This research was carried out in the Bamberg Doctoral Research Group on Behavioral Macroeconomics (BaGBeM) supported by the Hans-Böckler Foundation (PK 045)

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

Naira Kotb and Christian R. Proaño

Working Paper No. 158

July 2020

BERG Working Paper Series

Bamberg Economic Research Group
Bamberg University
Feldkirchenstraße 21
D-96052 Bamberg
Telefax: (0951) 863 5547
Telephone: (0951) 863 2687
felix.stuebben@uni-bamberg.de
http://www.uni-bamberg.de/vwl/forschung/berg/

ISBN 978-3-943153-79-8

Redaktion:
Dr. Felix Stübben*

* felix.stuebben@uni-bamberg.de

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

Naira Kotb[*a] and Christian R. Proaño[a,b]

[a]Otto-Friedrich-Universität Bamberg, Germany

[b]Centre for Applied Macroeconomic Analysis, Australia

July 8, 2020

Abstract

In this paper we incorporate a stock market and a banking sector in a behavioral macro-finance model with heterogenous and boundedly rational expectations. Households' savings are diversified among bank deposits and stock purchases, and banks' lending to firms is subject to capital-related costs. We find that households' participation in the stock market, coupled to the existence of a capital-constrained banking sector affects the transmission of monetary policy to the economy significantly, and that households' deposits act as a critical spill-over channel between the real and the financial sectors. In other words, we relate the regulatory stance in the banking sector with the degree of pass-through of monetary policy shocks. Further, we investigate the performance of a leaning-against-the-wind (LATW) monetary policy which targets asset prices concerning macroeconomic and financial stability.

Keywords: Behavioral Macroeconomics, Banking, Stock Markets, Monetary Policy

JEL classification: E44, E52, G21

---

[*]Corresponding author. E-mail: naira.kotb@uni-bamberg.de. We would like to thank Frank Westerhoff, Mishael Milakovic, Joep Lustenhouwer, Tomasz Makarewicz, Tim Hagenhoff and Andrea Gurgone for helpful comments and suggestions, as well as participants of the 6th GENED Meeting at Kiel University, the 2018 CFE conference in Pisa, the 2019 FMM conference in Berlin and the Minsky at 100 conference in Milan. Financial support by the Hans-Böckler Foundation is gratefully acknowledged.

1 Introduction

As pointed out by Woodford (2010), the 2007 Global Financial Crisis showed the importance of 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. Indeed, as pointed out by Milani (2017), abstracting from key markets such as the stock market in macro-financial models may lead to serious misspecification issues which may lead to a biased understanding of the interaction between the financial and the real sectors. Further, as pointed out by Caballero (2010), factors like boundedly rational behavior, expectations formation and complex dynamics cannot be abstracted from, as they seem to play a key role in the interaction between the financial and the real sectors, and in the emergence of macrofinancial instability.

The existence of different types of financial frictions has also important implications for the transmission of monetary policy, as it is well know. So far, the related literature has outlined two main channels: the *balance sheet channel* (Bernanke and Gertler, 1989) which stresses the impact of monetary policy on the borrowers' (firms and households) balance sheets (and hence on the external finance premium they are confronted with), and the *bank lending channel* (Bernanke and Blinder, 1988) 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 its 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, as discussed e.g. by Romer and Romer (1990) and Bernanke and Gertler (1995).

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*a*,*b*), 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.

Peek and Rosengren (1995) stress that capital-constrained banks and non-constrained banks respond very differently to monetary policy shocks: a change in monetary policy that drains bank deposits leads capital-constrained banks to cut their loan supply to firms, the latter, not having an adequate replacement to loans, would be forced to shrink their real activity. The bank lending channel requires thus two conditions to be effectively present. First, bank deposits are vital to banks and cannot be costlessly or frictionlessly replaced by other sources of funds. Second, firms are largely bank dependent in the sense that any disrupt in the supply of loans by banks would highly impact their real activities (Bernanke and Gertler, 1995; Kashyap and Stein, 1994; Lin, 2019). Bank capital requirements then establish the link between these two conditions: when deposit level falls, capital constrained banks have to cut loan supply, which in turn triggers a downward pressure on the real activity. Indeed, 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 the bank loan supply.

Against this background, the present paper seeks to contribute from a behavioral perspective to our understanding of the mechanisms through which the financial system and the real sector of the economy interact, and how the interaction between the banking sector and the stock market may affect the transmission mechanism of monetary policy. 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 a heterogeneous agents stock market and a capital-constrained banking sector in a behavioural New Keynesian model with heterogenous boundedly rational expectations. As for the stock market, our model includes two types of stock 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 as illustrated in Lengnick and Wohltmann (2016). However, 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 loan interest spread, and hence the entire economic activity. Regarding the banking sector, 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 of the loan rate over the deposits rate in a way that maximizes their profits given the costs of deviating from the regulatory capital-to-assets target ratio. 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.

Our model, though quite stylized, features a variety of interesting and innovative aspects. First and foremost, our model features an economy where both market-based and bank-based financial sectors are represented and can be easily analyzed. Each of these two sectors is governed by different sets of rules, transmits shocks to the real sector differently and reacts itself differently to exogenous shocks. Moreover, and as illustrated and stressed in the following sections, 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 recognizes the limited cognitive abilities of agents in the real world. Lastly and most importantly, our setup highlights the role of the regulatory stance of the banking sector in the degree of pass-through of monetary policy shocks. This issue has been recently investigated by Darracq Paries et al. (2020) which examine the way macroprudential policy (i.e. capital requirements) affects the monetary transmission mechanism (and vice versa) in different medium scale DSGE models and find that high levels of capital requirements make the economy less responsive to both conventional and unconventional monetary policy. Interestingly, we arrive to a similar result using our framework which is, to the best of our knowledge, the single contribution in this behavioral macroeconomics literature besides De Grauwe and Ji (2019). Their model does not feature however a stock market, and has thus a different focus than ours. At the empirical level, Lambertini and Uysal (2014) and Eickmeier et al. (2018) assess the macroeconomic effects of changes in regulatory capital requirements in the U.S., paying a special attention to the role of monetary policy in cushioning real and credit market effects of such requirements, and Garcia Revelo et al. (2020) analyze the interdependence between the effectiveness of macroprudential policies and the monetary policy stance.

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 in such a behavioral macrofinancial framework. Section 6 concludes.

2 The Model

2.1 The Real Sector

The real sector in our model is represented in a parsimonious manner by an aggregate demand equation and an expectations-augmented 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

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

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; $\tilde{E}_t[z_{t+1}]$ represents the aggregate expectations concerning a variable z (y_t or π_t) to be defined explicitly in equations (6) and (7) below; ρ_t is the loan interest rate charged by banks and is composed of r_t plus a spread term χ_t (see equation 18), and ϵ_t^c and ϵ_t^i are stochastic white noise terms.

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 the households' deposits; Λ_t represents the households' stock demand and l_t the amount of loans awarded to firms. Equation (4) states that households, who are also the owners of the firms, receive an aggregate real income y_t plus the interest income on their bank deposits. They use these incomes to consume, buy stocks Λ_t, accumulate bank deposits d_t and pay the interest on loans borrowed by (their) firms.[1]

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

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

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

where s_t is the stock price. Households demand thus more stocks when their income increases, and less stocks when the deposit (policy) rate or the stock price increases.

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. Galí (2008) and Lengnick and Wohltmann (2016).

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 or chartist (represented by the letter c) and fundamentalist (represented by the letter f), defined respectively as:

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

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

where z^* represents the fundamental value of z.

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:

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

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

$$\begin{aligned} \omega_t^{z,c} &= \frac{\exp(\gamma U_t^{z,c})}{\exp(\gamma U_t^{z,c}) + \exp(\gamma U_t^{z,f})}, \\ \omega_t^{z,f} &= \frac{\exp(\gamma U_t^{z,f})}{\exp(\gamma U_t^{z,c}) + \exp(\gamma U_t^{z,f})} = 1 - \omega_t^{z,c} \end{aligned} \tag{9}$$

and

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

where ρ is a memory parameter and $j \in (c, f)$ and γ reflects the reaction of ω_t to U_t.

