Stock Markets, Capital-Constrained Loan Creation and Monetary Policy in a Behavioral New Keynesian Model

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October 17, 2019

– Preliminary Draft –
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Abstract

In this paper we incorporate in a behavioral macro-finance model with heterogenous boundedly rational expectations a stock market and a banking sector. Households' savings are diversified among bank deposits and stock purchases, and bank's lending to firms is subject to capital-related costs. We find that households' participation in the stock market, in addition to the existence of a capital-constrained banking sector which sets the loan interest rate, alter the transmission of monetary policy to the economy, and that households' deposits act as a critical spill-over channel between the real and the financial sectors. A leaning-against-the-wind (LATW) monetary policy which targets asset prices is able to re-stabilize the stock market following a financial shock.

JEL classification: E5, E7, G00

*Corresponding author. E-mail: `naira.kotb@uni-bamberg.de`. We would like to thank Mishael Milakovic, Joep Lustenhouwer, Tomasz Makarewicz and Tim Hagenhoff for helpful comments and suggestions, as well as participants of the 6th GENED Meeting at Kiel University, and the 2018 CFE conference in Pisa. Financial support by the Hans-Böckler Foundation is gratefully acknowledged.

1 Introduction

As pointed out by Woodford (2010), the 2007 global financial crisis showed in the most clear manner the need for macroeconomic models in which financial intermediation and bank lending is modelled in accordance with institutional realities, and in which also different market-based funding sources are taken into account. This is especially true if developments in advanced economies like the US or the UK, where the financial system is highly developed and investment financing is largely market based, are to be better understood.[1] [2] Further, as pointed out by Caballero (2010), factors like boundedly rational behavior, expectations formation and complex dynamics seem to play a key role in the emergence of financial instability, and the interaction between the financial and the real sectors.

So far, the transmission mechanism of monetary policy in the presence of financial frictions has been explained in literature through two channels: the *balance sheet channel* which stresses the impact of monetary policy on the borrowers' (firms and households) balance sheets (and hence on the external finance premium they face), and the *bank lending channel* which focuses on the effects of monetary policy on the supply of credit (i.e. loans) by banks. The bank lending channel has traditionally been dependent on bank reserves as the main mechanism behind transmission: a contractionary monetary policy that drains bank reserves reduces the extent to which banks can take reservable deposits; if banks cannot substitute these with non-reservable forms of finance, banks would be forced to issue less loans or liquidate existing ones. However, as financial innovations and deregulations have massively enabled banks to raise non-reservable deposits, bank reserves have become unfit as an explanation to the transmission of monetary policy to the real economy through banking (Bernanke and Gertler, 1995; Thakor, 1996; Kopecky and VanHoose, 2004*b*).

Researchers attempting to find a more convincing explanation for the bank lending channel have turned their attention to the role of bank capital. Van den Heuvel (2002), Kopecky and VanHoose (2004*b*,*a*), Borio and Zhu (2012) and Gambacorta and Shin (2018) show that it is an inadequate level of bank capital, rather than reserves, what leads to sluggish lending.

[1] Milani (2017) e.g. states that omitting stock market variables may lead to misspecification in a macro-financial model.

[2] Levine and Zervos (1998), Demirguc-Kunt and Levine (1999), Beck and Levine (2004), Dritsaki and Dritsaki-Bargiota (2005) and Hollander and Liu (2016) are further examples of papers that consider stock market and banks simultaneously on studying the relationship between financial sector conditions and economic activity.

Peek and Rosengren (1995) stress that capital-constrained banks and non-constrained banks respond very differently to monetary policy shocks. Van den Heuvel (2006) argues that even in the presence of a "perfect" market for non-reservable liabilities for banks, capital constraints generate a mechanism through which monetary policy shifts bank loan supply.

Against this background, the present paper seeks to understand the mechanisms through which the financial system and the real sector of the economy interact, and how the interaction of the stock market and bank lending may affect the transmission mechanism of monetary policy from a behavioral perspective. Our model builds on the previous work by Branch and McGough (2010), De Grauwe (2011, 2012), Proaño (2011, 2013) and in particular, De Grauwe and Macchiarelli (2015). We do so by nesting an agent-based stock market and a capital-constrained banking sector in a behavioural New Keynesian model with heterogeneous expectations. Our model, though quite stylized, features a variety of interesting aspects. First and foremost, our model features an economy where both market-based and bank-based financial sectors can be represented and analyzed. Each of these two sectors are governed by different sets of rules, transmit shocks to the real sector differently and react themselves differently to real shocks. Moreover, and as illustrated and stressed in our model, the interaction between these two sectors leads to significantly important transmission channels that are otherwise neglected when we study each of them separately. Further, rather than adopting the benchmark rational expectations assumption, the boundedly rational expectation formation assumed for both the real sector and the stock market, recognises the limited cognitive abilities of agents.

The banking sector in our model has two important distinctive features. First, banks enjoy market power that allows them to set the loan rate and the quantity of loans available to firms accordingly. Second, we follow Gerali et al. (2010) in assuming that banks aim at keeping their capital-to-assets ratio as close as possible to an exogenous target level. They face quadratic costs when they divert from such a target. Banks set the spread rate in a way that maximizes their profits given the costs of deviation. In that manner, these costs constrain the banking sector from freely varying the spread rate based on market forces. As we will see, such a constraint creates a feedback loop between the real and the financial sides of the economy affecting the shape of the business cycle.

As for the stock market, our model includes two types of demand, one that is speculative by financial agents, and another that is non-speculative by households. These two types of stock demand follow different rules and have different determinants. To achieve this, we borrow from Lengnick and Wohltmann (2016) their micro-founded households' demand for stock and assume that households hold their savings either in the form of stocks or deposits. Unlike Lengnick and Wohltmann (2016) who do not explicitly study the role played by households' stock demand in the model, we devote special attention to this issue. In our paper, the mechanism through which households switch between stocks and deposits, and the sets of motivation they respond to, are central to the model. These not only directly affect the stock price, but also the banking activity and the level of the interest spread, and hence the entire economic activity.

Our stylized theoretical framework delivers a variety of interesting insights. On the one hand, we find that the monetary policy transmission mechanism depends significantly on whether households hold and demand stocks, as well as on the relative importance of the bank's capital-to-asset constraint (either from a regulatory or from a subjective perspective). On the other hand, we find that the bank's capital-to-assets constraint significantly affects the dynamics of the economy only if households' stock demand is present. In other words, "it takes two to tango": it is the interaction of stock and loan markets what significantly affects the transmission mechanism of monetary policy. Finally, we find a significant trade-off between price inflation and stock market stability which highlights the difficult task of monetary policy in countries with advanced financial systems.

The remainder of the paper is organised as follows. Section 2 explains the structure of the model. Section 3 discusses calibration. Section 4 discusses the main results. Section 5 evaluates the effectiveness of a leaning-against-the-wind monetary policy. Section 6 concludes.

2 The Model

2.1 The Real Sector

The real sector in our model is represented by an aggregate demand equation and a Phillips Curve equation. Concerning the former, following De Grauwe and Macchiarelli (2015) we assume that the two components of aggregate demand, aggregate consumption and aggregate investment (expressed as log-linearized deviations from their respective steady states), are given by

$$c_t = d_1 y_t + d_2 \tilde{E}_t[y_{t+1}] + d_3(r_t - \tilde{E}_t[\pi_{t+1}]) + \epsilon_t^c, \quad (1)$$

and

$$i_t = e_1\tilde{E}_t[y_{t+1}] + e_2(\rho_t - \tilde{E}_t[\pi_{t+1}]) + \epsilon_t^i, \tag{2}$$

where r_t is the nominal risk-free short-term interest rate (i.e. the policy rate); π_t is the inflation rate; y_t is the output gap; $\tilde{E}_t[x_{t+1}]$ represents the aggregate expectations concerning a variable x to be defined below; ρ_t is the loan interest rate charged by banks and paid by firms and is composed of r_t plus a spread χ_t, and ϵ_t is a white noise disturbance term.

The Phillips curve relationship is given by

$$\pi_t = \tilde{E}_t[\pi_{t+1}] + b_2 y_t + \epsilon_t^\pi. \tag{3}$$

Households and firms in our model face the following (real) consolidated budget constraint:

$$y_t + (r_{t-1} - \pi_t)d_{t-1} = c_t + d_t + \Lambda_t + (\rho_{t-1} - \pi_t)l_{t-1}, \tag{4}$$

where d_t represents households' deposits; Λ_t represents households' stock demand and l_t the amount of loans awarded to firms. Equation (4) basically states that households, who are also the owners of the firms, receive an aggregate real income that is equal to the value of the output gap; in addition to that, they receive interest income on their bank deposits. They use these incomes to consume, buy stocks, deposit and pay interest on loans borrowed by (their) firms.[3]

Following Lengnick and Wohltmann (2016), we assume that households (HH) demand stocks according to the following equation:

$$\Lambda_t = c_{\Lambda,y}y_t - c_{\Lambda,r}r_t - c_{\Lambda,s}s_t, \quad c_{\Lambda,y}, c_{\Lambda,r}, c_{\Lambda,s} > 0, \tag{5}$$

where s_t is the stock price.

