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Capital-constrained loan creation, household stock market participation and monetary policy in a behavioural new Keynesian model

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Abstract

In this paper, we incorporate a stock market and a banking sector in a behavioural 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 deviation 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. Further, we relate the deviation costs in the banking sector with the degree of pass-through of monetary policy shocks. Last, we investigate the performance of a leaning-against-the-wind monetary policy, which targets asset prices concerning macroeconomic and financial stability.

KEYWORDS

banking, Behavioural macroeconomics, monetary policy, stock markets

1 | INTRODUCTION

As pointed out, for example, by Woodford (2010), the incorporation of financial intermediation in macroeconomic models in a way that conforms with existing institutional frameworks is a necessary step for a better understanding of the transmission of monetary policy. Further, as argued by Milani (2017), abstracting from key financial 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 in economies such as the US or the UK.

So far, the literature on financial frictions and monetary policy transmission 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 & 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 for example, 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 (2004a, 2004b), 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 which, not having an adequate replacement to loans, would be in turn forced to reduce their economic 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 funding. And second, firms are largely bank dependent in the sense that any disruption in the supply of loans by banks would strongly impact their economic activities (Bernanke & Gertler, 1995; Kashyap & Stein, 1994; Lin, 2019). Bank capital requirements then establish the link between these two conditions: when deposit levels fall, 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. Further, as pointed out by Caballero (2010), factors like boundedly rational behaviour, expectations formation and complex dynamics should not be ignored, as they play a key role in the interaction between the financial and the real sectors, and in the emergence of macrofinancial instability.

Against this background, the present paper seeks to contribute, from a behavioural 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 heterogeneous boundedly rational expectations.

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. According to this setting, 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 capital-to-assets target ratio. As we will see, such a setting generates a feedback loop between the real and the financial sides of the economy affecting the shape of the business cycle that is not dependent on the agents' rational behaviour.

In contrast, our specification of the stock market is based on decisively more behavioural grounds. More specifically, we assume as in Lengnick and Wohltmann (2016) that households hold stocks for speculative and non-speculative motives, and that these two stock demand types are determined by different rules-of-thumb (also with different determinants). By adopting this stock market specification we aim at shedding some light on the macroeconomic implications of households' stock market participation when it is driven by bounded rationality and heterogenous behavioural expectations. As we will show below, the mechanism through which households switch between stocks and deposits, and the determinants for these economic decisions, are central to the model. These do 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.

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 analysed. 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, our setup highlights the role of the deviation costs in 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) who 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 behavioural macroeconomics literature besides De Grauwe and Ji (2019), who analyse a model with a banking sector but without a stock market, and have thus a different focus from 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) analyse the interdependence between the effectiveness of macroprudential policies and the monetary policy stance.

The remainder of the paper is organized 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 behavioural macro-financial framework. Section 6 concludes.

2 | THE MODEL

2.1 | The real sector

In the following we assume that the economy's potential output level is constant and that the actual aggregate output is not restrained by any supply factors, and is thus purely demand-driven. The economy's output gap y_t represents thus the log deviation of the current demand-driven output from its constant potential level. Similarly to De Grauwe and Macchiarelli (2015), we assume that the two components of aggregate demand, aggregate consumption (c_t) and aggregate investment (i_t) (expressed as log-linearized deviations from their respective steady states), are given by

$$c_t = d_1 y_t + d_2 \widetilde{E}_t[y_{t+1}] + d_3\left(r_t - \widetilde{E}_t[\pi_{t+1}]\right) + d_4 \widetilde{E}_t[\Delta s_{t+1} - \pi_{t+1}] + \epsilon_t^c, \tag{1}$$

and

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

where π_t is the inflation rate, r_t is the nominal risk-free short-term interest rate (i.e., the policy rate, defined below in Equation 19); ρ_t is the loan interest rate charged by banks consisting of r_t plus a spread term χ_t (see Equation 17), s_t is the stock price and ϵ_t^c and ϵ_t^i are stochastic disturbances following an AR(1) process. Equation (1) differs from De Grauwe and Macchiarelli (2015) in that the expected real stock price also influences (positively) private consumption.

Further, we assume that the aggregate price inflation is determined by a standard expectations-augmented Phillips Curve equation given by

$$\pi_t = b_1 \widetilde{E}_t[\pi_{t+1}] + b_2 y_t + \epsilon_t^\pi, \tag{3}$$

where b_1 determines the impact of future expected inflation on current inflation, b_2 is the slope of the Phillips Curve and ϵ_t^π is a stochastic cost-push term following an AR(1) process.

Analogously to Lengnick and Wohltmann (2016), but in the absence of taxes and stock dividend payments, the households' budget constraint is

$$c_t + d_t + (s_{t-1} - p_{t-1})\Lambda_t = (w_t - p_t)n_t + (r_{t-1} - \pi_t)d_{t-1} + (s_{t-1} - p_{t-1})\Lambda_{t-1} + \zeta_t$$

where p_t is the price level, $(w_t - p_t)n_t$ is the households' wage income in real terms, expressed as log deviations from its steady state, d_t is the households' deposits, Λ_t is the households' net stock demand and ζ_t represents the firms' profits which are assumed to be fully distributed to the households.[1] The firms' budget constraint is

$$(w_t - p_t)n_t + i_t + (\rho_{t-1} - \pi_t)l_{t-1} + \zeta_t = y_t + l_t$$

where l_t represents the firms' new loans. Under the assumption that firms finance their investments thoroughly through loans, so that $i_t = l_t$, as for example in Chiarella et al. (2012), the firms constraint reduces to

$$(w_t - p_t)n_t + (\rho_{t-1} - \pi_t)l_{t-1} + \zeta_t = y_t.$$

The consolidation of the two budget constraints yields then

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

2.2 | Expectations

Expectations are formed in a boundedly rational way according to the discrete choice learning approach by Brock and Hommes (1998). We follow De Grauwe and Macchiarelli (2015) in assuming two types of expectation rules: naive or chartist (represented by the letter c) and fundamentalist (represented by the letter f), defined respectively as:

$$\widetilde{E}_t^c[z_{t+1}] = z_{t-1} \qquad z \in (y, \pi, s), \tag{5}$$

$$\widetilde{E}_t^f[z_{t+1}] = z^* \qquad z^* \in (y^*, \pi^*, s^*), \tag{6}$$

where z^* represents the fundamental value of $z \in (y, \pi, s)$, assumed equal to zero, and $\widetilde{E}_t[z_{t+1}]$ represents the aggregate expectations concerning a variable z and is defined explicitly below.