2.2 The Banking Sector

The aggregate balance sheet of the banking sector is illustrated 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)	Household 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:

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

Unlike Gerali et al. (2010) who assume retaining all the profits, we assume that banks distribute a fraction (γ^b) of the profits as dividends. These in turn are deposited at the banks themselves.[2] 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.

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

As the banks' net worth (bank capital) is defined as the difference between the banks' assets and the banks' liabilities, the banks' capital-to-asset ratio (ν_t) is thus defined as follows:

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

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 $\nu^\star$. To keep our calculations linear, however, we rearrange the previous equation to express it in terms of a fraction of loan supply, i.e.

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

Using this modified expression, the banks profit maximization problem can be expressed as:

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

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:

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

with $\eta = \frac{1}{\kappa(1-\nu^\star)^2}$. Accordingly, the banks' loan supply is a positive function of banks' marginal profits from loans (i.e. the spread rate χ_t), households' deposits d_t, the accumulated dividends D_t and the regulatory target for the capital-to-asset ratio $\nu^\star$.

Under the assumption that banks know the loan demand function expressed by equation (2) (the firms' investment function), 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. Rearranging equation (17) yields:

$$\chi_t = \kappa(1-\nu^\star)((1-\nu^\star)l_t - d_t - D_t), \tag{18}$$

where $l_t = i_t$. The left-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 $v^\star$). Banks choose the level of loan supply that equalizes the marginal benefit with the marginal cost (leading to a marginal profit of zero). For $\kappa \to 0$,[3] the profit maximizing spread rate is approximately zero.

[3] 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).[4] Two types of financial agents are assumed: chartists and fundamentalists:

$$\tilde{E}_t^c[s_{t+1}] = \theta_s^c(s_{t-1} - s_{t-2}) + s_{t-1}, \tag{19}$$

$$\tilde{E}_t^f[s_{t+1}] = \theta_s^f(s_{t-1}^f - s_{t-1}) + s_{t-1}, \tag{20}$$

where $\tilde{E}_t^f[s_{t+1}]$ and $\tilde{E}_t^c[s_{t+1}]$ denote the expectations of fundamentalists and chartists with respect to the future real stock price, respectively, and s_t^f is the fundamental value of s_t according to the fundamentalists. Following Lengnick and Wohltmann (2016), s_t^f is assumed equal to y_t.

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

$$\begin{aligned} D_t^c &= \beta^c(\tilde{E}_t^c s_{t+1} - s_{t-1}), \\ D_t^f &= \beta^f(\tilde{E}_t^f s_{t+1} - s_{t-1}). \end{aligned} \tag{21}$$

The utility of each rule is defined as follows:

$$U_t^{s,k} = -(1-m)(s_{t-1} - \tilde{E}_{t-2}^k s_{t-1})^2 + mU_{t-1}^{s,k}, \qquad k \in (c, f), \tag{22}$$

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

$$\omega_t^{s,k} = \frac{exp(\mu U_t^{s,k})}{exp(\mu U_t^{s,f}) + exp(\mu U_t^{s,c})}, \tag{23}$$

where μ 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:

$$s_t = s_{t-1} + (\omega_t^{s,f} D_t^f + \omega_t^{s,c} D_t^c + \Lambda_t) + \epsilon_t^s, \tag{24}$$

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.

[4]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 Monetary Policy

We assume that the policy rate is determined by the following Taylor rule as in De Grauwe and Macchiarelli (2015):

$$r_t = \phi_\pi(\pi_t - \pi^*) + \phi_y(y_t - y^*) + \phi_r r_{t-1} + \phi_s s_t + \epsilon_t^r, \tag{25}$$

where π^* is the explicitly announced inflation target of the central bank, y^* is the corresponding steady state value of the output gap (both are assumed to be zero here) and ϵ_t^r a stochastic disturbance term. Note however that we include an additional term $\phi_s s_t$ which represents for $\phi_s > 0$ a leaning-against-the-wind (LATW) policy by the central bank.

3 Calibration

The baseline parametrization of our model (summarized in Table 2) follows Lengnick and Wohltmann (2016) (for the stock market and households' stock demand), 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 θ_s^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)[5] 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 higher value for θ_s^f. The same applies to the parameter θ_s^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. $(\nu_t - \nu^\star)^2$) is measured proportional to the outstanding bank capital, then multiplied by the cost factor. 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).

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

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	$(1-d_1)(0.5)-e_1{}^\star$
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	$(-0.5)(1-d_1)-d_3{}^\star$
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 mechanism	10
ρ	speed of declining weights in mean squares errors (memory)	0.5
θ^c	coefficient in chartists' expectations	0
θ^f	coefficient in fundamentalists' expectations	1
Monetary Policy		
ϕ_π	coefficient of inflation in Taylor equation	1.5
ϕ_y	coefficient of output in Taylor equation	0.5
ϕ_r	interest smoothing parameter in Taylor equation	0.5
ϕ_s	coefficient of stock price in Taylor equation	0
π^*	the central bank's inflation target	0
y^*	the central bank's output gap target	0
σ_{ϵ^r}	standard deviation shocks Taylor equation	0.1
Expectations		
θ_s^c	coefficient in households' chartist expectations	0.4
θ_s^f	coefficient in households' fundamentalist expectations	0.4
β^c	coefficient in traders' chartist stock demand	1
β^f	coefficient in traders' fundamentalist stock demand	1
μ	switching parameter in Brock Hommes mechanism	100
m	speed of declining weights in mean squares 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
$\nu^\star$	target capital-to-loans ratio	0.09
κ	deviation cost parameter	1

* The derivation of the parameters of the investment and consumption functions can be found in De Grauwe and Macchiarelli (2015).

4 Simulation Results

Figure 1 illustrates the role of the regulatory capital requirements (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.

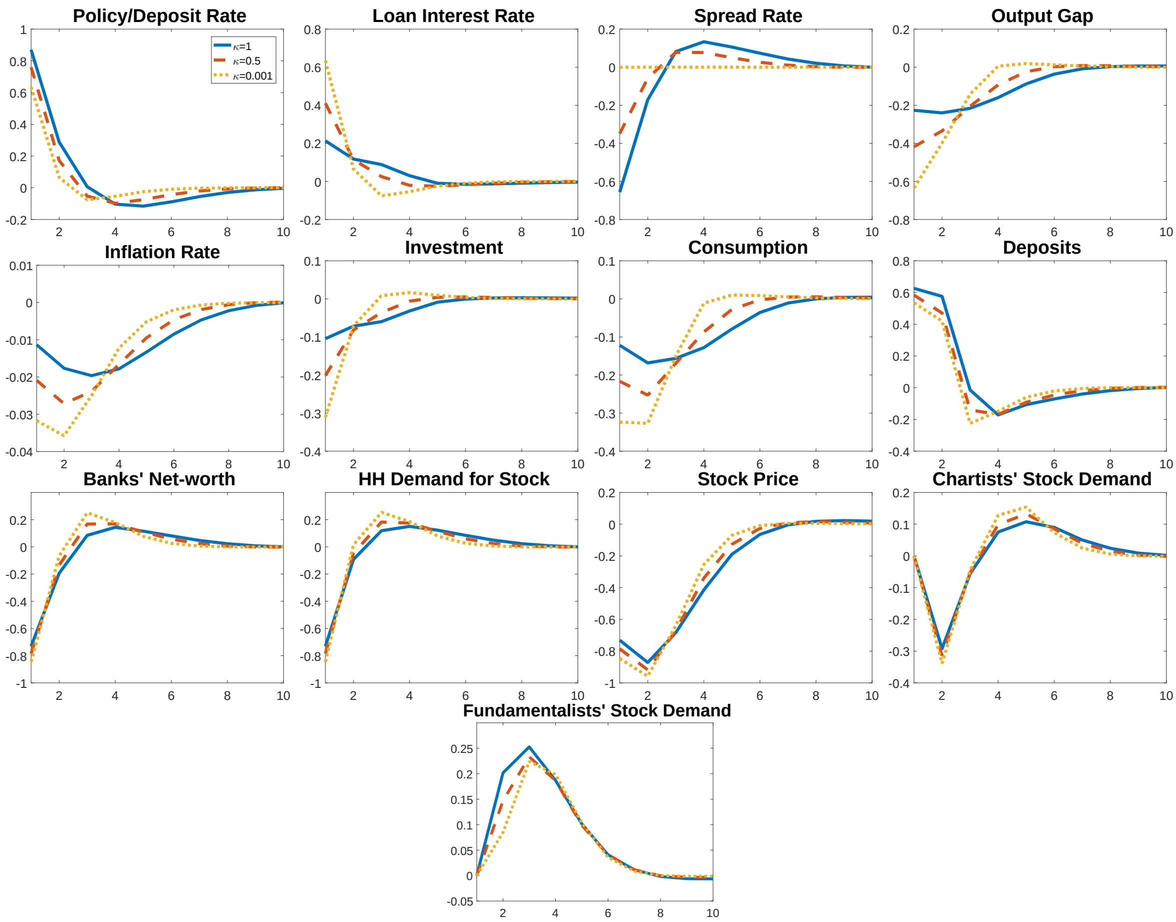

Figure 1: Impulse responses to a one-unit monetary policy shock for different values of the regulatory deviation cost parameter κ.