Thus, at every period t, households receive income equal to $(y_t + (r_{t-1} - \pi_t)d_{t-1})$, they consume according to equation 1, purchase stocks according to equation 5, pay interest on their debts (i.e. loans borrowed by their firms), and deposit the rest of their income. Accordingly, bank deposits are treated similar to bonds purchases in standard microfounded macro-models; see e.g. Lengnick and Wohltmann (2016); Gali (2008).

[3]The model abstains from loan repayment (principal payment) and dividends on stocks. Further, it includes no government sector or international trade.

Next is to determine how expectations are being formed. In our model, expectations are formed in a boundedly rational way using discrete choice learning as in Brock and Hommes (1998). We follow De Grauwe and Macchiarelli (2015) in assuming two types of expectation rules: extrapolative (represented by the letter e) and fundamentalist (represented by the letter f), defined respectively as:

$$\tilde{E}_t^e[z_{t+1}] = \theta^e(z_{t-1} - z_{t-2}) + z_{t-1} \qquad z \in (y, \pi), \tag{6}$$

$$\tilde{E}_t^f[z_{t+1}] = \theta^f(z^\star - z_{t-1}) + z_{t-1} \qquad z^\star \in (y^\star, \pi^\star). \tag{7}$$

As it is standard in this type of theoretical models, see e.g. Brock and Hommes (1998), agents (households) switch between the two rules, and the aggregate market expectations are the weighted average of both rules:

$$\tilde{E}_t[z_{t+1}] = \alpha_{z,t}^e E_t^e[z_{t+1}] + \alpha_{z,t}^f E_t^f[z_{t+1}]. \tag{8}$$

The weights of agents and the utility function associated with each rule (α_t and U_t, respectively) are determined as follows:

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

$$\alpha_{z,t}^f = \frac{\exp(\gamma U_{z,t}^f)}{\exp(\gamma U_{z,t}^e) + \exp(\gamma U_{z,t}^f)} = 1 - \alpha_{z,t}^e \tag{9}$$

and

$$U_{z,t}^j = \rho U_{z,t-1}^j - (1-\rho)(\tilde{E}_{t-2}^j z_{t-1} - z_{t-1})^2, \tag{10}$$

where ρ is a memory parameter and $j \in (f, e)$.

2.2 The Banking Sector

The aggregate balance sheet of the banking sector is shown in Table 1. While both aggregate deposits d_t, and the interest rate paid on them r_t (assumed to be equal to the policy rate to be discussed below) are determined outside the banking sector, banks determine the loan-deposit spread rate (χ_t) and consequently the aggregate loan supply level (l_t). They respond to shocks; cyclical conditions in the real sector, and indirectly, stock market conditions by adjusting the spread rate, while obeying a balance sheet identity (Assets=Liabilities + Net worth).

Table 1: The aggregate balance sheet of the banking sector

Assets	Liabilities
loans (l_t)	HH deposits (d_t)
	deposited dividends (D_t)
	net-worth

Banks make loans (l_t) to firms earning a revenue of $\rho_t l_t$, and accept deposits (d_t) from households that cost interest payment of $r_t d_t$. In addition to that, they pay a cost δ^b on their outstanding (retained) profits (k_t). At period t, banks' profits are calculated as follows:

$$j_t = \rho_{t-1} l_{t-1} - r_{t-1} d_{t-1} - \delta^b k_{t-1}. \tag{11}$$

Unlike Gerali et al. (2010) who assume retaining all the profits, we assume that banks distribute a positive fraction (γ^b) of the profits as dividends, these in turn are deposited by the banks themselves.[4] The rest of the profits are retained, as part of the banks' net-worth.

At time t, the value of the (accumulated) deposited dividends (D_t) is calculated as follows:

$$\begin{aligned} D_t &= D_{t-1} + \gamma^b j_t \\ &= \gamma^b \sum_{n=1}^{t} j_n, \end{aligned} \tag{12}$$

and banks retained earnings are thus given by:

$$\begin{aligned} k_t &= k_{t-1} + (1-\gamma^b) j_t \\ &= (1-\gamma^b) \sum_{n=1}^{t} j_n. \end{aligned} \tag{13}$$

At $\gamma^b = 0$, banks distribute no dividends and all profits are retained. Banks' net worth (bank capital) is the difference between banks' assets and banks' liabilities. The banks' capital-to-asset ratio (ν_t) is thus defined as follows:

$$\nu_t = \frac{\text{bank net worth}}{\text{bank assets}} = \frac{l_t - d_t - D_t}{l_t} = \frac{l_t - d_t - \sum_{n=1}^{t} j_n + k_t}{l_t}. \tag{14}$$

[4]For simplicity we abstain from interest payment on these deposits.

Following Gerali et al. (2010), banks are assumed to pay a quadratic cost (parametrized by a coefficient κ) whenever the capital-to-asset ratio ν_t moves away from the target value ν^0. To keep our calculations linear, we rearrange the previous equation, i.e.

$$l_t - d_t - D_t = \nu_t l_t. \tag{15}$$

Then, banks face the following profit maximization problem:

$$\max_{l_t} \quad \rho_t l_t - r_t d_t - \frac{\kappa}{2}(l_t - d_t - D_t - \nu^0 l_t)^2. \tag{16}$$

Banks take the aggregate deposits level d_t as given. Maximizing the previous expression with respect to l_t leads to the following first-order condition:

$$l_t = \eta(\chi_t + \kappa(1-\nu^0)d_t + \kappa(1-\nu^0)D_t), \tag{17}$$

with $\eta = \frac{1}{\kappa(1-\nu^0)^2}$.

Equation (17) states that banks' loan supply is a positive function of banks' marginal profits from loans (i.e. the spread rate χ_t); households' deposits d_t and the accumulated dividends D_t.

Assuming that banks know the investment function (loan demand function) expressed by equation (2), they set the spread rate such that the level of loan demanded by firms is equal to the profit maximizing loan level that banks wish to supply. This means that the loan market always clears:

$$l_t = i_t \tag{18}$$

Finally, rearranging equation (17) yields:

$$\chi_t = \kappa(1-\nu^0)((1-\nu^0)l_t - d_t - D_t), \tag{19}$$

where $l_t = i_t$ as given by equation (18). The right-hand side of the equation represents the marginal benefit from increasing lending (an increase in profits equal to the spread); the right-hand side is the marginal cost from doing so (an increase in the costs of deviation from v^0). Banks choose the level of loan supply that equalizes the marginal benefit with the marginal cost (leading to a marginal profit of zero). At $\kappa \approx 0$,[5] the profit maximizing spread rate is approximately zero. A low value for κ could be interpreted as a loose regulatory regime/requirements; a higher value indicates a tight regime.

[5] We do not set $\kappa = 0$ to avoid a division by zero in equation 17.

2.3 The Stock Market

The stock market in our model is borrowed from Westerhoff (2008) and we integrate it in a macroeconomic setup as done by Lengnick and Wohltmann (2016).[6]

Two types of financial agents are assumed: chartists and fundamentalists. Capital letters C and F are used to denote chartists and fundamentalists respectively to distinguish them from real sector's agents.

$$\tilde{E}_t^F[s_{t+1}] = k^F(s^0 y_{t-1} - s_{t-1}) + s_{t-1}, \tag{20}$$

$$\tilde{E}_t^C[s_{t+1}] = k^C(s_{t-1} - s_{t-2}) + s_{t-1}, \tag{21}$$

where $\tilde{E}_t^F[s_{t+1}]$ and $\tilde{E}_t^C[s_{t+1}]$ denote the expectations of fundamentalists and chartists w.r.t. the future real stock price, respectively.

The fundamentalists' and chartists' stock demand at time t are respectively given by

$$\begin{aligned} D_t^F &= k^{F\prime}(\tilde{E}_t^F s_{t+1} - s_{t-1}), \\ D_t^C &= k^{C\prime}(\tilde{E}_t^C s_{t+1} - s_{t-1}). \end{aligned} \tag{22}$$

The attractivity (i.e. utility) of each rule is defined as follows:

$$A_t^k = -(s_{t-1} - \tilde{E}_{t-2}^k s_{t-1})^2 + mA_{t-1}^k, \qquad k \in (C, F), \tag{23}$$

where m is a memory parameter. The weights of agents associated with every rule are determined as follows:

$$\omega_t^k = \frac{exp(eA_t^k)}{exp(eA_t^F) + exp(eA_t^C)}, \tag{24}$$

where e is a switching parameter, analogous to γ in the real sector.