As it is standard in the discrete choice learning approach, agents switch between the two rules, and the aggregate market expectations are the weighted average of both rules:

$$\widetilde{E}_t[z_{t+1}] = \omega_t^{z,c}\widetilde{E}_t^c[z_{t+1}] + \omega_t^{z,f}\widetilde{E}_t^f[z_{t+1}], \tag{7}$$

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

$$\begin{aligned} \omega_t^{z,c} &= \frac{\exp\left(\gamma U_t^{z,c}\right)}{\exp\left(\gamma U_t^{z,c}\right) + \exp\left(\gamma U_t^{z,f}\right)}, \\ \omega_t^{z,f} &= \frac{\exp\left(\gamma U_t^{z,f}\right)}{\exp\left(\gamma U_t^{z,c}\right) + \exp\left(\gamma U_t^{z,f}\right)} = 1 - \omega_t^{z,c} \end{aligned} \tag{8}$$

with

$$U_t^{z,j} = mU_{t-1}^{z,j} - \left(\widetilde{E}_{t-2}^j[z_{t-1}] - z_{t-1}\right)^2, \tag{9}$$

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

2.3 | The stock market

Following Lengnick and Wohltmann (2016), two types of stock demand are assumed: speculative and non-speculative. In contrast to Lengnick and Wohltmann (2016), where households demand stock only non-speculatively, while speculative demand is left for financial agents who do not play any other role in the model (e.g., in the real sector), we assume that households demand stock both for non-speculative and for speculative motives.[2] The households' net stock demand is thus represented by:

$$\Lambda_t = \underbrace{\left[c_{\Lambda,y}y_t - c_{\Lambda,r}(r_t) - c_{\Lambda,s}(s_t - p_t)\right]}_{\text{non-speculative demand}} + \underbrace{\left[\omega_t^{s,f}D_t^f + \omega_t^{s,c}D_t\right]}_{\text{speculative demand}}. \tag{10}$$

where D_t^c and D_t^f are the net stock demand of chartists and fundamentalists, defined in turn by:

$$D_t^j = \widetilde{E}_t^j[s_{t+1}] - s_{t-1} \qquad j \in (c,f). \tag{11}$$

Equation (10) shows that households have two types of stock demand: a speculative demand which depends on households' expectation (speculation) for s_{t+1} and a non-speculative demand. According to the former, households demand more stock when they expect an increase in the stock price, and viceversa. According to the latter, households demand more stocks when their income increases, and less stocks when the deposit (policy) rate or the stock price increases.

More specifically, the households' non-speculative demand for stocks (i) increases if an agent can afford buying more stocks (as a result of a higher output gap y_t), (ii) decreases if the real price of stock ($s_t - p_t$) increases, and (iii) decreases when the yield on deposits (r_t) increases.[3] On the other hand, the non-speculative stock demand does not (directly) depend on the expected stock price (i.e., non-speculative motive).

Finally, 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:

$$s_t = s_{t-1} + \Lambda_t + \epsilon_t^s, \tag{12}$$

which relates stock price changes positively to excess households' stock demand, where ϵ_t^s is an AR(1) disturbance term.

2.4 | 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), as for example, in Samitas et al. (2018). They respond to shocks; cyclical conditions in the real sector,

TABLE 1 The aggregate balance sheet of the banking sector

Assets	Liabilities
Loans (l_t)	Household deposits (d_t)
	Net worth

and indirectly, stock market conditions by adjusting the spread rate, while obeying a balance sheet identity (Assets = Liabilities + 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 $r_t d_t$.

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:

$$\nu_t = \frac{\text{bank net worth}}{\text{bank assets}} = \frac{l_t - d_t}{l_t}. \quad (13)$$

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 deviates (either way) from the target value ν^*. To keep our calculations linear, however, we rearrange the previous equation to express it in terms of a fraction of loan supply, that is,

$$l_t - d_t = \nu_t l_t. \quad (14)$$

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

$$\max_{l_t} \quad \chi_t l_t - \frac{\kappa}{2}(l_t - d_t - \nu^* l_t)^2. \quad (15)$$

Following Gerali et al. (2010), the first term in the maximization problem (15) is the banks' total profits from loans, the second term is the total cost of deviating from the target ν^*. 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[4]:

$$l_t = \eta(\chi_t + \kappa(1-\nu^*)d_t), \quad (16)$$

with $\eta = \frac{1}{\kappa(1-\nu^*)^2}$. Accordingly, the banks' loan supply depends positively on the banks' marginal profits from loans (i.e., the spread rate χ_t), and the households' deposits d_t, and negatively on the target for the capital-to-asset ratio ν^*.

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.[5] Rearranging Equation (16) yields:

$$\chi_t = \kappa(1-\nu^*)((1-\nu^*)l_t - d_t), \quad (17)$$

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 ν^*). Banks choose the level of loan supply that equalizes the marginal benefit with the marginal cost (leading to a marginal profit of zero). For $\kappa \to 0$,[6] the profit maximizing spread rate is approximately zero.

2.5 | Monetary policy

We assume in our baseline model that the policy rate is determined by the following standard Taylor rule:

$$r_t = \phi_\pi(\pi_t - \pi^*) + \phi_y(y_t - y^*) + \phi_r r_{t-1} + \epsilon_t^r. \quad (18)$$

Accordingly, the central bank's policy interest rate is a function of the past policy rate (pursuing therefore an interest rate smoothing policy) and of the deviations of current output and inflation from their respective targets (which are assumed to be equal to their fundamental levels y^* and π^*, respectively), and of ϵ_t^r, a stochastic disturbance term.

In section 5, by contrast, we will also consider the following specification

$$r_t = \phi_\pi(\pi_t - \pi^*) + \phi_y(y_t - y^*) + \phi_r r_{t-1} + \phi_s(s_t - s^*) + \epsilon_t^r, \quad (19)$$

where the additional term $\phi_s(s_t - s^*)$ represents, for $\phi_s > 0$, a leaning-against-the-wind (LATW) policy by the central bank with respect to stock price deviations from its fundamental value.

3 | CALIBRATION

The baseline calibration 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, being the most important one the way κ was 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., $[\nu_t - \nu^*]^2$) is measured proportional to the outstanding bank capital, then multiplied by the cost factor. In our model we sought linearity in calculating the

TABLE 2 Baseline parametrization

Parameter	Description	Value
Real Sector, stock market and expectations		
d_1	Marginal propensity of consumption out of income	0.5
d_2	Coefficient on expected y in consumption equation	$(1-d_1)(0.5)-e_1$[a]
d_3	Coefficient on real rate in consumption equation	−0.01
d_4	Coefficient on expected real stock price in consumption equation	0.1
e_1	Coefficient on expected y in investment equation	0.1
e_2	Coefficient on real rate in investment equation	$(-0.5)(1-d_1)-d_3$[a]
b_1	Coefficient of expected inflation in inflation equation	0.99
b_2	Coefficient of output gap in inflation equation	0.05
σ_{ϵ^y}	Standard deviation shocks output gap equation	0.08
σ_{ϵ^π}	Standard deviation shocks inflation equation	0.08
$\rho^{\pi/y/s}$	Shock persistence	0.15
$c_{\Lambda,r}$	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
m	Speed of declining weights in mean squares errors (memory)	0.5
σ_{ϵ^s}	Standard deviation shocks stock price function	0.08
s^*	Fundamental value of stock price	0
Monetary policy		
ϕ_π	Coefficient of inflation in Taylor equation	1.5
ϕ_y	Coefficient of output gap 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	0.08
ρ^r	Shock persistence	0.15
Banking sector		
ν^*	Target capital-to-loans ratio	0.09
κ	Deviation cost parameter	1

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

divergence cost (see Equation 14), and thus cannot apply the same parametrization of Gerali et al. (2010) for this term.