On impact, an increase in the policy/deposit rate leads to a drop in consumption, investment and output. Households' stock demand decreases and their deposits increase.[6] This leads to a sharp decrease in the stock price.

The increase in the policy rate leads to a decrease in the banks' net worth through the higher

[6]The rise in deposit inflows as a result of interest rate increase is illustrated in e.g. Yankov (2014).

level of household deposit and the lower loan demand (investment demand). According to equation (18), both developments lead to a smaller loan spread rate. At higher values of κ, the fall in the spread rate is bigger, as a result, the loan rate increases on impact by a smaller extent 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 shock is only partially transmitted to the economy when the capital requirements are particularly tight (high κ). By contrast, when capital requirements are loose ($\kappa \to 0$), a contractionary monetary policy is fully transmitted to the economy on impact, as the loan rate increases by nearly the same amount as the policy rate. As a result, output and inflation react more strongly to the policy shock.

The value of κ has also a significant impact on the dynamics of the economy in the following periods. While the increase in the loan rate vanishes rather quickly for $\kappa \to 0$, 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 and far away from zero, the spread rate is a function of the value of banks' net-worth (as per equation 18), which by definition is backward looking. This adds a significant amount of inertia to the model variables.

In Figure 2, households' demand for stock is switched on and off under $\kappa = 1$. In absence of the households' stock demand (represented by the dashed lines), the increase in the policy interest rate has an almost negligible effect on the level of households' deposits, as households do not have any stocks to sell in order to buy more deposits. As banks' net worth remains almost unaffected, banks do not need to modify the loan spread to fulfill the regulatory requirements, transmitting the monetary policy shock fully to the loan rate. The lower level of investment induced by the higher loan interest rate leads to a decrease in output y_t. According to the budget constraint given by equation (4) this causes the deposit level to fall. The positive effect of such a fall on the loan 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 fully transmitted to the real economy on impact, even in the presence of a capital-constrained banking sector. It is only when the households' stock demand Λ_t is switched on, that we witness a significant imperfect pass-through of monetary policy shocks

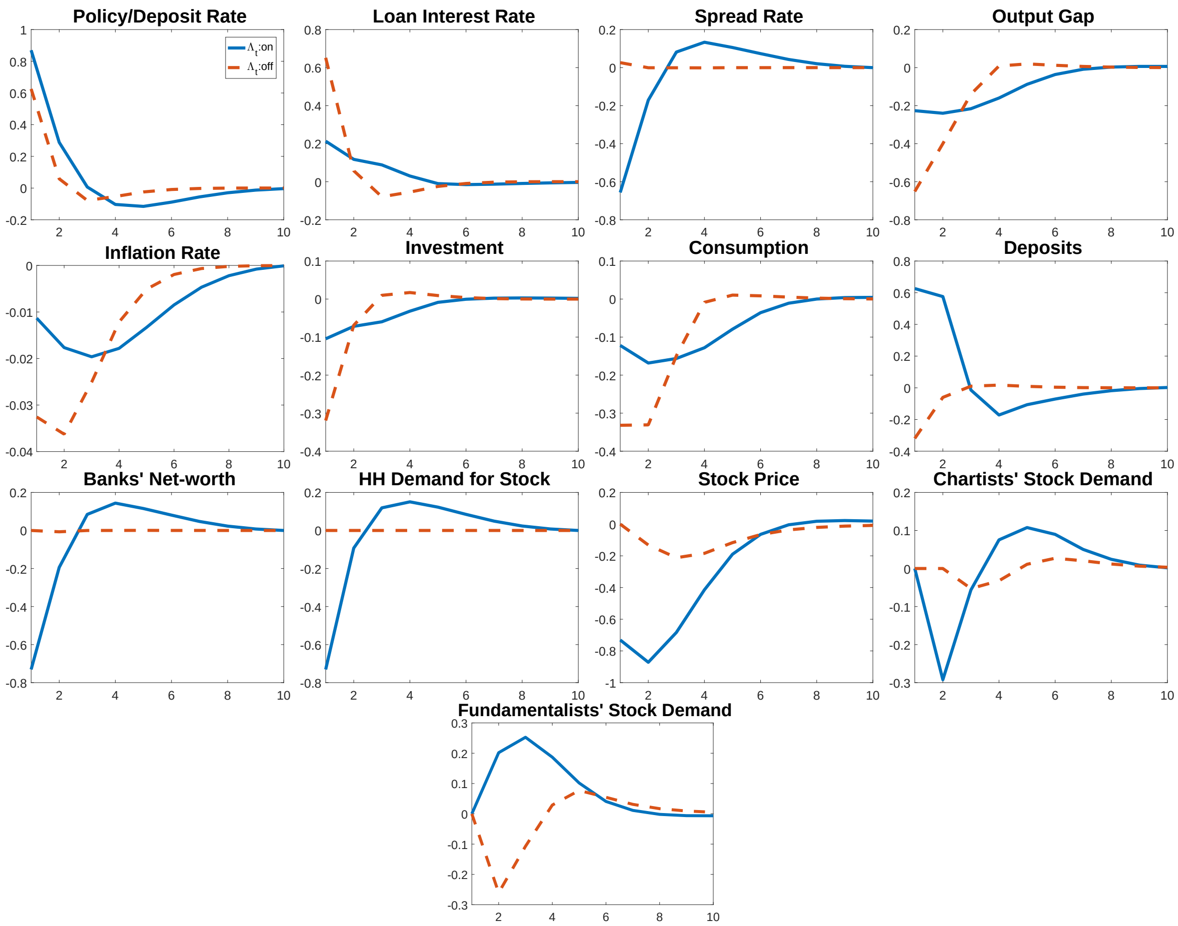

Figure 2: Impulse responses to a one-unit monetary policy shock when households' demand for stock is switched on (continuous line) and when it is switched off (dashed line) for $\kappa = 1$.

to loan rates as discussed above. It is thus the interplay between stock market demand by households and the regulatory capital requirements for the banking sector which leads to a significantly imperfect interest rate pass-through, and thus to a significant weakening of the transmission channel of monetary policy.

Figure 3 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 capital constraint is almost non-binding ($\kappa \to 0$), 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 are not particularly affected.[7] On

[7]Note that in our model aggregate investment does not depend on the stock price. Therefore aggregate investment reacts only when the financing conditions are modified, or when output expectations are revised.