Following Westerhoff (2008) and Lengnick and Wohltmann (2016), we assume that the evolution of the log stock price s_t is determined by the following impact function:

$$s_t = s_{t-1} + (\omega_t^F D_t^F + \omega_t^C D_t^C + \Lambda_t) + \epsilon_t^s, \tag{25}$$

where ϵ_t^s is a white noise disturbance term.

It is important to clarify here that the only role played by the financial agents in the model is trading stocks. They do not consume or produce. One can think of them as foreign investors who only buy and sell stocks and have no other role in the economy.

[6] However, unlike Lengnick and Wohltmann (2016) who explicitly distinguish between the daily frequency in the stock market and the quarterly frequency in the real sector, we assume, for simplicity, a uniform frequency among all the sectors (i.e. quarterly).

2.4 Spillover Channels

Figure 1 illustrates the interaction channels that connect together the real sector, the banking sector and the stock market. Through the banks' setting of the loan spread rate, the banking sector directly influences the real sector through firms' investments, which are solely financed by bank loans and are negatively dependent on the spread rate. In the other direction, the real sector's conditions spill over to the banking sector through households' deposits. The latter are determined outside the banks' frame of market power.

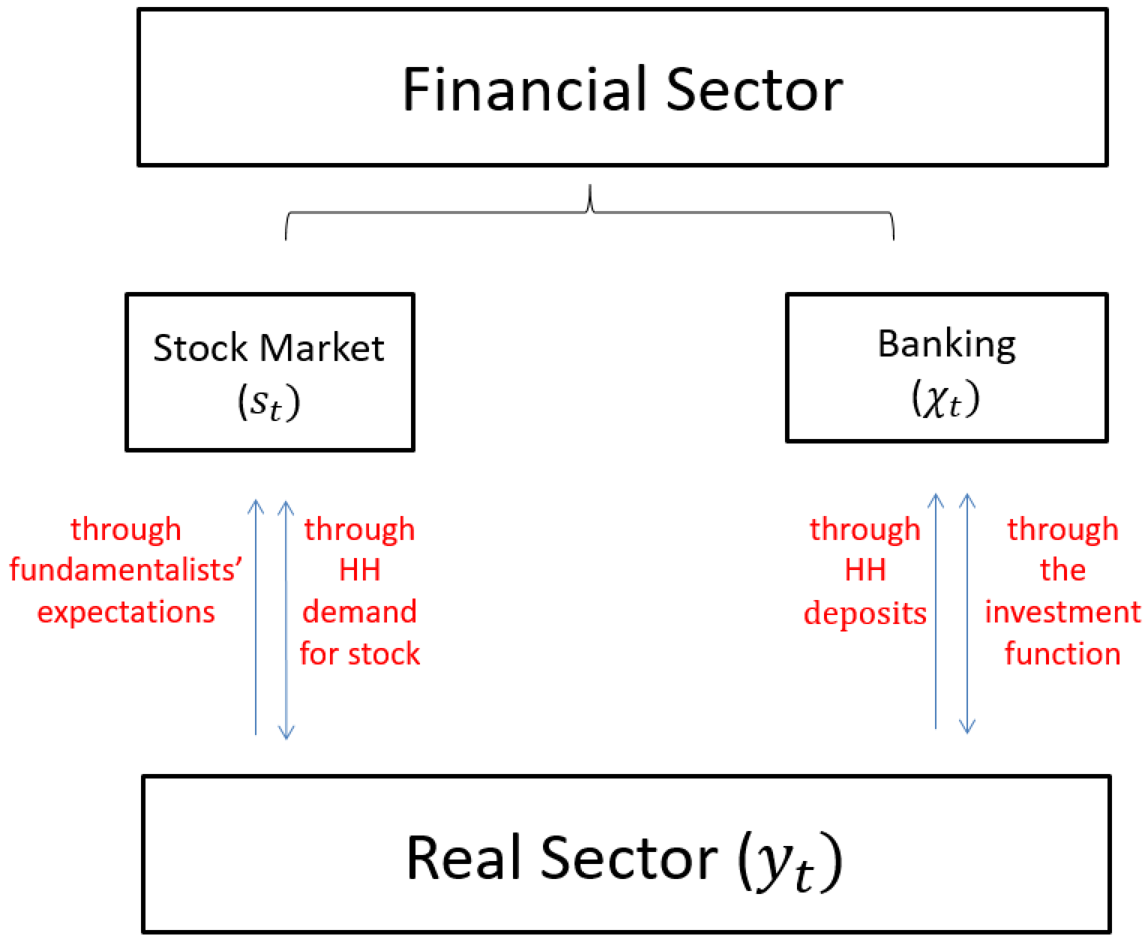

Figure 1: Real-financial spill-over channels in the model.

Households' demand for stock creates a two-way-spill-over-channel, where the real sector and the stock market affect one another. Finally, the way fundamentalists make their expectations about the stock prices creates an additional real-sector-to-stock-market spill-over channel.

2.5 Monetary Policy

We assume that the policy rate is determined by the following Taylor rule:

$$r_t = c_1(\pi_t - \pi^*) + c_2(y_t - y^\star) + c_3 r_{t-1} + c_4 s_t + \epsilon_t^r, \tag{26}$$

where $\pi^\star$ is the explicitly announced inflation target of the central bank, and $y^\star$ is the corresponding steady state value of the output gap (both are assumed to be zero here). When $c_4 \neq 0$, the central bank is also targeting stock price stability.

3 Calibration

The baseline parametrization in our model follows Lengnick and Wohltmann (2016) (for the stock market and households demand for stock), De Grauwe and Macchiarelli (2015) (for the real sector) and Gerali et al. (2010) (for the banking sector), with some minor adjustments from our side. For example, in Lengnick and Wohltmann (2016), the baseline value for k^F is 0.04. Since they assume a daily frequency for their stock market, this means that, roughly speaking, a stock price divergence happening today needs, according to the expectations of fundamentalists, $\frac{1}{0.04} = 25$ days (≈ 0.4 quarter)[7] to be adjusted. Our model on the other hand assumes a homogeneous frequency for all the sectors of the economy (i.e. quarterly). We thus choose a much higher value for k^F. The same applies to the parameter k^C. We also use a value for the memory parameter (m) lower than the one assumed in Lengnick and Wohltmann (2016).

Another adjustment that we had to make is the way κ is calibrated. In Gerali et al. (2010), the cost of divergence is calculated as follows: the quadratic divergence from the targeted capital-to-asset ratio (i.e. $(\nu_t - \nu^0)^2$) is measured proportional to the outstanding bank capital, then multiplied by the cost factor.[8] In our model we sought linearity in calculating the divergence cost (see equation 15). Since the assumption of a capital-to-asset target and the way the divergence cost is calculated are both *ad hoc* in the first place, we believe that we are still capturing the idea in Gerali et al. (2010).

[7] In their model a quarter is composed of 64 days.

[8] Consult Gerali et al. (2010) for more details.

Table 2: Baseline parametrization

Parameter	Description	Value
Real Sector		
d_1	marginal propensity of consumption out of income	0.5
d_2	coefficient on expected y in consumption equation	$(1-d_1)(0.5)-e_1$
d_3	coefficient on real rate in consumption equation	-0.01
e_1	coefficient on expected y in investment equation	0.1
e_2	coefficient on real rate in investment equation	$(-0.5)(1-d_1)-d_3$
b_2	coefficient of output in inflation equation	0.05
σ_{ϵ^y}	standard deviation shocks output equation	0.1
σ_{ϵ^π}	standard deviation shocks inflation equation	0.1
$c_{\Lambda,r}$	coefficient of interest rate in households' demand for stock equation	1
$c_{\Lambda,y}$	coefficient of output gap in households' demand for stock equation	1
$c_{\Lambda,s}$	coefficient of stock price in households' demand for stock equation	0.5
γ	switching parameter in Brock Hommes	10
ρ	speed of declining weights in mean squares errors (memory)	0.5
Monetary Policy		
c_1	coefficient of inflation in Taylor equation	1.5
c_2	coefficient of output in Taylor equation	0.5
c_3	interest smoothing parameter in Taylor equation	0.5
c_4	coefficient of stock price in Taylor equation	0
$\pi^\star$	the central bank's inflation target	0
$y^\star$	the central bank's output gap target	0
σ_{ϵ^r}	standard deviation shocks Taylor equation	0.1
Stock Market		
k^C	coefficient in chartists' expectations	0.4
k^F	coefficient in fundamentalists' expectations	0.4
e	switching parameter in Brock Hommes	100
m	speed of declining weights in mean squared errors (memory)	0.5
σ_{ϵ^s}	standard deviation shocks stock price function	0.1
Banking Sector		
γ^b	fraction of profit distributed as dividends	0.8
δ^b	cost of managing bank capital	0.1049
ν^0	target capital-to-loans ratio	0.09
κ	deviation cost	1
η	a simplifying parameter	$\frac{1}{\kappa(1-\nu^0)^2}$