4 | SCENARIO ANALYSIS

In the following we describe the dynamic adjustment paths of our model to different kinds of shocks by means of impulse-responses obtained via Monte Carlo simulations.[7]

Figure 1 describes how our model economy reacts to a contractionary monetary policy shock in three different scenarios: when households do not participate directly in the stock market (dotted line), when their stock demand is purely non-speculative (dashed line), and when their demand is both non-speculative and speculative (continuous line). We will consider this latter case as our baseline scenario in the following simulations. In all three cases, we assume that loan creation is capital-constrained (with $\kappa = 1$), and that monetary policy is conducted in a traditional manner (with $\phi_y > 0$, $\phi_\pi > 0$ and $\phi_s = 0$). All

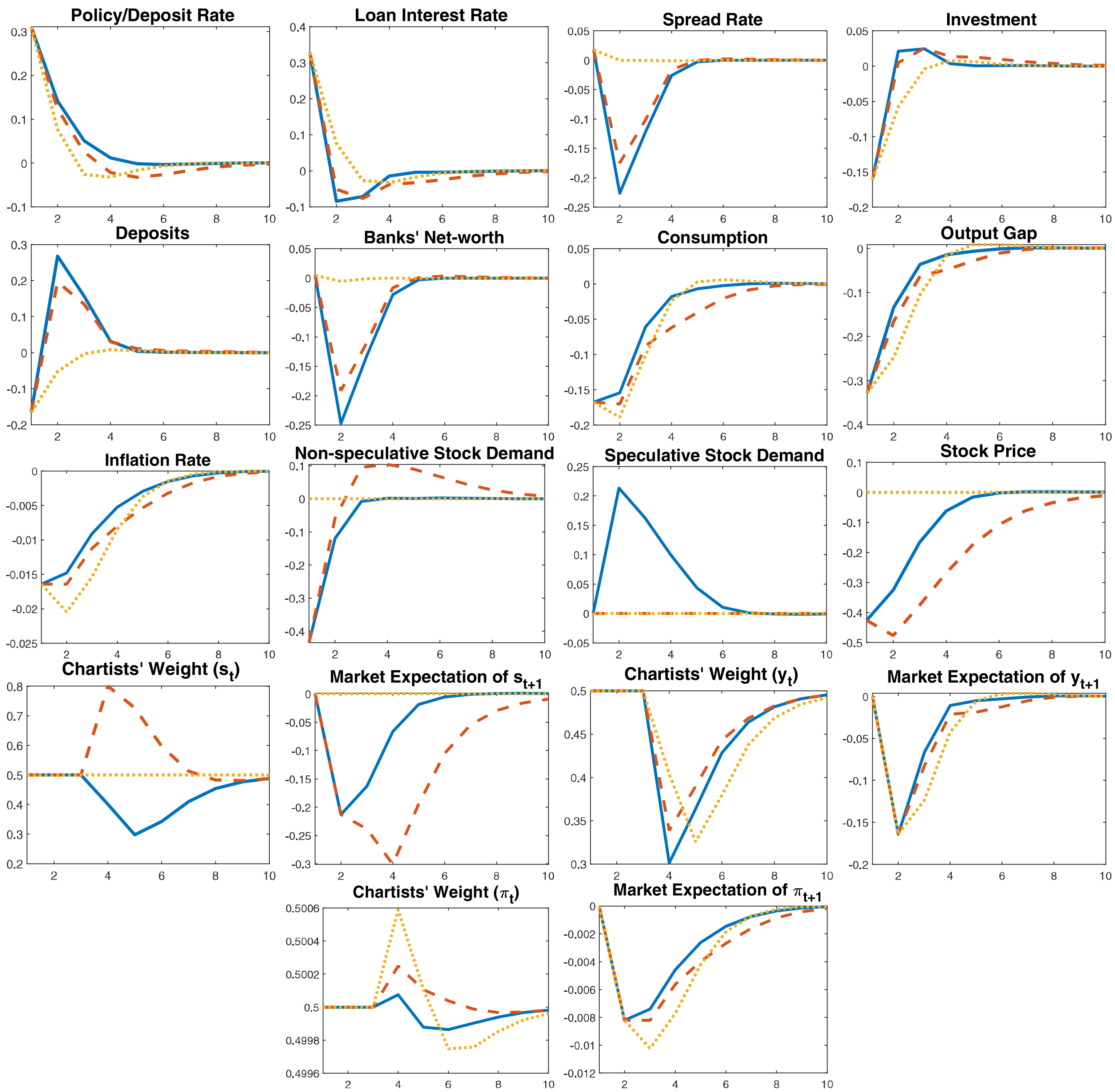

FIGURE 1 Impulse responses to monetary policy shock under no households' stock market participation (dotted line), under only non-speculative stock demand (dashed line) and under both households' non-speculative and speculative stock demand (continuous line) for $\kappa = 1$ and $\phi_s = 0$ [Colour figure can be viewed at wileyonlinelibrary.com]

other coefficients follow the baseline values reported in Table 2.

As it can be observed, an increase in the policy rate leads to a rise in the loan interest rate which in turn leads to a decrease in aggregate investment, consumption, output and price inflation.[8] On impact, the spread between the loan and the deposit rates shows nearly no reaction to the shock in all three depicted cases due to the presence of two opposite effects that cancel one another: on the one hand, the fall in inflation rate, output gap as well as the stock price have a downward pressure on the spread rate (see Equation A25), on the other hand the fall in deposits and the positive monetary shock itself have an upward pressure on the spread rate.

Through the budget constraint and the stock net demand Equations (4 and 10, respectively), a drop in income (output gap) lowers the households' deposits and their non-speculative net stock demand. The decrease of the latter leads to an immediate drop in the stock price. This is inline with the explanation illustrated in

(Lengnick & Wohltmann, 2016, p. 156). Manifestly, these effects are absent when households do not participate in the stock market neither non-speculatively nor speculatively. Indeed, in this case, the stock market does not react at all to the increase in the policy rate, and therefore there is no feedback mechanism affecting the households' deposits and thus the banks' net worth in the following periods.

The importance of the households' stock market participation, and thus of the behavioural stock market specification along the lines of Lengnick and Wohltmann (2016) is clearly illustrated by the dashed (only non-speculative stock demand) and continuous (both non-speculative and speculative stock demand) lines in Figure 1. Following the drop in stock prices above discussed, households increase their deposits in the banking sector what leads to a deterioration of the banks' net worth. This effect is larger under full stock market participation (that is, under households' both non-speculative and speculative stock demand). This leads to a drop in the spread between the loan and the policy (deposit) rate which effectively lowers the loan interest rate, boosting aggregate investment in the following periods.