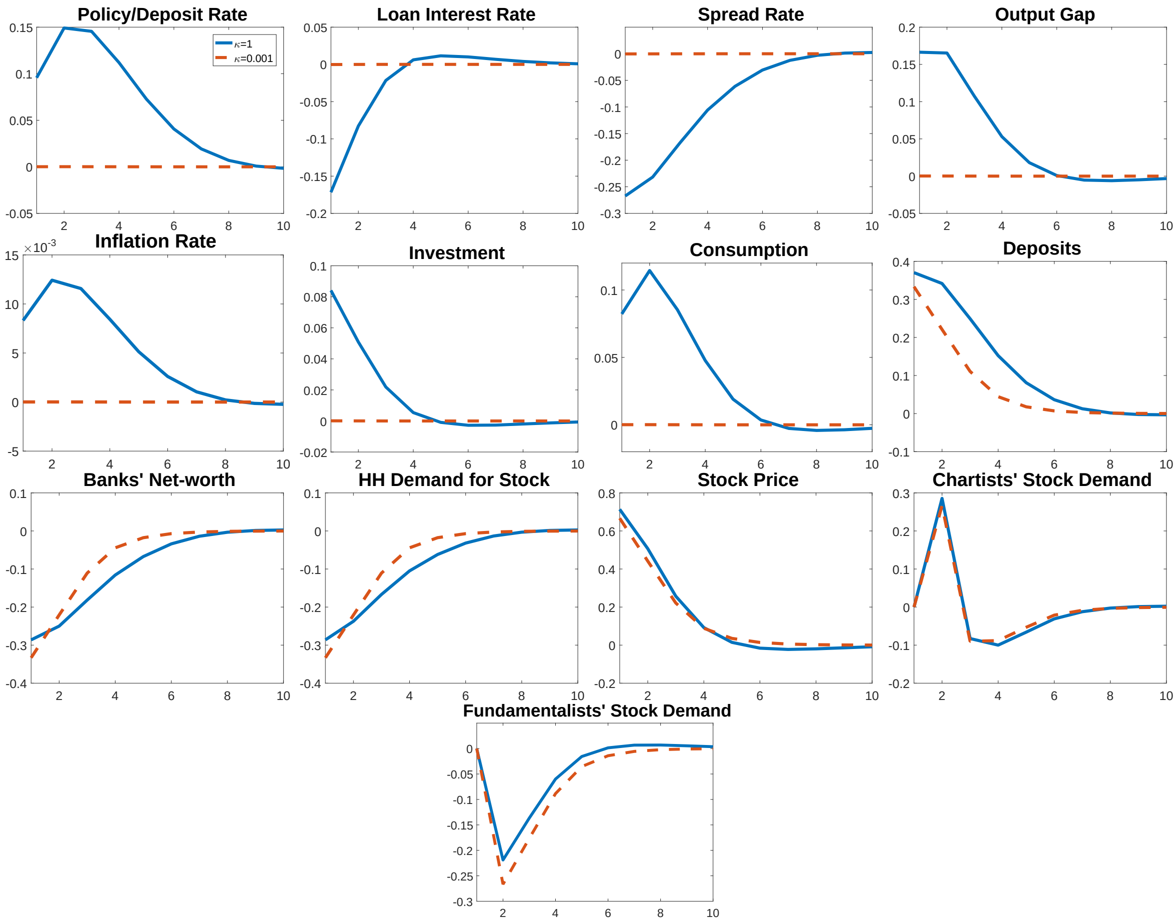

Figure 3: Impulse responses to a one-unit stock price shock for different values of κ.

the other hand, at a positive cost of deviation (i.e. $\kappa > 0$), higher deposits lead to a lower loan spread rate, boosting aggregate investment and aggregate output.

Although the model does not feature 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 loan 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. In our model the capital constraint on loan creation (represented by a positive κ) is thus a potential source for an imperfect pass-through of monetary policy in contrast to the Calvo-like specification used e.g. in Gerke and Hammermann (2016).[8]

[8] For an overview on the empirical evidence for the incomplete interest rate pass-through from policy to loan rates see de Bondt et al. (2005).

The fact that in our model the deposit level 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 spread rate is adjusted. This is in line with Drechsler et al. (2017), which singles 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 loan 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.

In our model, similar to e.g. Lin (2019), when households change their assets allocation between stocks and deposits, banks' lending to firms is altered, and by extension aggregate investment and aggregate output. The process through which households' deposits, responding to different shocks (e.g. monetary policy shocks), affect the real economic activity is only made possible through the presence of capital constraints on the bank sector. 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 allow ϕ_s in equation (25) to be positive and thus investigate the effectiveness of a leaning against the wind (LATW) monetary policy (see e.g. Bernanke and Gertler, 1999, Gilchrist and Leahy, 2002) in stabilizing the stock market and whether this comes at the cost of output gap and inflation stability. We evaluate the effectiveness of a leaning-against-the-wind (LATW) policy in two different ways. First, we study impulse responses of the model variables to a one-time stock price shock under different values of ϕ_s in order to assess the ability of a LATW monetary policy to stabilize the stock market following a financial shock. Then, we analyze the effect of varying the value of ϕ_s on the variances of y_t, π_t and s_t for various constellations of real and financial shocks.

Figure 4 illustrates the dynamic reaction of the main model variables to a one-unit stock

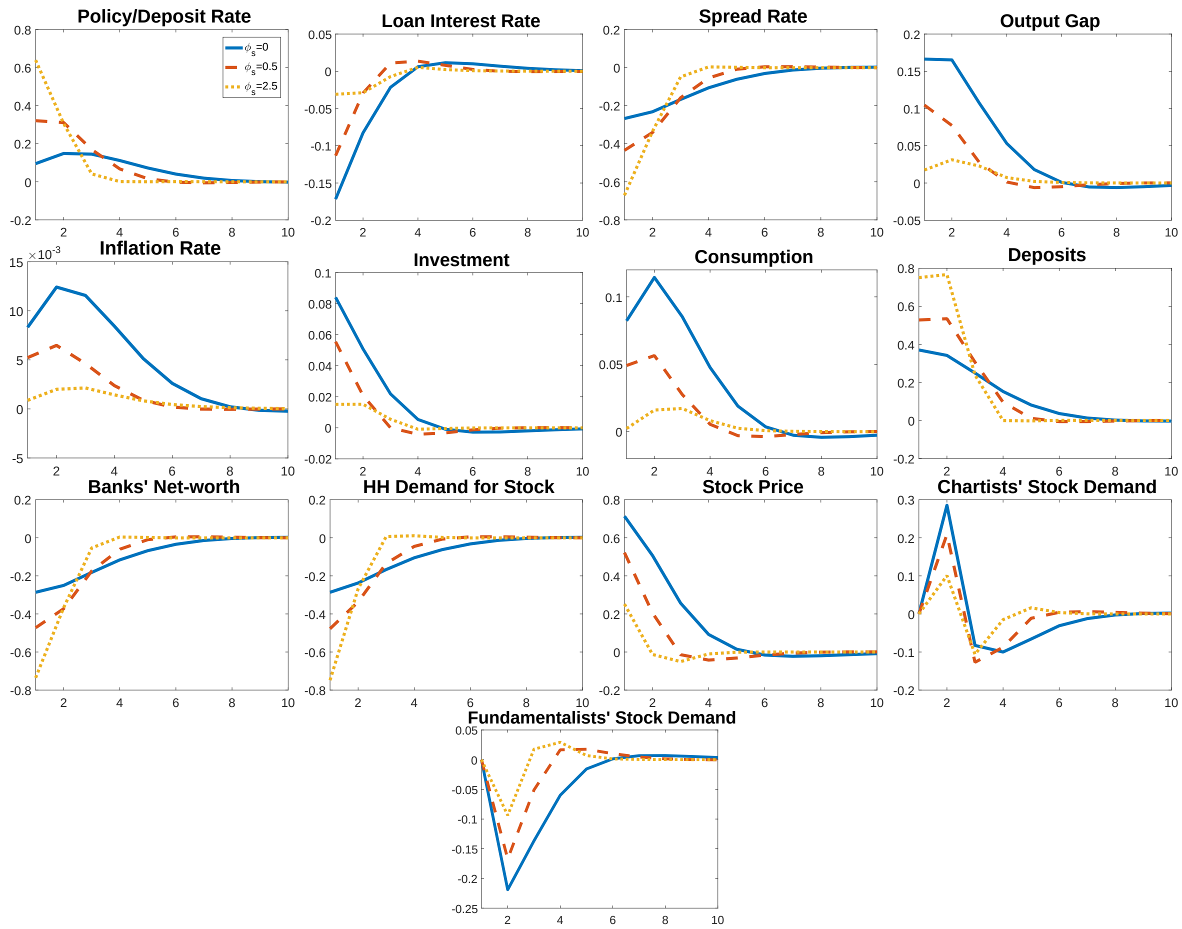

Figure 4: Impulse responses to a one-unit stock price shock at different values of ϕ_s with $\kappa = 1$ (high regulatory deviation costs)

.

price shock for different values of ϕ_s. As it can be clearly observed, the higher the value of ϕ_s, the lower the immediate response of s_t to a stock price shock and the faster the stock price converges to the steady state. This is because at higher values of ϕ_s the policy rate r_t is increased more on impact to a positive stock price shock. The households' demand for stocks on impact decreases too, as households rebalance their financial portfolio towards bank deposits. This leads to a downward pressure on the stock price that partially offsets the effect of the shock. A LATW monetary policy is thus highly effective in stabilizing the stock market following a financial shock in the current framework. Further, at higher values of ϕ_s, 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 LATW monetary policy is thus able to shield the real sector against excess volatility induced by stock price fluctuations, see also Filardo and Rungcharoenkitkul (2016).