4 Simulation Results

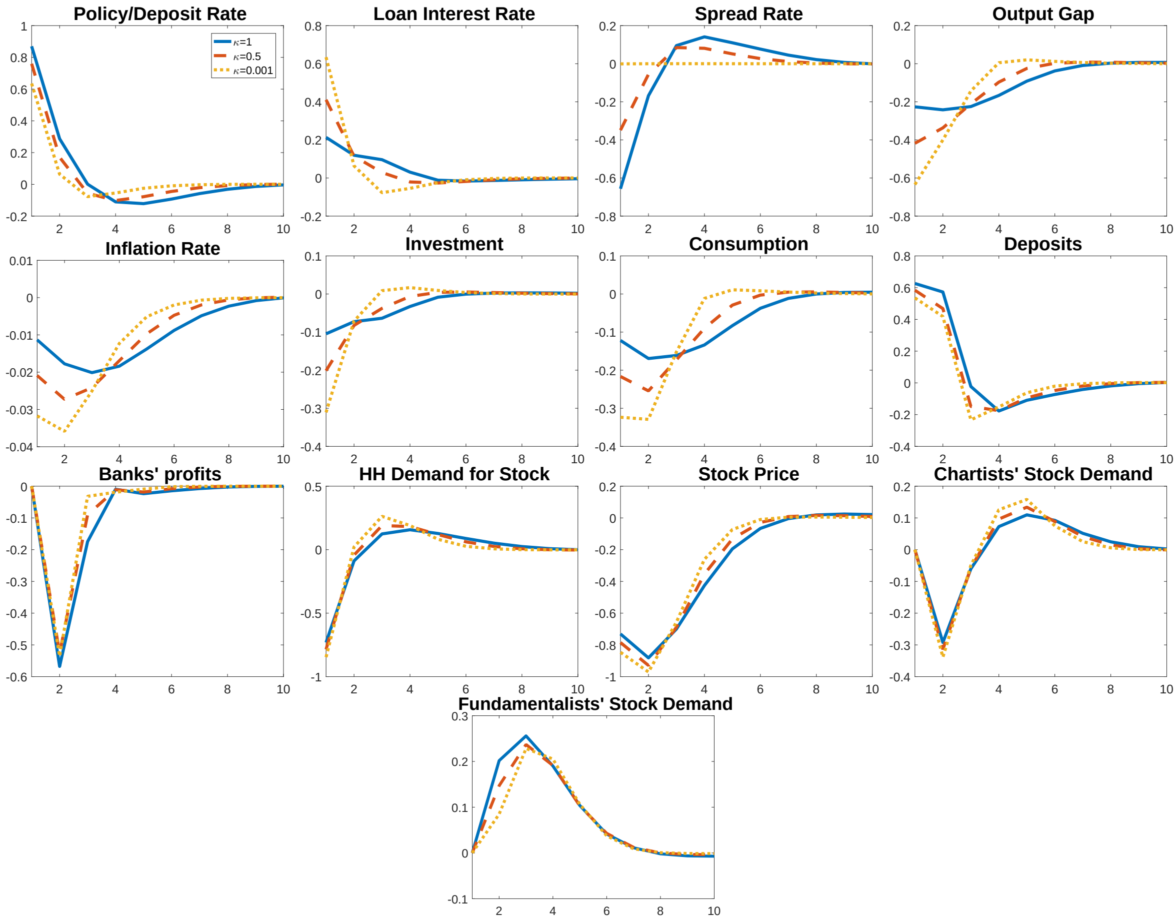

Figure 2: Impulse responses to a one-unit monetary policy shock at different values of κ.

Figure 2 illustrates the role of the costs of deviation (represented by different values of κ) for the dynamics of the economy following a contractionary monetary policy shock based on the model parameters reported in Table 2, through impulse response analysis following the method explained in detail in Appendix B (see also Lengnick and Wohltmann, 2013).

On impact, an increase in the policy/deposit rate leads to a drop in consumption, investment and output. Households' demand for stock decreases and their deposits increase. This leads to a sharp decrease in the stock price. Equation 19 shows that, at $\kappa > 0$, both the increased deposit level and the decreased loan demand (investment demand) lead to a decrease in the spread rate. As a result, the on impact increase in the loan rate is much lower than the original increase in the policy rate. This in turn means that the effect of the policy shock on investment, output and inflation is "diluted". In other words, on impact, a contractionary monetary policy is only partially transmitted to the economy. At $\kappa \approx 0$, the spread rate does not decrease when r_t increases; output and inflation react more strongly to the policy shock; a contractionary monetary policy is fully transmitted to the economy on impact.

The value of κ has a significant impact on the dynamics of the economy in the following periods. While the contractionary impulse of the loan rate vanishes almost immediately for $\kappa \approx 0$, for $\kappa = 0.5$ and $\kappa = 1.0$ the increase in the loan rate lasts longer. This of course deteriorates the firms' financing conditions, depressing thus aggregate investment, output and consumption for some periods, which brings the policy rate further down.

This pattern in the dynamics can be attributed to the fact that when κ is positive, the spread rate is a function of the value of banks' net-worth (as per equation 19), which by definition is backward looking. This in turn adds inertia to the model variables. We can conclude that the capital constraint on loan creation (represented by a positive κ) weakens the impact of the policy shock on the economy but causes it to last longer.

In Figure 3, households' demand for stock is switched on and off under $\kappa = 1$. In absence of households' stock demand, the positive effect of the policy interest rate on the deposit level is weak (i.e. households do not have stocks to sell in order to buy more deposits). The lower level of investment induced by the higher interest rate leads to a decrease in y_t; according to the budget constraint shown in equation (4), this causes the deposit level to slightly fall. The positive effect of such a fall on the spread rate is offset by the negative effect of the decreased loan (investment) demand. Therefore, the spread rate does not change and the loan interest rate increases on impact by roughly the same amount as the policy rate. A contractionary monetary policy is thus able to fully pass through to the real economy on impact, even in the presence of a capital constrained banking sector. It is only when Λ_t is switched on, that we witness a delayed transmission of monetary policy as discussed above.

Figure 4 illustrates the dynamic adjustments of this model economy to a positive stock price shock. As it can be observed, an increase in the stock price decreases households' stock demand and consequently increases their deposits. If the lending constraint is almost non-existent ($\kappa \approx 0$), the loan spread χ_t does not change, and hence there is no further effect on the economy; interest rates, inflation rate and output gap do not change. On the other hand, at a positive cost of deviation (i.e. $\kappa > 0$), higher deposits lead to a lower spread rate, which