Regarding the dynamics in the stock market, when households demand stocks speculatively as well as non-speculatively, a drop of the stock price below its steady state causes a spike in fundamentalists' demand as they expect the stock price to rise and go back to the steady state. This has a positive effect on the stock price which is clearly observable relative to the case where there is no households' speculative stock demand and therefore where the impact of a fundamentalists' net stock demand is not present. The presence of speculative stock demand based on boundedly rational expectations has thus an impact on the actual development of the stock price and by extension, through the mechanisms previously outlined, on the evolution of the banks' net worth and aggregate investment.

Figure 2 illustrates the impact of a stock price shock under two scenarios: only non-speculative households' stock demand and both speculative and non-speculative demand.[9] In the presence of non-speculative stock demand, the stock price rises on impact by less than the value of the shock because part of the rise is offset due to an immediate drop in the non-speculative demand. Note that while the non-speculative stock demand reacts on impact, the speculative demand reacts with a delay. Therefore both models react similarly and the real sector is unaffected on impact.

In the following periods, the chartists' expectations lead to a rise in expected stock price, pushing aggregate private consumption up. As a result, the output gap and aggregate investment also increase. When speculative demand is present (continuous line), a stock price above the steady state means that fundamentalists are demanding less stocks, and are diverting more of their funds towards bank deposits instead. Accordingly, deposits thus slightly rise. Consequently, the spread rate decreases, which enhances investment, consumption and output gap even further. Finally, we can observe that, in the presence of speculative demand, the stock price returns quicker to the steady state (due to the fall in fundamentalists' demand). Therefore, we can conclude that the presence of fundamentalists' demand aids the stability of the stock market following a stock price shock.

We can also observe that while the effect of the expected stock price on consumption and the effect of the stock price itself on the non-speculative stock demand are existent in both model scenarios, the presence of fundamentalists' stock demand adds another mechanism through which the stock market spills over to the real sector, mainly through the effect of such demand on deposits, and thus on the spread rate. Such a channel can only exist in the presence of a capital constrained banking sector through a positive κ.

To further investigate the role played by different kinds of stock demand on the model dynamics, Table 3 reports the variances of key macrofinancial variables under two scenarios: only non-speculative stock demand and both speculative and non-speculative stock demand. We can observe that under the presence of all real, monetary as well as financial shocks, the fundamentalists' demand slightly enhances the stability of the model (i.e., slightly lowers variances for all variables). The reason behind this, as discussed before, is that fundamentalists demand stock in a manner that pushes the stock price to the steady state faster, bringing the variability of the entire model down.[10]

Our next exercise is aimed at exploring the role of the capital requirements (represented by different values of κ) in the dynamics of the economy. Figure 3 investigates the model dynamics following a contractionary monetary policy shock based on the model parameters reported in Table 2. On impact, the loan interest rate rises by the same amount as r_t, and consumption, investment, output gap, inflation as well as non-speculative stock demand and stock price fall. In the following period, at a non-zero value for κ, the spread rate reacts negatively, creating a relatively strong downward pressure on the loan interest rate. At higher values of κ, the fall in the spread rate is more prominent, and as a result, the contractionary effect of the policy shock on inflation, consumption, investment and output gap is "diluted." In other words, a contractionary monetary policy shock is only partially transmitted to the economy when the capital requirements are

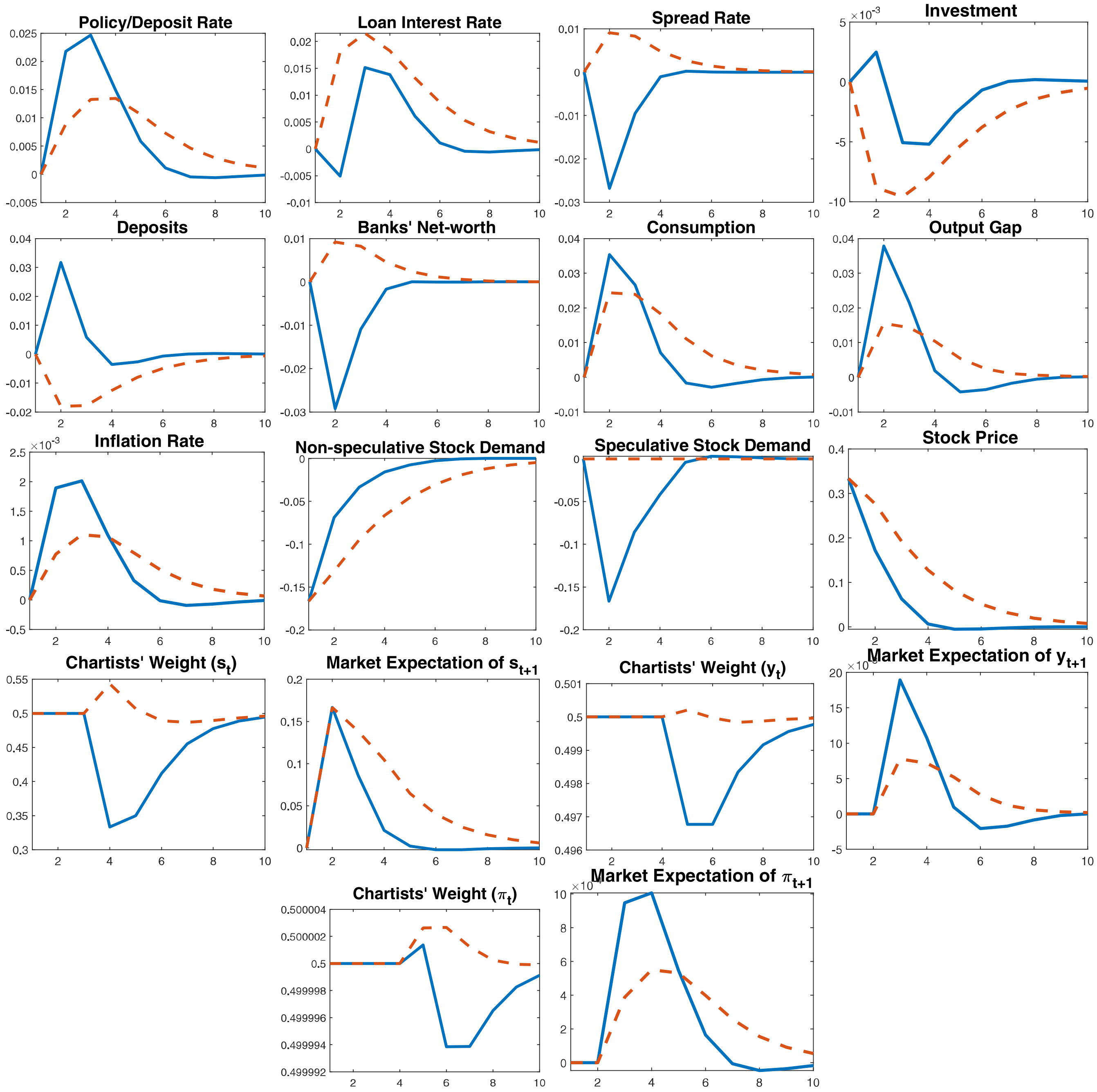

FIGURE 2 Impulse responses to stock price shock under only households' non-speculative stock demand (dashed line) and with both households' non-speculative and speculative stock demand (continuous line) for $\kappa = 1$ and $\phi_s = 0$ [Colour figure can be viewed at wileyonlinelibrary.com]

particularly tight (high κ). By contrast, when capital requirements are loose ($\kappa \to 0$), a contractionary monetary policy is fully transmitted to the economy.[11]