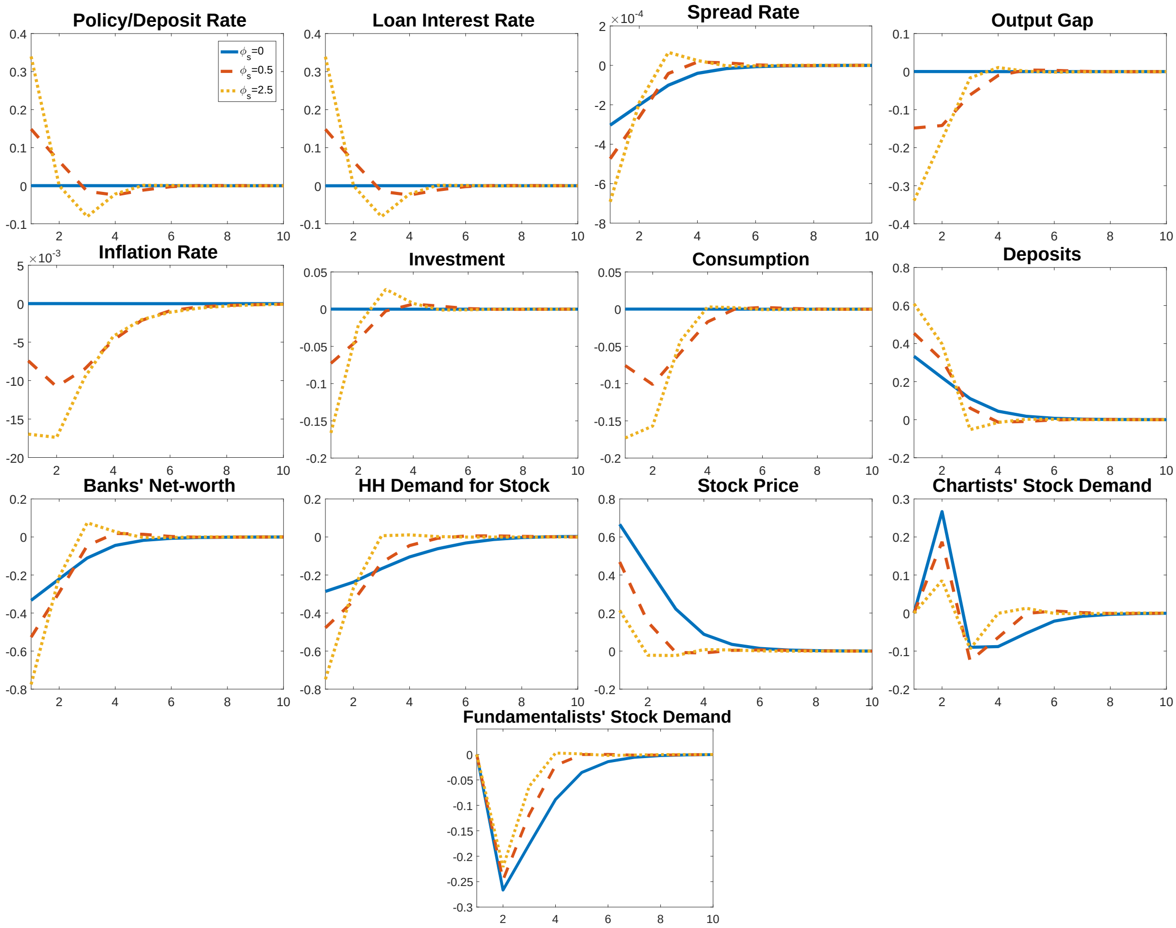

Figure 5: Impulse responses to a one-unit stock price shock at different values of ϕ_s with $\kappa = 0.001$ (low regulatory deviation costs).

Figure 5 reports the dynamic adjustments of the economy following a one-unit stock price shock when the banks' costs from deviating from the regulatory target are switched off. As explained before (i.e. in Figure 3), the negative effect of a stock price shock on the loan spread, and hence the positive effect on output gap and inflation, in this case is almost non-existent. At the same time, at $\phi_s > 0$, the policy rate increases on impact when stock price increases, leading to a downward pressure on inflation and output. Thus, in absence of the regulatory capital requirement costs, a LATW monetary policy has a negative impact on the real sector when responding to positive stock price shocks. This means that a LATW policy, in this case, can only stabilize the stock market on the expenses of the stability of the real sector.

To examine further the interplay of the banking regulatory stance (represented by κ) and the performance of a LATW monetary policy with respect to macroeconomic and financial stabilization we simulate our theoretical model for 2000 periods and compute the variances of the output gap, price inflation and the stock price for various values of ϕ_s and κ in the presence of all real and financial shocks hitting the economy in every of the 2000 periods used in the simulation.

Figure 6: Variances of y_t, π_t and s_t at different combinations of ϕ_s and κ.

Figure 6 illustrates the results of this simulation exercise. As it can be observed, the implementation of a LATW monetary policy is subject to a trade-off between output and stock price volatility on the one side and price inflation volatility on the other side for all considered values of κ: for low values of ϕ_s, a lower price inflation volatility can be achieved at the cost of higher output gap and stock price volatility and vice versa. Interestingly, this trade-off seems to be more pronounced for lower values of κ, i.e. for low regulatory deviation costs. This is in line with our previous finding that the extent of the pass-through of monetary policy shocks to the loan rate is inversely related with the value of κ, see Figure 1. Further, it is also interesting to note that the effectiveness of a LATW policy concerning stock price volatility seems to be unrelated to the value of κ. It is also worth it to highlight the fact that there seems to be no trade-off between output gap and stock price stability for any value of κ. 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. These results are similar to the ones obtained in Lengnick and Wohltmann (2016).

Finally, we repeat this simulation exercise considering only stock price shocks and abstracting from all other real and monetary disturbances ($\sigma_{\epsilon^\pi} = \sigma_{\epsilon^r} = \sigma_{\epsilon^y} = 0$), and report again variances of the output gap, of the price inflation and of the stock price for different values of ϕ_s and κ.

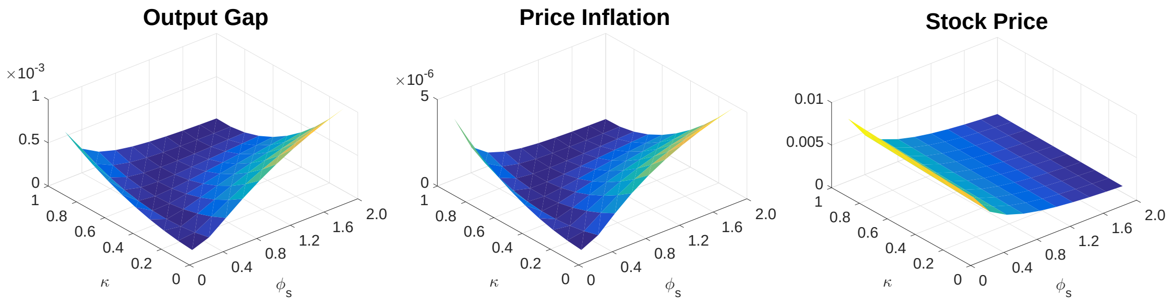

Figure 7: Variances of y_t, π_t and s_t at different combinations of ϕ_s and κ ($\sigma_{\epsilon^\pi} = \sigma_{\epsilon^r} = \sigma_{\epsilon^y} = 0$).

Figure 7 illustrates the results of this final exercise. As it can be observed, when only stock price shocks are considered, a much more complex picture emerges. On the one hand, for low values of κ, a different trade-off is observable, namely one between the output gap and price inflation volatility on the one hand and the stock price volatility on the other hand. A stronger LATW policy, represented by higher values of ϕ_s, reduces indeed the variance of the stock price, but at the same time increases the variance of output and inflation. For higher values of κ, on the other hand, a stricter LATW policy seems to be able to decrease the volatility of the output gap, the price inflation and the stock price.