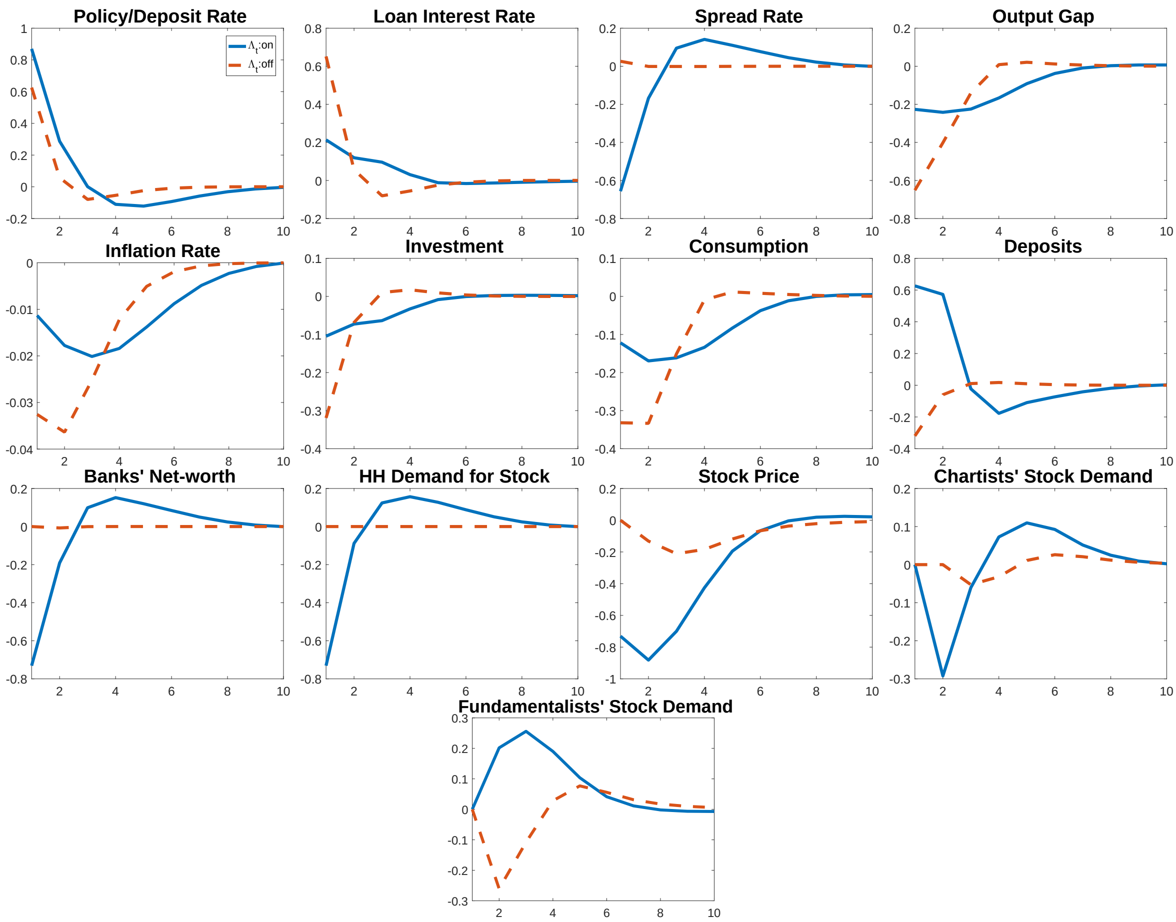

Figure 3: Impulse responses to a one-unit monetary policy shock when households' demand for stock is switched on and when it is switched off (for $\kappa = 1$).

boosts investment and output.

Although, as we can see in figure 1, the model does not have a direct link between the stock market and the banking sector, the coexistence of the banks' balance sheet constraints, households' demand for stocks and banks' setting power over the spread rate creates an indirect link between the two sectors which in turn strengthens the spill over effects between these sectors and the real sector.

The fact that the deposit level, in our model, falls outside the frame of the banks' market power, and is rather decided at the households' level, makes deposits a "channel variable" through which changes in the real sector and the stock market affect the banking sector. The latter sector then spills over to the first two sectors through the process through which the

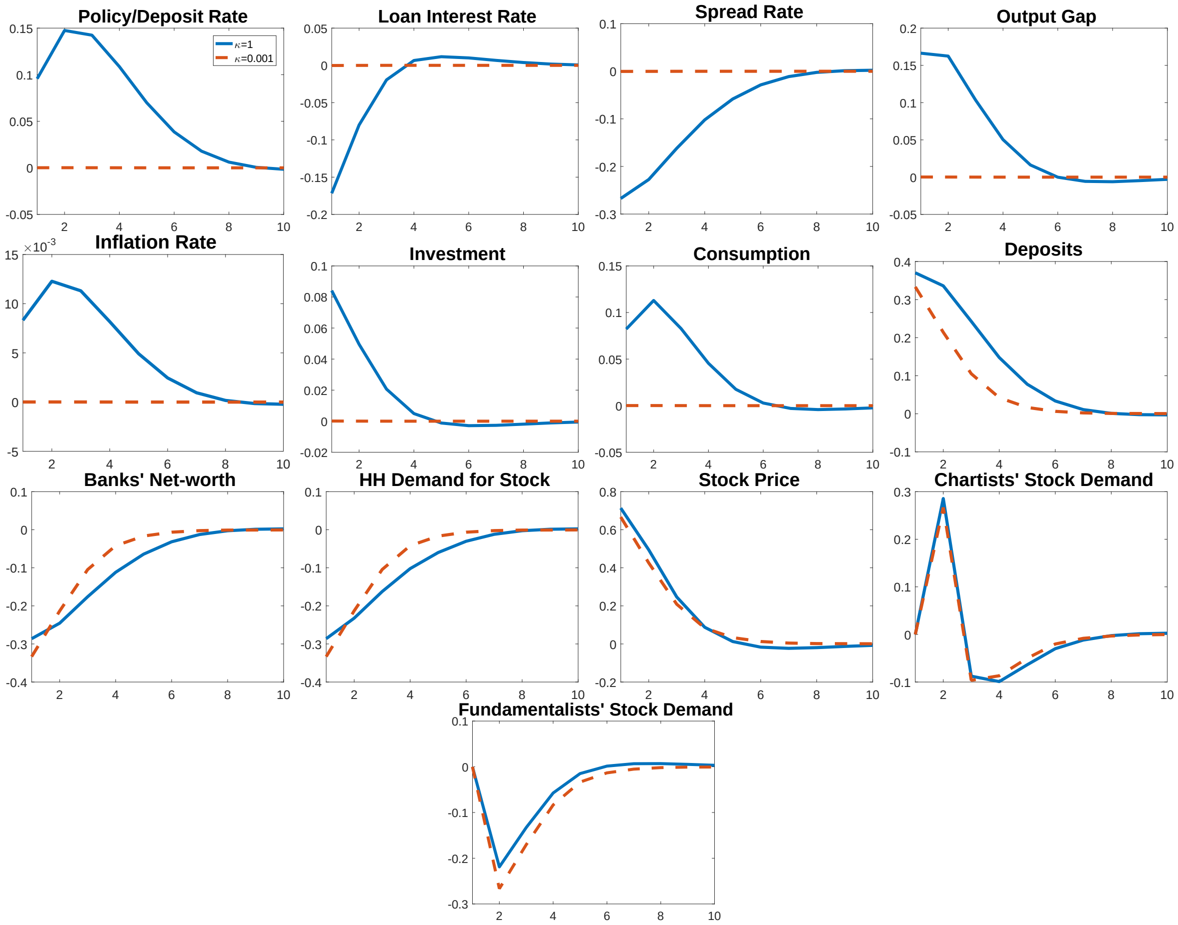

Figure 4: Impulse responses to a one-unit stock price shock at different values of κ.

spread rate is adjusted. This is in line with Drechsler et al. (2017), which single out deposits as being: (1) a uniquely stable funding source for banks, (2) the main source of liquid assets for households, and consequently, (3) an important channel through which monetary policy is transmitted. Similarly, in our model households can sell (withdraw) deposits to consume, buy stocks, or pay interest on their debts (i.e. deposits are liquid assets for households). Banks have to cut their lending (raise the spread) when the deposit level falls and vice versa (i.e. deposits are a critical source of funding to banks). And finally, as seen above, deposits respond strongly to monetary policy shocks and transmit these to the banking sector and consequently to the rest of the economy.

The process through which households' deposits, responding to different stimulations (e.g. monetary policy shocks), affect the real economic activity is only made possible through the presence of capital constraints on the bank level. This is in line with the literature on the role of banks' capital constraints in monetary policy transmission discussed above.

5 Leaning Against the Wind Monetary Policy

In this section we investigate the effectiveness of monetary policy in stabilising the stock market and whether this comes at the cost of output gap and inflation stability. We do this by allowing c_4 in equation (26) to be positive. Then we proceed by evaluating the effectiveness of a leaning-against-the-wind (LATW) policy in two different ways. First, we measure the effect of varying the value of c_4 on the variances of y_t, π_t and s_t. Second, we study impulse responses of the model variables to a one-time stock price shock under different values of c_4 in order to assess the ability of a LATW monetary policy to restabilize the stock market following a financial shock.

Table 3 reports the variances of the output gap, price inflation and the stock price for various values of c_4. As it can be observed, there is a clear trade-off between inflation and asset price stability: while the inflation rate variance is at its lowest level at $c_4 = 0$, the stock price variance is at its highest. Similarly, when c_4 is high, the stock price variance is at its lowest level, and the inflation rate variance at its highest.

Table 3: Variances of key variables at different values of c_4. Boldfaced is the lowest value of the row.

Variable	Value of c_4				
	0	1	2	3	4
π_t	**0.0135**	0.0142	0.0145	0.0146	0.0146
y_t	0.0425	0.0244	0.0236	0.0234	**0.0233**
s_t	0.2069	0.0192	0.0074	0.004	**0.0025**

Finally, it is worth noting that the output gap variance, similar to the variance of the stock price, is also minimized at relatively higher values of c_4. The main reason behind this outcome is that the output gap, through the effect of households' demand for stock, is highly influenced by stock price variation. Therefore, a monetary policy that stabilizes the stock price also stabilizes the output gap.

In Figure 5, it can be seen that the higher the value of c_4, the lower the immediate response

Table 4: Variances of key variables at different values of $c_4(\sigma_{\epsilon^\pi} = \sigma_{\epsilon^r} = \sigma_{\epsilon^y} = 0$ and $\kappa = 1)$. Boldfaced is the lowest value of the row.