In Figure 4, the effect of a positive stock price shock is analysed. The continuous line is the baseline case discussed in Figure 2. The dashed line represents the reaction of the model to the shock under no deviation costs (i.e., $\kappa \to 0$). We can observe that consumption in both scenarios increases due to the rise in expected stock price (brought by chartists' expectations). This raises output gap and inflation slightly. Since the spread rate does not decrease in case of a zero κ, the dashed lines show less boost in the real activity (i.e., consumption, inflation an output gap) than the baseline scenario with the continuous line.

Similar to Table 3, Table 4 reports the variances of key macrofinancial variables for different values of the deviation costs parameter κ. It can be observed that when

TABLE 3 Monte-Carlo-based variances of key macrofinancial variables

Output	Inflation	Consumption	Investment	Bank's net worth	Stock price
Only non-speculative household stock market participation					
0.0194	0.0058	0.011	0.003	0.016	0.035
Non-speculative and speculative household stock market participation					
0.0143	0.0057	0.0074	0.0026	0.006	0.027

Note: Variances based on a Monte-Carlo simulation of 10,000 runs.

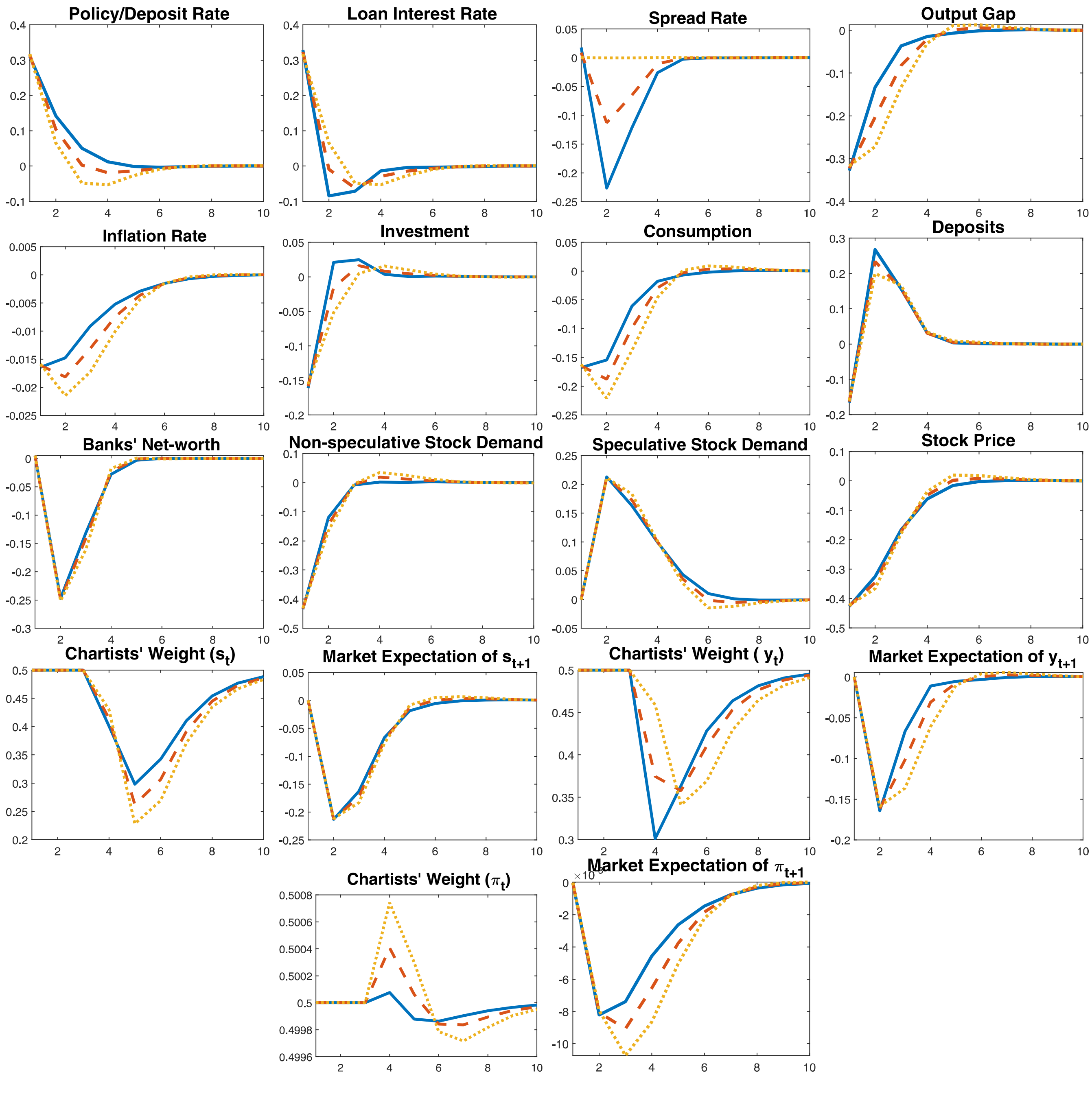

FIGURE 3 Impulse responses to monetary policy shock for different values of the deviation cost parameter $\kappa = 0.001$ (dotted line), 0.5 (dashed line), and 1 (continuous line) under households' non-speculative and speculative stock market participation and $\phi_s = 0$ [Colour figure can be viewed at wileyonlinelibrary.com]