The finding that the performance of the LATW monetary policy is dependent on the nature of the shocks hitting the economy is also discussed in Gourio et al. (2018). In their model, when only real shocks (i.e. productivity and demand shocks) are considered, the central bank achieves both inflation stability AND simultaneously limits risk of financial crises by targeting inflation stability. On the other hand, when financial shocks are present, the failure to respond to such shocks exposes the economy to larger crisis risk. In this case, it is optimal for the central bank to consider a LATW policy to reduce crisis risk against the costs of larger fluctuations in output and inflation.

6 Concluding Remarks

While the need for a better regulation of the financial system has widely acknowledged in the economics profession since the global financial crises, there are still many open questions concerning the aggregate effects of the individual regulatory and macroprudential policies which have been implemented around the world, and how and under which circumstances may such policies interact with the more traditional monetary and fiscal policies. Against this background, this paper extended the literature on macro-financial linkages by analyzing the interaction between the stock market, the banking sector and the real sector in a behavioral macroeconomic model along the lines of De Grauwe and Macchiarelli (2015).

Two main findings of our study are to be highlighted: First, households' stock market participation creates an important link between the stock market and aggregate investment through the impact of stock market developments on the households' holding of bank deposits, and thus on the impact of regulatory bank requirements. 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 capital-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, the banks' constraints, together with the existence of a households' stock demand, create a mechanism which affects the transmission of monetary policy to the real sector through its impact on the pass-through of the policy rate to the loan interest rate. In a country where the households' stock market participation is not particularly high one should not expect significant effects of stock market fluctuations on the bank's balance sheet position, and thus on the banks' lending capacity, and vice versa. And second, while a leaning-against-the-wind (LATW) monetary policy seems to be an effective strategy for the stabilization of the stock market, the related trade-off between financial and macroeconomic and price inflation stability depends on the regulatory stance for the banking sector, as well as on the type of shocks to which the economy is subject.

References

Bernanke, B. and Blinder, A. (1988), 'Credit, money and aggregate demand', *American Economic Review* **78**, 435–39.

Bernanke, B. and Gertler, M. (1989), 'Agency costs, net worth, and business fluctuations', *American Economic Review* **79**(1), 14–31.

Bernanke, B. and Gertler, M. (1995), 'Inside the black box: The credit channel of monetary policy transmission', *Journal of Economic Perspectives* **9**(4), 27–48.

Bernanke, B. and Gertler, M. (1999), 'Monetary policy and asset price volatility', *Federal Reserve Bank of Kansas City Economic Review* **84**(Q IV), 17–51.

Borio, C. and Zhu, H. (2012), 'Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism?', *Journal of Financial Stability* **8**(4), 236–251.

Branch, W. and McGough, B. (2010), 'Dynamic predictor selection in a New Keynesian model with heterogeneous expectations', *Journal of Economic Dynamics and Control* **34**(8), 1492–1508.

Brock, W. and Hommes, C. (1998), 'Heterogeneous beliefs and routes to chaos in a simple asset pricing model', *Journal of Economic Dynamics and Control* **22**, 1235 – 1274.

Caballero, R. J. (2010), 'Macroeconomics after the crisis: Time to deal with the pretense-of-knowledge syndrom', *Journal of Economic Perspectives* **24**(4), 85–102.

Darracq Paries, M., Karadi, P., KÃ¶rner, J., Kok, C., Mazelis, F., Nikolov, K., Rancoita, E., Van der Ghote, A., Cozzi, G. and Weber, J. (2020), Macroprudential policy measures: macroeconomic impact and interaction with monetary policy, Working Paper Series 2376, European Central Bank.

de Bondt, G., Mojon, B. and Valla, N. (2005), Term structure and the sluggishness of retail bank rates in euro area countries, Working Paper 518, European Central Bank.

De Grauwe, P. (2011), 'Animal spirits and monetary policy', *Economic Theory* **47**(2-3), 423–457.

De Grauwe, P. (2012), 'Booms and busts in economic activity: A behavioral explanation', *Journal of Economic Behavior and Organization* **83**(3), 484–501.

De Grauwe, P. and Ji, Y. (2019), Banks in the behavioral model. Paper presented at the Second Behavioral Macroeconomics Model at the University of Bamberg.

De Grauwe, P. and Macchiarelli, C. (2015), 'Animal spirits and credit cycles', *Journal of Economic Dynamics and Control* **59**(C), 95–117.

Drechsler, I., Savov, A. and Schnabl, P. (2017), 'The deposits channel of monetary policy', *The Quarterly Journal of Economics* **132**(4), 1819–1876.

Eickmeier, S., Kolb, B. and Prieto, E. (2018), Effects of bank capital requirement tightenings on inequality, Discussion Papers 54/2018, Deutsche Bundesbank.

Filardo, A. and Rungcharoenkitkul, P. (2016), A quantitative case for leaning against the wind, BIS Working Papers 594, Bank for International Settlements.

Galí, J. (2008), *Monetary policy, inflation, and the business cycle: An introduction to the New Keynesian framework*, Princeton University Press.

Gambacorta, L. and Shin, H. S. (2018), 'Why bank capital matters for monetary policy', *Journal of Financial Intermediation* **35**(PB), 17–29.

Garcia Revelo, J. D., Lucotte, Y. and Pradines-Jobet, F. (2020), 'Macroprudential and monetary policies: The need to dance the tango in harmony', *Journal of International Money and Finance* . forthcoming.

Gerali, A., Neri, S., Sessa, L. and Signoretti, F. (2010), 'Credit and banking in a DSGE model of the euro area', *Journal of Money, Credit and Banking* **42**(s1), 107–141.

Gerke, R. and Hammermann, F. (2016), 'Robust monetary policy in a New Keynesian model with imperfect interest rate pass-through', *Macroeconomic Dynamics* **20**, 1504–1526.

Gilchrist, M. and Leahy, J. (2002), 'Monetary policy and asset prices', *Journal of Monetary Economics* **49**(1), 3228–54.

Gourio, F., Kashyap, A. K. and Sim, J. (2018), 'The trade offs in leaning against the wind', *IMF Economic Review* **66**(1), 70–115.

Kashyap, A. and Stein, J. (1994), Monetary policy and bank lending, *in* 'Monetary Policy', National Bureau of Economic Research, Inc, pp. 221–261.

Kopecky, K. J. and VanHoose, D. (2004*a*), 'Bank capital requirements and the monetary transmission mechanism', *Journal of Macroeconomics* **26**(3), 443–464.

Kopecky, K. J. and VanHoose, D. (2004*b*), 'A model of the monetary sector with and without binding capital requirements', *Journal of Banking and Finance* **28**, 633–646.

Lambertini, L. and Uysal, P. I. (2014), Macroeconomic implications of bank capital requirements. mimeo.

Lengnick, M. and Wohltmann, H.-W. (2013), 'Agent-based financial markets and New Keynesian macroeconomics: A synthesis', *Journal of Economic Interaction and Coordination* **8**(1), 1–32.

Lengnick, M. and Wohltmann, H.-W. (2016), 'Optimal monetary policy in a New Keynesian model with animal spirits and financial markets', *Journal of Economic Dynamics and Control* **64**(C), 148–165.

Lin, L. (2019), 'Bank deposits and the stock market', *The Review of Financial Studies* . forthcoming.

Milani, F. (2017), 'Learning about the interdependence between the macroeconomy and the stock market', *International Review of Economics and Finance* **49**(C), 223–242.

Peek, J. and Rosengren, E. (1995), 'Is bank lending important for the transmission of monetary policy? an overview', *New England Economic Review* **39**(Nov), 3–11.

Proaño, C. R. (2011), 'Exchange rate determination, macroeconomic dynamics and stability under heterogeneous behavioral FX expectations', *Journal of Economic Behavior and Organization* **77**(2), 177–88.

Proaño, C. R. (2013), 'Monetary policy rules and macroeconomic stabilization in small open economies under behavioral FX trading: Insights from numerical simulations', *Manchester School* **81,**(6), 992–1011.

Romer, C. and Romer, D. (1990), 'New evidence on the monetary transmission mechanism', *Brookings Papers on Economic Activity* **1**, 149–214.

Van den Heuvel, S. (2002), 'Does bank capital matter for monetary transmission?', *Economic Policy Review* **8**(May), 259–265.

