2.34</td>
<td>9.39</td>
</tr>
<tr>
<td>$n^f_t$</td>
<td>2.21</td>
<td>-0.34</td>
<td>16.37</td>
</tr>
</tbody>
</table>

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