Variable	Value of c_4				
	0	1	2	3	4
π_t	$3.5e^{-6}$	$1.8e^{-7}$	$3.2e^{-8}$	$\mathbf{2.2e^{-8}}$	$3.2e^{-8}$
y_t	$5.5e^{-4}$	$5.3e^{-5}$	$1.3e^{-5}$	$5.8e^{-6}$	$\mathbf{5.76e^{-6}}$
s_t	0.0073	0.0018	$8.8e^{-4}$	$5.3e^{-4}$	$\mathbf{3.6e^{-4}}$

Table 5: Variances of key variables at different values of $c_4(\sigma_{\epsilon^\pi} = \sigma_{\epsilon^r} = \sigma_{\epsilon^y} = 0$ and $\kappa = 0.001)$. Boldfaced is the lowest value of the row.

Variable	Value of c_4				
	0	1	2	3	4
π_t	$\mathbf{2.95e^{-12}}$	$4.2e^{-6}$	$6.1e^{-6}$	$7.04e^{-6}$	$7.6e^{-6}$
y_t	$\mathbf{5.4e^{-10}}$	$7.9e^{-4}$	0.0013	0.0015	0.0017
s_t	0.0062	0.0013	$6.3e^{-4}$	$3.8e^{-4}$	$\mathbf{2.5e^{-4}}$

of s_t to a stock price shock and the sooner it converges to the steady state. This is because at higher values of c_4, r_t reacts on impact to a positive stock price shock more strongly upward. Households' demand for stocks decreases accordingly on impact. This leads to a downward pressure on the stock price that partially offsets the effect of the shock. A leaning-against-the-wind monetary policy is thus highly effective in stabilising the stock market following a financial shock.

At lower values of c_4, output gap and inflation react strongly positively to a stock price shock on impact. On the other hand, at higher values of c_4, the immediate negative effect of raising the policy interest rate on output and inflation can offset the positive effect of the higher stock price; as a result, y_t and π_t react only slightly positively to a positive stock price shock on impact. A leaning-against-the-wind monetary policy is thus able to shield the real sector against excess volatility induced by stock price fluctuations.

In figure 6, banks' cost of deviation is switched off. As explained before (i.e. in figure 4), the negative effect of a stock price shock on the spread, and hence the positive effect on output gap and inflation, in this case is almost non-existent. At the same time, at $c_4 > 0$, the

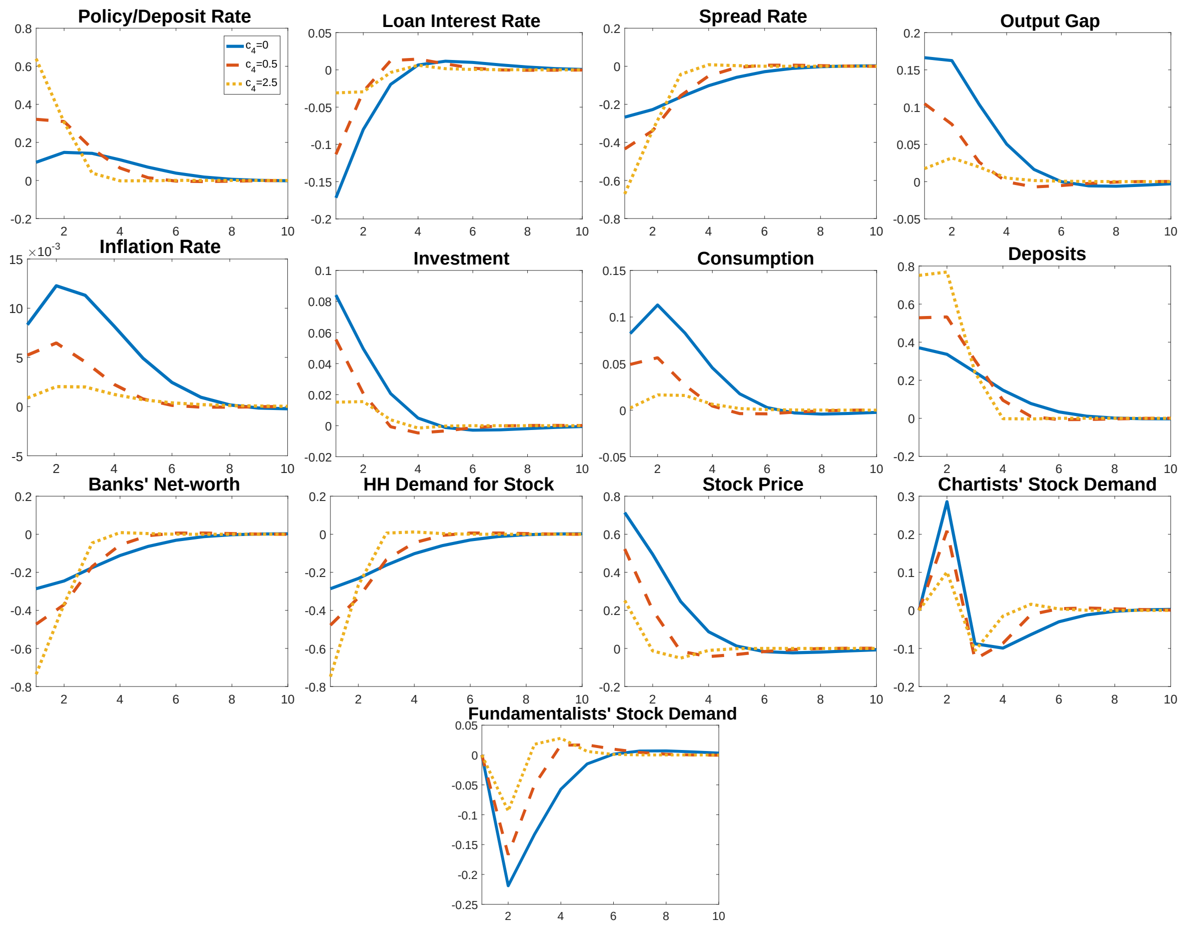

Figure 5: Impulse responses to a one-unit stock price shock at different values of c_4 ($\kappa = 1$).

policy rate increases on impact when stock price increases, leading to a downward pressure on inflation and output. This means that in absence of banking deviation costs, a leaning-against-the-wind monetary policy has a destabilizing effect on the real sector following a stock price shock.

To further examine the effect of the value of κ on the performance of a LATW policy. We turn real and monetary volatilities off ($\sigma_{\epsilon^\pi} = \sigma_{\epsilon^r} = \sigma_{\epsilon^y} = 0$), which means that only stock market volatility is present, and report variances of the variables under two cases: $\kappa = 1$ (table 4) and $\kappa = 0.001$ (table 5). It can be seen that, at the first case, higher values of c_4 are associated with more output gap and inflation stability, while the opposite is true in case of a very low value for κ.

We conclude from this that a stock-price-targeting monetary policy does bring stability to the stock market and the output gap at the cost of inflation stability. When only stock price volatilities are considered, a LATW monetary policy is still rather effective in bringing stability to the stock market. Its effect on the stability of the real sector however depends on the value of the cost of deviation κ: at relatively higher values of κ, a LATW policy is able to shield the real economy against stock price volatility, at lower values of κ a LATW policy destabilizes the real sector.