Van den Heuvel, S. (2006), The bank capital channel of monetary policy, 2006 Meeting Papers 512, Society for Economic Dynamics.

Westerhoff, F. (2008), ‘The use of agent-based financial market models to test the effectiveness of regulatory policies’, *Journal of Economics and Statistics* **228**(2-3), 195–227.

Woodford, M. (2010), ‘Financial intermediation and macroeconomic analysis’, *Journal of Economic Perspectives* **24**(4), 21–44.

Yankov, V. (2014), In Search of a Risk-free Asset, Finance and Economics Discussion Series 2014-108, Board of Governors of the Federal Reserve System (U.S.).

Appendix A Model Derivation

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

$$\pi_t = \tilde{E}_t \pi_{t+1} + b_2 y_t + \epsilon_t^{\pi}. \tag{26}$$

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

$$\begin{aligned} E_t \pi_{t+1} &= \omega_t^{\pi,c} E_t^c \pi_{t+1} + (1 - \omega_t^{\pi,c}) E_t^f \pi_{t+1}, && (27) \\ E_t y_{t+1} &= \omega_t^{y,c} E_t^c y_{t+1} + (1 - \omega_t^{y,c}) E_t^f y_{t+1}, && (28) \end{aligned}$$

where ω_t^c is the weight of chartists and $1 - \omega_t^c$ is the weight of fundamentalists.

Fundamentalists and chartists' expectations are given by:

$$\begin{aligned} \tilde{E}_t^c z_{t+1} &= \theta_z^c (z_{t-1} - z_{t-2}) + z_{t-1} && z \in (y, \pi), \\ \tilde{E}_t^f z_{t+1} &= \theta_z^f (z^* - z_{t-1}) + z_{t-1} && z^\star \in (y^*, \pi^*), && (29) \end{aligned}$$

where θ^f is assumed equal 1, and y^*, π^* and θ^c are assumed equal 0. Equations 27 and 28 could thus be simplified respectively to:

$$\begin{aligned} E_t \pi_{t+1} &= \omega_t^{\pi,c} \pi_{t-1}, && (30) \\ E_t y_{t+1} &= \omega_t^{y,c} y_{t-1}. && (31) \end{aligned}$$

Plug equation 30 in equation 26 to reach the first state equation:

$$\pi_t = \omega_t^{\pi,c} \pi_{t-1} + b_2 y_t + \epsilon_t^{\pi}. \tag{32}$$

Taylor rule is defined by:

$$r_t = \phi_\pi (\pi_t - \pi^*) + \phi_y (y_t - y^*) + \phi_r r_{t-1} + \phi_s s_t + \epsilon_t^r, \tag{33}$$

where s_t is the stock price.

Output gap is decomposed into consumption and investment:

$$y_t = c_t + i_t + \epsilon_t^y. \tag{34}$$

Consumption is defined by:

$$c_t = d_1 y_t + d_2 \tilde{E}_t y_{t+1} + d_3 (r_t - \tilde{E}_t \pi_{t+1}). \tag{35}$$

Investment is defined by:

$$\begin{aligned} i_t &= e_1 \tilde{E}_t y_{t+1} + e_2(\rho_t - \tilde{E}_t \pi_{t+1}) \\ &= e_1 \tilde{E}_t y_{t+1} + e_2(r_t + \chi_t - \tilde{E}_t \pi_{t+1}). \end{aligned} \tag{36}$$

Plug Taylor rule and market expectations of π_t and y_t in 35 and 36 then plug these in 34 and rearrange to reach the <u>second state equation</u>:

$$\begin{aligned} (1 - d_1 - \phi_y d_3 - \phi_y - \phi_y e_2) y_t =& (d_3 + e_2)\phi_\pi \pi_t + e_2 \chi_t + (d_2 \omega_t^{y,c} + e_1 \omega_t^{y,c}) y_{t-1} \\ & - (d_3 \omega_t^{\pi,c} + e_2 \omega_t^{\pi,c}) \pi_{t-1} + \epsilon_t^y + (d_3 + e_2)\phi_r r_{t-1} + (d_3 + e_2)\epsilon_t^r. \end{aligned} \tag{37}$$

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

$$y_t + (r_{t-1} - \pi_t) d_{t-1} = c_t + d_t + \Lambda_t + (\rho_{t-1} - \pi_t) l_{t-1}. \tag{38}$$

Households' demand for stock is defined by:

$$\Lambda_t = c_{\Lambda,y} y_t - c_{\Lambda,r} r_t - c_{\Lambda,s} s_t. \tag{39}$$

Substitute c_t, Λ_t and l_t in equation 38 with equations 35 and 39 and i_t respectively, then plug in the Taylor rule and the market expectations to reach the <u>third state equation</u> :

$$\begin{aligned} d_t =& (c_{\Lambda,r}\phi_\pi - d_3\phi_\pi - i_{t-1} + d_{t-1})\pi_t + (1 - d_1 - c_{\Lambda,y} - d_3\phi_y + c_{\Lambda,r}\phi_y) y_t + c_{\Lambda,s} s_t \\ & + d_3 \omega_t^{\pi,c} \pi_{t-1} - d_2 \omega_t^{y,c} y_{t-1} + (c_{\Lambda,r} - d_3)\epsilon_t^r + r_{t-1} d_{t-1} - \rho_{t-1} i_{t-1} + (c_{\Lambda,r} - d_3)\phi_r r_{t-1}. \end{aligned} \tag{40}$$

Banking

The banking sector faces the following maximization problem:

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

Taking derivative with respect to l_t:

$$\begin{aligned} & \rho_t - r_t - \kappa((1-\nu^\star) l_t - d_t - D_t)(1 - \nu^\star) = 0 \\ & \chi_t + r_t - r_t - \kappa(1-\nu^\star)((1-\nu^\star) l_t - d_t - D_t) = 0 \\ & \chi_t - \kappa(1-\nu^\star)^2 l_t + \kappa(1-\nu^\star) d_t + \kappa(1-\nu^\star) D_t = 0 \\ & \kappa(1-\nu^\star)^2 l_t = \chi_t + \kappa(1-\nu^\star) d_t + \kappa(1-\nu^\star) D_t \\ & l_t = \frac{1}{\kappa(1-\nu^\star)^2}\chi_t + \frac{1}{1-\nu^\star} d_t + \frac{1}{1-\nu^\star} D_t. \end{aligned} \tag{41}$$

Assume $\frac{1}{\kappa(1-\nu^\star)^2} = \eta$. Equation 41 becomes:

$$l_t = \eta\chi_t + \kappa\eta(1-\nu^\star)d_t + \kappa\eta(1-\nu^\star)D_t, \tag{42}$$

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

$$D_t = D_{t-1} + \gamma^b j_t = \gamma^b \sum_{n=1}^{t} j_n, \tag{43}$$

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

$$j_t = \rho_{t-1}l_{t-1} - r_{t-1}d_{t-1} - \delta^b k_{t-1}, \tag{44}$$

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

$$k_t = k_{t-1} + (1-\gamma^b)j_t = (1-\gamma^b)\sum_{n=1}^{t} j_n. \tag{45}$$

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:

$$\begin{aligned} i_t &= l_t \\ e_1\omega_t^{y,c}y_{t-1} + e_2 r_t - e_2\omega_t^{\pi,c}\pi_{t-1} + e_2\chi_t &= \eta\chi_t + \kappa\eta(1-\nu^\star)d_t + \kappa\eta(1-\nu^\star)D_t. \end{aligned} \tag{46}$$

Plugging in the Taylor rule and solving for χ_t yields the fourth state equation:

$$\begin{aligned} (e_2-\eta)\chi_t = &- e_2\phi_\pi\pi_t - e_2\phi_y y_t + \kappa\eta(1-\nu^\star)d_t + e_2\omega_t^{\pi,c}\pi_{t-1} - e_1\omega_t^{y,c}y_{t-1} \\ &- e_2\epsilon_t^r + \kappa\eta(1-\nu^\star)D_t - e_2\phi_r r_{t-1}. \end{aligned} \tag{47}$$