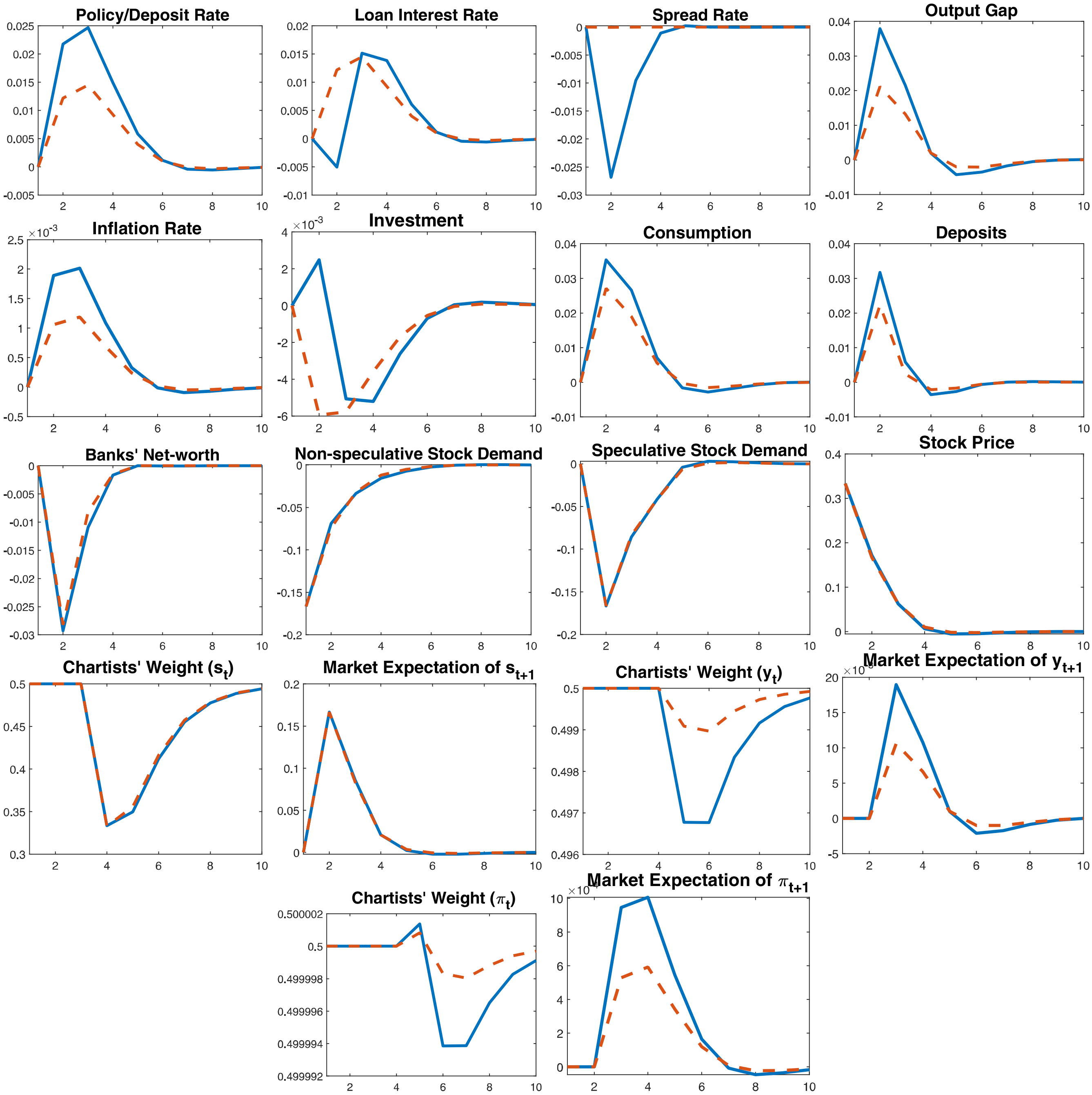

FIGURE 4 Impulse responses to stock price shock for $\kappa = 0.001$ (dashed line) and $\kappa = 1$ (continuous line) under households' non-speculative and speculative stock market participation (with $\phi_s = 0$) [Colour figure can be viewed at wileyonlinelibrary.com]

all the relevant macro-financial shocks are considered, higher values for κ translate into higher instability (i.e., slightly higher variances). There are various factors that can explain this result: first and foremost, 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' net 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.

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, creates and additional "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

TABLE 4 Monte-Carlo-based variances of key macrofinancial variables

Output	Inflation	Consumption	Investment	Bank's net worth	Stock price
$\kappa = 0.001$					
0.011	0.0057	0.0055	0.0021	0.0044	0.026
$\kappa = 0.5$					
0.012	0.0057	0.0059	0.0023	0.0045	0.0261
$\kappa = 1$					
0.014	0.0057	0.0074	0.0026	0.0059	0.0266

Note: Variances based on a Monte-Carlo simulation of 10,000 runs.

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.

Further, similar to for example, 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 demand. 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 | MONETARY POLICY AND STOCK PRICES

We now turn our focus on the conduct of monetary policy in our framework. In particular, we allow the parameter ϕ_s in Equation (19) to be positive and take on different values in order to investigate in more detail the effectiveness of a LATW monetary policy (see e.g., Bernanke & Gertler, 1999; Gilchrist & Leahy, 2002) in stabilizing the stock market and whether this comes at the cost of output and inflation stability. We evaluate the effectiveness of a 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 stock market shock. Then, we analyse 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 5 illustrates the model dynamics following a stock price shock under different values for ϕ_s. We can observe that the rise in the stock price is on impact negatively related to the value of ϕ_s. This is because the higher the value of ϕ_s, the larger is the reaction of the policy rate r_t to the shock, therefore the larger is the rise in deposits as well as the fall in the non-speculative stock demand. Such an immediate fall in the stock demand offsets partially the initial shock effect. For $\phi_s = 0$, the real and banking variables do not react on impact to the shock (continuous line). By contrast, for a slightly positive value of ϕ_s (dotted line), the rise in the policy rate has a contractionary effect on the real economy on impact; output gap, investment, consumption and inflation fall. Further, when ϕ_s has a non-zero value, the rise of the policy rate induces a rise in deposits, leading to a reduction in the banks' net worth and thus to a fall in the loan spread rate.

The developments of the variables in the following periods depend on the value of ϕ_s. For $\phi_s = 0$, the rise in the expected stock price induces a rise in consumption which in turn has an expansionary effect on the real economy. At a high value for ϕ_s, the negative effect of the higher policy rate outweighs the positive effect of the stock shock, being the final effect contractionary, leading consumption, investment, output gap and inflation to fall below their respective long-run steady state levels. For a relatively moderate value for ϕ_s, the expansionary effect of the shock and the contractionary effect of the policy reaction offset one another, leaving the model variables fairly stable around the steady state level.