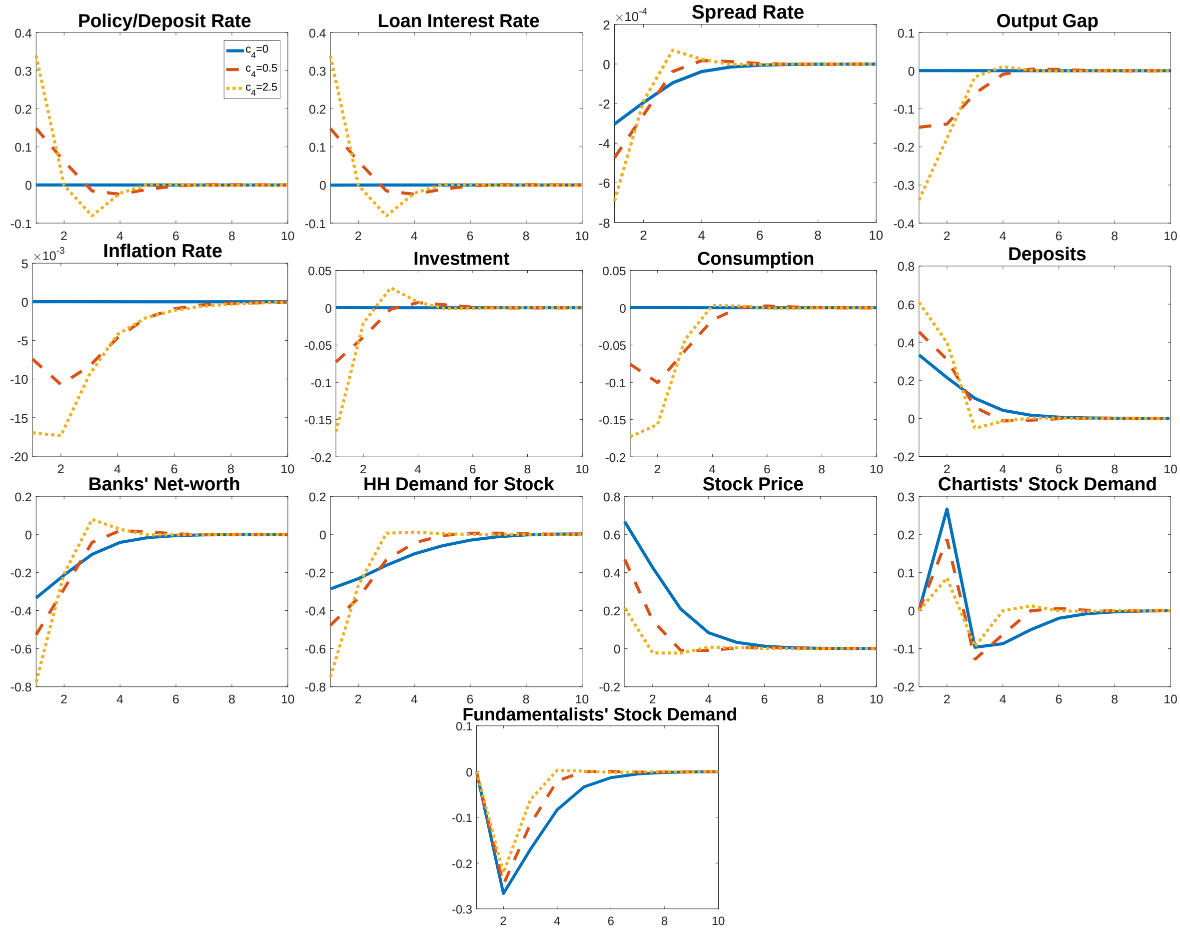

Figure 6: Impulse responses to a one-unit stock price shock at different values of c_4 ($\kappa = 0.001$).

6 Concluding Remarks

This paper extends the literature on macro-financial linkages by nesting a budget-constrained banking sector and an agent-based stock market in a behavioral New-Keynesian model with boundedly rational expectations. In our model, households diversify their savings among stock purchases and bank deposits. Banks enjoy a market power in determining the loan-deposit spread rate and consequently the loan supply level. They are capital constrained in the sense that they beare a cost when their capital-to-assets ratio diverges from a certain exogenously-set target.

We find that when the central bank raises (lowers) the deposit interest rate, deposits become more (less) attractive to households compared to stocks. They respond by demanding relatively more (less) bank deposits and less (more) stocks. The increased (decreased) level of deposits then forces the leverage constrained banking sector to lower (raise) the loan spread rate. Such a decrease (an increase) in the spread rate partially offsets the increase (decrease) in the policy rate. The net effect on the loan interest rate on impact is a rise (fall) much less than the original change in the policy rate.

Thus, instead of being transmitted at once and vanishing quickly, banks' constraints together with the existence of a households' demand for stock create a mechanism such that the contractionary or expansionary effect of a monetary policy shock on the economy is weakened but lasts longer. This can be attributed to the fact that when banks are capital constrained, the loan creation process is a function of the banks' net-worth, which is by definition a backward looking variable. In an economy where firms exclusively (or mainly) depend on bank loans for financing their production, these dynamic effects are passed through to the rest of the economy leading to a weaker, but more persistent transmission mechanism.

We also find that stock price appreciations lead to higher output gap levels and vice versa. This is due to the fact that households respond to higher stock prices by demanding relatively more deposits and less stocks; loan interest rate falls and investment rises. The opposite also holds true. A leaning-against-the-wind monetary policy is found effective in stabilizing the stock market. Its effect on the stability of the real sector depends on conditions in the banking sector (i.e. cost of deviation from the capital-to-assets target ratio).

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Appendix A Model Derivation

The aggregate supply equation (Phillips Curve) is defined as:

$$\pi_t = \tilde{E}_t \pi_{t+1} + b_2 y_t + \epsilon_t^{\pi}. \tag{27}$$

Market expectations for π_{t+1} and y_{t+1} are given by:

$$E_t \pi_{t+1} = \alpha_{\pi,t}^e E_t^e \pi_{t+1} + (1 - \alpha_{\pi,t}^e) E_t^f \pi_{t+1}, \tag{28}$$

$$E_t y_{t+1} = \alpha_{y,t}^e E_t^e y_{t+1} + (1 - \alpha_{y,t}^e) E_t^f y_{t+1}. \tag{29}$$

Fundamentalists and extrapolators' expectations are given by:

$$\begin{aligned} \tilde{E}_t^e z_{t+1} &= \theta^e (z_{t-1} - z_{t-2}) + z_{t-1} \qquad && z \in (y, \pi), \\ \tilde{E}_t^f z_{t+1} &= \theta^f (z^\star - z_{t-1}) + z_{t-1} \qquad && z^\star \in (y^\star, \pi^\star), \end{aligned} \tag{30}$$

where α_t is the weight of extrapolators. $1 - \alpha_t$ is the weight of fundamentalists. θ^f is assumed equal 1, and y^* and π^* and θ^e are assumed equal 0. Equations 28 and 29 could thus be simplified respectively to:

$$E_t \pi_{t+1} = \alpha_{\pi,t}^e \pi_{t-1}, \tag{31}$$

$$E_t y_{t+1} = \alpha_{y,t}^e y_{t-1}. \tag{32}$$

Plug equation 31 in equation 27 to reach the first state equation :

$$\pi_t = \alpha_{\pi,t}^e \pi_{t-1} + b_2 y_t + \epsilon_t^{\pi} \tag{33}$$

Taylor rule is defined by:

$$r_t = c_1(\pi_t - \pi^*) + c_2 y_t + c_3 r_{t-1} + \epsilon_t^r, \tag{34}$$

where π^*, the central bank's inflation target, is assumed to be zero. Output gap is decomposed into consumption and investment:

$$y_t = c_t + i_t + \epsilon_t^y. \tag{35}$$

Consumption is defined by:

$$c_t = d_1 y_t + d_2 \tilde{E}_t y_{t+1} + d_3 (r_t - \tilde{E}_t \pi_{t+1}). \tag{36}$$

Investment is defined by:

$$\begin{aligned} i_t &= e_1 \tilde{E}_t y_{t+1} + e_2(\rho_t - \tilde{E}_t \pi_{t+1}) \\ &= e_1 \tilde{E}_t y_{t+1} + e_2(r_t + \chi_t - \tilde{E}_t \pi_{t+1}). \end{aligned} \tag{37}$$

Plug taylor rule and market expectations of π_t and y_t in 36 and 37 then plug these in 35 and rearrange to reach the second state equation:

$$\begin{aligned} (1 - d_1 - c_2 d_3 - c_2 - c_2 e_2) y_t =& (d_3 + e_2) c_1 \pi_t + e_2 \chi_t + (d_2 \alpha^e_{y,t} + e_1 \alpha^e_{y,t}) y_{t-1} \\ & - (d_3 \alpha^e_{\pi,t} + e_2 \alpha^e_{\pi,t}) \pi_{t-1} + \epsilon^y_t + (d_3 + e_2) c_3 r_{t-1} + (d_3 + e_2) \epsilon^r_t. \end{aligned} \tag{38}$$

The consolidated budget constraint of households and firms is defined by:

$$y_t + (r_{t-1} - \pi_t) d_{t-1} = c_t + d_t + \Lambda_t + (\rho_{t-1} - \pi_t) l_{t-1}. \tag{39}$$

Households' demand for stock is defined by:

$$\Lambda_t = c_{\Lambda,y} y_t - c_{\Lambda,r} r_t - c_{\Lambda,s} s_t, \tag{40}$$

substitute c_t, Λ_t and l_t in equation 39 with equations 36 and 40 and i_t respectively, then plug in the Taylor rule and the market expectations to reach the third state equation :

$$\begin{aligned} d_t =& (c_{\Lambda,r} c_1 - d_3 c_1 - i_{t-1} + d_{t-1}) \pi_t + (1 - d_1 - c_{\Lambda,y} - d_3 c_2 + c_{\Lambda,r} c_2) y_t + c_{\Lambda,s} s_t \\ & + d_3 \alpha^e_{\pi,t} \pi_{t-1} - d_2 \alpha^e_{y,t} y_{t-1} + (c_{\Lambda,r} - d_3) \epsilon^r_t + r_{t-1} d_{t-1} - \rho_{t-1} i_{t-1} + (c_{\Lambda,r} - d_3) c_3 r_{t-1}. \end{aligned} \tag{41}$$