The stock market

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

$$s_t = s_{t-1} + a(\omega_t^{s,f}D_t^f + \omega_t^{s,c}D_t^c + \Lambda_t) + \epsilon_t^s, \tag{48}$$

where a is assumed equal 1. For simplicity it is eliminated from the derivation. Plug in households' demand for stock (equation 39):

$$s_t = s_{t-1} + \omega_t^{s,f}D_t^f + \omega_t^{s,c}D_t^c + c_{\Lambda,y}y_t - c_{\Lambda,r}r_t - c_{\Lambda,s}s_t + \epsilon_t^s. \tag{49}$$

Plug in Taylor rule and rearrange:

$$(1 + c_{\Lambda,s})s_t = s_{t-1} + \omega_t^{s,f} D_t^f + \omega_t^{s,c} D_t^c + c_{\Lambda,y} y_t + \epsilon_t^s - c_{\Lambda,r}(\phi_\pi \pi_t + \phi_y y_t + \phi_r r_{t-1} + \epsilon_t^r). \quad (50)$$

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

$$\begin{aligned} D_t^f &= \theta^f (y_{t-1} - s_{t-1}), \\ D_t^c &= \theta^c (s_{t-1} - s_{t-2}). \end{aligned} \quad (51)$$

Plug these in equation 50 and rearrange to reach the <u>fifth state equation</u>:

$$\begin{aligned} (1 + c_{\Lambda,s})s_t = &- c_{\Lambda,r}\phi_\pi \pi_t + (c_{\Lambda,y} - \phi_y c_{\Lambda,r}) y_t + \omega_t^{s,f} \theta^f y_{t-1} + (1 + \omega_t^{s,c}\theta^c - \omega_t^{s,f}\theta^f) s_{t-1} \\ &- \omega_t^{s,c}\theta^c s_{t-2} - c_{\Lambda,r}\phi_r r_{t-1} - c_{\Lambda,r}\epsilon_t^r + \epsilon_t^s. \end{aligned} \quad (52)$$

The state space representation

The state space representation then reads:

$$\begin{pmatrix} \pi_t \\ y_t \\ d_t \\ \chi_t \\ s_t \end{pmatrix} = \mathbf{A}_t^{-1}\mathbf{B_t} \begin{pmatrix} \pi_{t-1} \\ y_{t-1} \\ d_{t-1} \\ \chi_{t-1} \\ s_{t-1} \end{pmatrix} + \mathbf{A}_t^{-1}\mathbf{C} \begin{pmatrix} \epsilon_t^\pi \\ \epsilon_t^y \\ \epsilon_t^r \\ \epsilon_t^s \end{pmatrix} + \mathbf{A}_t^{-1}\mathbf{F_t}, \quad (53)$$

where:

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

$$B_t = \begin{pmatrix} \omega_t^{\pi,c} & 0 & 0 & 0 & 0 \\ -(d_3 + e_2)\omega_t^{\pi,c} & (d_2 + e_1)\omega_t^{y,c} & 0 & 0 & 0 \\ d_3\omega_t^{\pi,c} & -d_2\omega_t^{y,c} & r_{t-1} & 0 & 0 \\ e_2\omega_t^{\pi,c} & -e_1\omega_t^{y,c} & 0 & 0 & 0 \\ 0 & \omega_t^{s,f}\theta^f & 0 & 0 & 1 + \omega_t^{s,c}\theta^c - \omega_t^{s,f}\theta^f \end{pmatrix},$$

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

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.

BERG Working Paper Series (most recent publications)

126 Christian **Menden** and Christian R. **Proaño**, Dissecting the Financial Cycle with Dynamic Factor Models, May 2017

127 Christoph **March** and Marco **Sahm**, Contests as Selection Mechanisms: The Impact of Risk Aversion, July 2017

128 Ivonne **Blaurock**, Noemi **Schmitt** and Frank **Westerhoff**, Market entry waves and volatility outbursts in stock markets, August 2017

129 Christoph **Laica**, Arne **Lauber** and Marco **Sahm**, Sequential Round-Robin Tournaments with Multiple Prizes, September 2017

130 Joep **Lustenhouwer** and Kostas **Mavromatis**, Fiscal Consolidations and Finite Planning Horizons, December 2017

131 Cars **Hommes** and Joep **Lustenhouwer**, Managing Unanchored, Heterogeneous Expectations and Liquidity Traps, December 2017

132 Cars **Hommes**, Joep **Lustenhouwer** and Kostas **Mavromatis**, Fiscal Consolidations and Heterogeneous Expectations, December 2017

133 Roberto **Dieci**, Noemi **Schmitt** and Frank **Westerhoff**, Interactions between stock, bond and housing markets, January 2018

134 Noemi **Schmitt**, Heterogeneous expectations and asset price dynamics, January 2018

135 Carolin **Martin** and Frank **Westerhoff**, Regulating speculative housing markets via public housing construction programs: Insights from a heterogeneous agent model, May 2018

136 Roberto **Dieci**, Noemi **Schmitt** and Frank **Westerhoff**, Steady states, stability and bifurcations in multi-asset market models, July 2018

137 Steffen **Ahrens**, Joep **Lustenhouwer** and Michele **Tettamanzi**, The Stabilizing Role of Forward Guidance: A Macro Experiment, September 2018

138 Joep **Lustenhouwer**, Fiscal Stimulus in an Expectation Driven Liquidity Trap, September 2018

139 Tim **Hagenhoff**, An aggregate welfare optimizing interest rate rule under heterogeneous expectations, October 2018

140 Johanna Sophie **Quis**, Anika **Bela** and Guido **Heineck**, Preschoolers' self-regulation, skill differentials, and early educational outcomes, December 2018

141 Tomasz **Makarewicz,** Traders, forecasters and financial instability: A model of individual learning of anchor-and-adjustment heuristics, January 2019

142 Carolin **Martin**, Noemi **Schmitt** and Frank **Westerhoff**, Housing markets, expectation formation and interest rates, January 2019

143 Marc P. **Saur**, Markus G. **Schlatterer** and Stefanie Y. **Schmitt**, Horizontal product differentiation with limited attentive consumers, January 2019

144 Tim **Hagenhoff** and Joep **Lustenhouwer**, The Rationality Bias, February 2019

145 Philipp **Mundt** and Ilfan **Oh**, Asymmetric competition, risk, and return distribution, February 2019

146 Ilfan **Oh**, Autonomy of Profit Rate Distribution and Its Dynamics from Firm Size Measures: A Statistical Equilibrium Approach, February 2019

147 Philipp **Mundt**, Simone **Alfarano** and Mishael **Milakovic**, Exploiting ergodicity in forecasts of corporate profitability, March 2019

148 Christian R. **Proaño** and Benjamin **Lojak**, Animal Spirits, Risk Premia and Monetary Policy at the Zero Lower Bound, March 2019

149 Christian R. **Proaño**, Juan Carlos **Peña** and Thomas **Saalfeld**, Inequality, Macroeconomic Performance and Political Polarization: An Empirical Analysis, March 2019

150 Maria Daniela **Araujo P.**, Measuring the Effect of Competitive Teacher Recruitment on Student Achievement: Evidence from Ecuador, April 2019

151 Noemi **Schmitt** and Frank **Westerhoff**, Trend followers, contrarians and fundamentalists: explaining the dynamics of financial markets, May 2019

152 Yoshiyuki **Arata** and Philipp **Mundt**, Topology and formation of production input interlinkages: evidence from Japanese microdata, June 2019

153 Benjamin **Lojak**, Tomasz **Makarewicz** and Christian R. **Proaño**, Low Interest Rates, Bank's Search-for-Yield Behavior and Financial Portfolio Management, October 2019

154 Christoph **March**, The Behavioral Economics of Artificial Intelligence: Lessons from Experiments with Computer Players, November 2019

155 Christoph **March** and Marco **Sahm**, The Perks of Being in the Smaller Team: Incentives in Overlapping Contests, December 2019

156 Carolin **Martin**, Noemi **Schmitt** and Frank **Westerhoff**, Heterogeneous expectations, housing bubbles and tax policy, February 2020

157 Christian R. **Proaño**, Juan Carlos **Peña** and Thomas **Saalfeld**, Inequality, Macroeconomic Performance and Political Polarization: A Panel Analysis of 20 Advanced Democracies, June 2020

158 Naira **Kotb** and Christian R. **Proaño**, Capital-Constrained Loan Creation, Stock Markets and Monetary Policy in a Behavioral New Keynesian Model, July 2020