While a LATW monetary policy seems thus to be highly effective in stabilizing the stock market following a stock price shock, its effect on the real sector depends however on the value of ϕ_s. A moderate value can

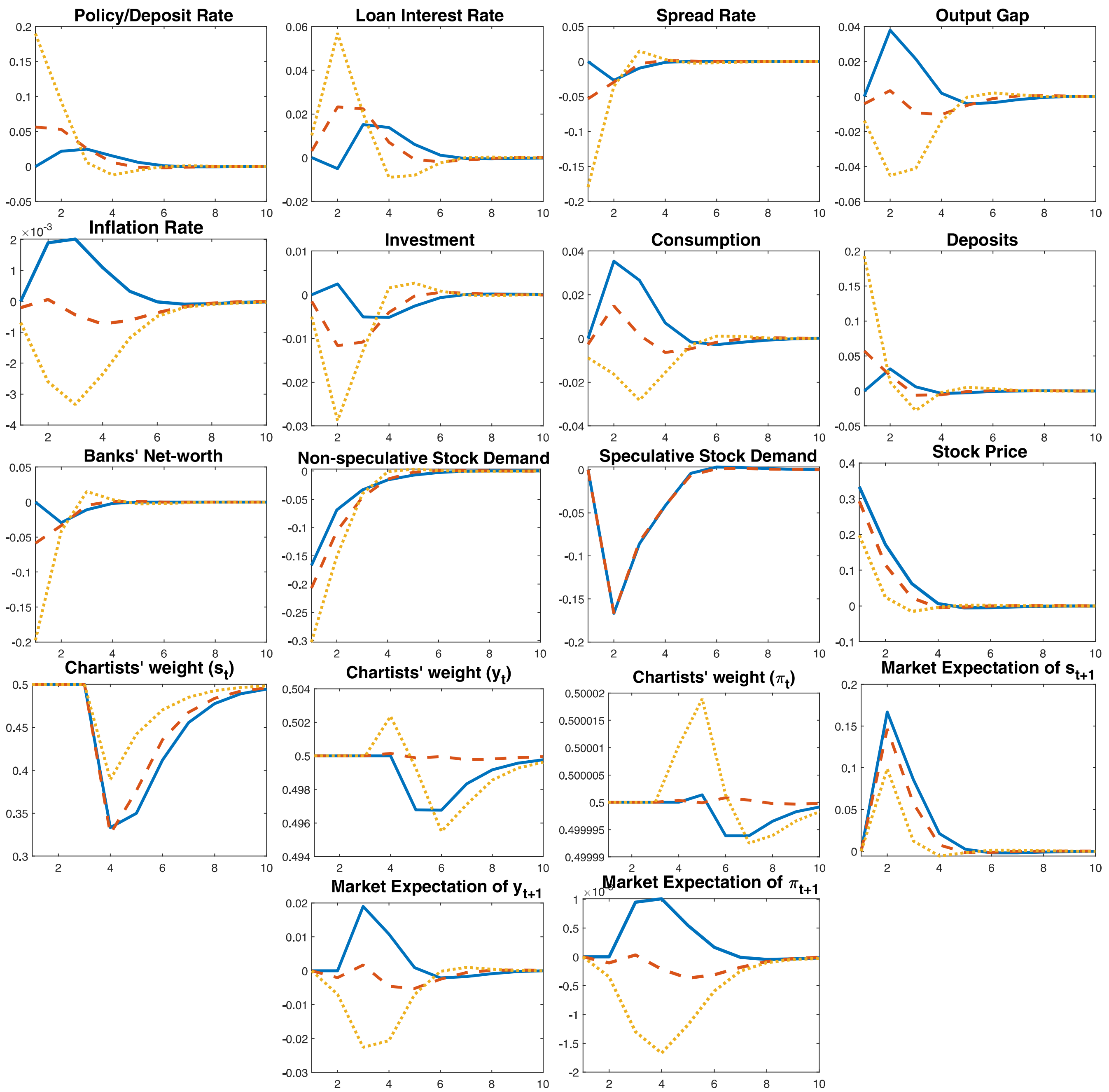

FIGURE 5 Impulse responses to stock price shock at $\phi_s = 0$ (continuous line), $\phi_s = 0.2$ (dashed line) and $\phi_s = 1$ (dotted line) with $\kappa = 1$ (high-deviation costs) [Colour figure can be viewed at wileyonlinelibrary.com]

stabilize the real sector together with the stock market, but a high value would stabilize the stock market at the expenses of the real stability (see also Filardo and Rungcharoenkitkul (2016)).

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 10,000 runs, 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.

Figure 6 illustrates the results of this simulation exercise. As it can be observed, the stock price is always better stabilized at higher values of ϕ_s regardless the value of κ, and the output gap is more stable at a combination of high ϕ_s and low κ. Thus, when all real, financial and monetary shocks are accounted for, there seems to be no trade-off between output and stock price stability. This is because, through households' stock demand, the real activity is highly connected to the stock price, stabilizing one would stabilize the other. These results are similar to the ones obtained in Lengnick and Wohltmann (2016).

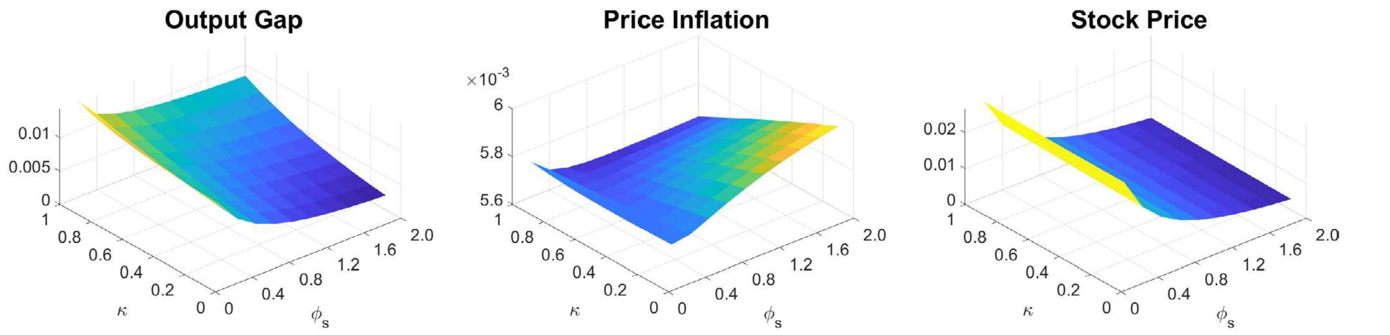

FIGURE 6 Variances of y_t, π_t and s_t at different combinations of ϕ_s and κ. variances are based on a Monte-Carlo simulation of 10,000 runs with $\sigma_{\epsilon^\pi} = \sigma_{\epsilon^r} = \sigma_{\epsilon^s} = \sigma_{\epsilon^y} = 0.08$ [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 7 Variances of y_t, π_t and s_t at different combinations of ϕ_s and κ, based on a Monte-Carlo simulation of 10,000 runs with $\sigma_{\epsilon^s} = 0.05$ and $\sigma_{\epsilon^\pi} = \sigma_{\epsilon^r} = \sigma_{\epsilon^y} = 0$ [Colour figure can be viewed at wileyonlinelibrary.com]

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 the variances of the output gap, price inflation and the stock price for different values of ϕ_s and κ.

Figure 7 illustrates the results of this final exercise. As it can be observed, when only stock price shocks are considered, a trade-off between output and price inflation volatility on the one hand and the stock price volatility on the other hand becomes evident. A more aggressive 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 (see Figure 5).

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 the 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 crises risks. In this case, it is optimal for the central bank to consider a LATW policy to reduce financial risks against the costs of larger fluctuations in aggregate demand and inflation.

6 | CONCLUDING REMARKS

While the need for a better regulation of the financial system has been 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 analysing the interaction between the stock market, the banking sector and the real sector in a behavioural macroeconomic model along the lines of De Grauwe and Macchiarelli (2015).