Banking

The banking sector faces the following maximization problem:

$$\max_{l_t} \quad \rho_t l_t - r_t d_t - \frac{\kappa}{2}(l_t - d_t - D_t - \nu^0 l_t)^2.$$

Taking derivative with respect to l_t:

$$\begin{aligned} & \rho_t - r_t - \kappa((1 - \nu^0) l_t - d_t - D_t)(1 - \nu^0) = 0 \\ & \chi_t + r_t - r_t - \kappa(1 - \nu^0)((1 - \nu^0) l_t - d_t - D_t) = 0 \\ & \chi_t - \kappa(1 - \nu^0)^2 l_t + \kappa(1 - \nu^0) d_t + \kappa(1 - \nu^0) D_t = 0 \\ & \kappa(1 - \nu^0)^2 l_t = \chi_t + \kappa(1 - \nu^0) d_t + \kappa(1 - \nu^0) D_t \\ & l_t = \frac{1}{\kappa(1 - \nu^0)^2} \chi_t + \frac{1}{1 - \nu^0} d_t + \frac{1}{1 - \nu^0} D_t. \end{aligned} \tag{42}$$

Assume $\frac{1}{\kappa(1-\nu^0)^2} = \eta$. Equation 42 becomes:

$$l_t = \eta\chi_t + \kappa\eta(1-\nu^0)d_t + \kappa\eta(1-\nu^0)D_t, \tag{43}$$

where D_t is the value of the accumulated deposited dividends and is calculated as follows:

$$D_t = D_{t-1} + \gamma^b j_t = \gamma^b \sum_{n=1}^{t} j_n, \tag{44}$$

where γ^b measures the share of profits distributed as dividends and j_t measures the current period's profits. The later is calculated as follows:

$$j_t = \rho_{t-1}l_{t-1} - r_{t-1}d_{t-1} - \delta^b k_{t-1}, \tag{45}$$

where δ^b is the cost of managing banks' retained profits k_t. The later is equal to:

$$k_t = k_{t-1} + (1-\gamma^b)j_t = (1-\gamma^b)\sum_{n=1}^{t} j_n. \tag{46}$$

Banks are assumed to set the spread rate such that the quantity of loans demanded by firms is equal to the profit maximizing loan level they wish to supply. In other words, the spread rate takes the value that clears the credit market:

$$\begin{aligned} i_t &= l_t \\ e_1\alpha^e_{y,t}y_{t-1} + e_2 r_t - e_2\alpha^e_{\pi,t}\pi_{t-1} + e_2\chi_t &= \eta\chi_t + \kappa\eta(1-\nu^0)d_t + \kappa\eta(1-\nu^0)D_t. \end{aligned} \tag{47}$$

Plugging in the Taylor rule and solving for χ_t yields the <u>fourth state equation</u>:

$$\begin{aligned} (e_2-\eta)\chi_t = &- e_2c_1\pi_t - e_2c_2y_t + \kappa\eta(1-\nu^0)d_t + e_2\alpha^e_{\pi,t}\pi_{t-1} - e_1\alpha^e_{y,t}y_{t-1} \\ &- e_2\epsilon^r_t + \kappa\eta(1-\nu^0)D_t - e_2c_3r_{t-1}. \end{aligned} \tag{48}$$

The stock market

Lastly, the stock log price impact function is defined as:

$$s_t = s_{t-1} + a(\omega^F_t D^F_t + \omega^C_t D^C_t + \Lambda_t) + \epsilon^s_t, \tag{49}$$

where a is assumed equal 1. For simplicity it is eliminated from the derivation. Plug in households' demand for stock (equation 40):

$$s_t = s_{t-1} + \omega^F_t D^F_t + \omega^C_t D^C_t + c_{\Lambda,y}y_t - c_{\Lambda,r}r_t - c_{\Lambda,s}s_t + \epsilon^s_t. \tag{50}$$

Plug in Taylor rule and rearrange:

$$(1 + c_{\Lambda,s})s_t = s_{t-1} + \omega_t^F D_t^F + \omega_t^C D_t^C + c_{\Lambda,y} y_t + \epsilon_t^s - c_{\Lambda,r}(c_1\pi_t + c_2 y_t + c_3 r_{t-1} + \epsilon_t^r). \quad (51)$$

The fundamentalists' and chartists demand for stock are defined respectively by:

$$\begin{aligned} D_t^F &= K^F(y_{t-1} - s_{t-1}), \\ D_t^C &= K^C(s_{t-1} - s_{t-2}). \end{aligned} \quad (52)$$

Plug these in equation 51 and rearrange to reach the fifth state equation:

$$\begin{aligned} (1 + c_{\Lambda,s})s_t = &- c_{\Lambda,r}c_1\pi_t + (c_{\Lambda,y} - c_2 c_{\Lambda,r})y_t + \omega_t^F k^F y_{t-1} + (1 + \omega_t^C k^C - \omega_t^F k^F)s_{t-1} \\ &- \omega_t^C k^C s_{t-2} - c_{\Lambda,r}c_3 r_{t-1} - c_{\Lambda,r}\epsilon_t^r + \epsilon_t^s. \end{aligned} \quad (53)$$

The state space representation

The state space representation then reads:

$$\begin{pmatrix} \pi_t \\ y_t \\ d_t \\ \chi_t \\ s_t \end{pmatrix} = \mathbf{A}_t^{-1}\mathbf{B_t} \begin{pmatrix} \pi_{t-1} \\ y_{t-1} \\ d_{t-1} \\ \chi_{t-1} \\ s_{t-1} \end{pmatrix} + \mathbf{A}_t^{-1}\mathbf{C} \begin{pmatrix} \epsilon_t^\pi \\ \epsilon_t^y \\ \epsilon_t^r \\ \epsilon_t^s \end{pmatrix} + \mathbf{A}_t^{-1}\mathbf{D_t}, \quad (54)$$

where:

$$A_t = \begin{pmatrix} 1 & -b_2 & 0 & 0 & 0 \\ -c_1(e_2 + d_3) & 1 - d_1 - (d_3 + e_2)c_2 & 0 & -e_2 & 0 \\ (d_3 - c_{\Lambda,r})c_1 + i_{t-1} - d_{t-1} & -(1 - d_1 - c_{\Lambda,y} - d_3 c_2 + c_{\Lambda,r}c_2) & 1 & 0 & -c_{\Lambda,s} \\ c_1 e_2 & c_2 e_2 & -\kappa\eta(1 - \nu^0) & e_2 - \eta & 0 \\ c_{\Lambda,r}c_1 & c_{\Lambda,r}c_2 - c_{\Lambda,y} & 0 & 0 & 1 + c_{\Lambda,s} \end{pmatrix},$$

$$B_t = \begin{pmatrix} \alpha_{\pi,t}^e & 0 & 0 & 0 & 0 \\ -(d_3 + e_2)\alpha_{\pi,t}^e & (d_2 + e_1)\alpha_{y,t}^e & 0 & 0 & 0 \\ d_3\alpha_{\pi,t}^e & -d_2\alpha_{y,t}^e & r_{t-1} & 0 & 0 \\ e_2\alpha_{\pi,t}^e & -e_1\alpha_{y,t}^e & 0 & 0 & 0 \\ 0 & \omega_t^F k^F & 0 & 0 & 1 + \omega_t^C k^C - \omega_t^F k^F \end{pmatrix},$$

$$C = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & d_3 + e_2 & 0 \\ 0 & 0 & c_{\Lambda,r} - d_3 & 0 \\ 0 & 0 & -e_2 & 0 \\ 0 & 0 & -c_{\Lambda,r} & 1 \end{pmatrix}, \qquad \text{and} \qquad D_t = \begin{pmatrix} 0 \\ (d_3 + e_2)c_3 r_{t-1} \\ -\rho_{t-1} l_{t-1} + (c_{\Lambda,r} - d_3)c_3 r_{t-1} \\ \kappa\eta(1 - \nu^0)p_t - e_2 c_3 r_{t-1} \\ -\omega_t^C k^C s_{t-2} - c_{\Lambda,r} c_3 r_{t-1} \end{pmatrix}.$$

Appendix B Impulse Response Analysis

To calculate impulse response functions, we follow the steps of the experiment discussed in Lengnick and Wohltmann (2013). These steps are described as follows:

1. Generate model dynamics for one particular random seed.
2. Generate the dynamics again with the same random seed, but with ϵ_{50}^r increased by 1. In other words, at time $t = 50$, the value of the interest rate shock is higher than the same shock at the same time in the previous step with an amount $+1$.
3. Calculate the difference between the trajectories of steps 1 and 2 which gives the isolated impact of the additional cost shock.
4. Repeat steps 1-3 for 10000 times.