Our paper highlights households' participation in the stock market as well as constrains on the banking sector as two critical channels through which developments in the financial sector spill over to the real sector and monetary policy effect on the real sector is altered. Further, we consider the effectiveness of a LATW monetary policy in stabilizing the stock market and whether this comes at cost of the real stability. We find that a moderate policy reaction to stock market disturbances can achieve the stability of the stock market at a fairly low level of instability in the real activity. However, a strong policy reaction to stock prices may largely destabilize the real sector.

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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@100 conference in Milan. Financial support by the Hans-Böckler Foundation is gratefully acknowledged.

ENDNOTES

[1] In order to avoid a quite complicated nonlinearity which would arise if Λ_t would be multiplied by s_t or p_t (see equation 10), we replaced s_t and p_t with the past values in this budget constraint.

[2] Indeed, assuming that financial agents remain "model outsiders" in the real sector creates a leakage problem which may affect the dynamics of the model. By merging these types of demands together, we solve such a problem while still keeping the key idea of Lengnick and Wohltmann (2016).

[3] For more details on the derivation and the explanation of the non-speculative households' stock demand, refer to Lengnick and Wohltmann (2016).

[4] For the full derivation, refer to equation A22 in Appendix A.

[5] If banks choose a lower interest rate than this rate, loan (investment) demand will be higher than the level of loans desired by banks to be supplied. On the other hand, if they choose a higher interest rate, loan demand will be lower than the level desired to be supplied.

[6] We do not set $\kappa = 0$ to avoid a division by zero in equation (16).

[7] See Appendix A for a description of how we computed these impulse-responses.

[8] As described in Appendix B, we always consider a shock of size 0.5.

[9] The case with no households' net stock demand is obviously irrelevant in the case of a stock price shock, and is therefore not included in the analysis.

[10] This rather counterintuitive result stems from the fact that the chartist speculative demand, based on $E_t^c s_{t+1} = s_{t-1}$, see equations (6) and (11), does not exert a particularly destabilizing influence on the stock price. We consider this chartist expectations parametrization to keep our model as close as possible to De Grauwe and Macchiarelli (2015) and leave the analysis of more destabilizing chartist rules for further research.

[11] 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).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX A: Model Derivation

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

$$\pi_t = b_1 \widetilde{E}_t \pi_{t+1} + b_2 y_t + \epsilon_t^{\pi}. \tag{A1}$$

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

$$\widetilde{E}_t \pi_{t+1} = \omega_t^{\pi,c} \widetilde{E}_t^c \pi_{t+1} + \left(1 - \omega_t^{\pi,c}\right) \widetilde{E}_t^f \pi_{t+1}, \tag{A2}$$

$$\widetilde{E}_t y_{t+1} = \omega_t^{y,c} \widetilde{E}_t^c y_{t+1} + \left(1 - \omega_t^{y,c}\right) \widetilde{E}_t^f y_{t+1}, \tag{A3}$$

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

Fundamentalists and chartists' expectations are given by:

$$\begin{aligned} \widetilde{E}_t^c z_{t+1} &= z_{t-1} \quad z \in (y, \pi), \\ \widetilde{E}_t^f z_{t+1} &= z^* \quad z^* \in (y^*, \pi^*), \end{aligned} \tag{A4}$$

where y^*, π^* are assumed equal 0. Equations A2 and A3 could thus be simplified respectively to:

$$\widetilde{E}_t \pi_{t+1} = \omega_t^{\pi,c} \pi_{t-1}, \tag{A5}$$

$$\widetilde{E}_t y_{t+1} = \omega_t^{y,c} y_{t-1}. \tag{A6}$$

Plug Equation A5 in Equation A1 to reach *the first state equation*:

$$\pi_t = b_1 * \omega_t^{\pi,c} \pi_{t-1} + b_2 y_t + \epsilon_t^{\pi}. \tag{A7}$$

Taylor rule is defined by:

$$r_t = \phi_\pi (\pi_t - \pi^*) + \phi_y (y_t - y^*) + \phi_r r_{t-1} + \phi_s s_t + \epsilon_t^r, \tag{A8}$$

where s_t is the real stock price.

Aggregate demand is decomposed into consumption and investment:

$$y_t = c_t + i_t. \tag{A9}$$

Consumption is defined by:

$$\begin{aligned} c_t = d_1 y_t + d_2 \widetilde{E}_t y_{t+1} + d_3 \left(r_t - \widetilde{E}_t \pi_{t+1} \right) \\ + d_4 \widetilde{E}_t (\Delta s_{t+1} - \pi_{t+1}). \end{aligned} \tag{A10}$$

market expectations of s is given by:

$$\widetilde{E}_t s_{t+1} = \omega_t^{s,c} \widetilde{E}_t^c s_{t+1} + \left(1 - \omega_t^{s,c}\right) \widetilde{E}_t^f s_{t+1}, \tag{A11}$$

where

$$\widetilde{E}_t^c [s_{t+1}] = s_{t-1}, \tag{A12}$$

$$\widetilde{E}_t^f [s_{t+1}] = s^*, \tag{A13}$$

where $\widetilde{E}_t^f[s_{t+1}]$ and $\widetilde{E}_t^c[s_{t+1}]$ denote the expectations of fundamentalists and chartists with respect to the future real stock price, respectively, and s_t^* is the fundamental value of s_t according to the fundamentalists. It is assumed equal to 0.

Equation A11 Could thus be simplified to

$$\widetilde{E}_t s_{t+1} = \omega_t^{s,c} s_{t-1}. \tag{A14}$$

Investment is defined by:

$$\begin{aligned} i_t &= e_1 \widetilde{E}_t y_{t+1} + e_2 \left(\rho_t - \widetilde{E}_t \pi_{t+1} \right) \\ &= e_1 \widetilde{E}_t y_{t+1} + e_2 \left(r_t + \chi_t - \widetilde{E}_t \pi_{t+1} \right), \end{aligned} \tag{A15}$$

where χ_t is the interest rate spread.

Plug Taylor rule and market expectations of π_t and y_t in A10 and A15 then plug these in A9 and rearrange to reach the *second state equation*:

$$\begin{aligned} (1 - d_1 - \phi_y d_3 - \phi_y e_2) y_t = &(d_3 + e_2)\phi_\pi \pi_t + e_2 \chi_t \\ &+ (d_2 \omega_t^{y,c} + e_1 \omega_t^{y,c}) y_{t-1} \\ &- \left(d_3 \omega_t^{\pi,c} + e_2 \omega_t^{\pi,c} + d_4 \omega_t^{\pi,c}\right) \pi_{t-1} \\ &+ (d_3 + e_2)\phi_r r_{t-1} + (d_3 + e_2)\epsilon_t^r \\ &+ (d_3 \phi_s + e_2 \phi_s) s_t + d_4 \omega_t^{s,c} s_{t-1}. \end{aligned} \tag{A16}$$

The consolidated budget constraint of households is defined by:

$$\begin{aligned} y_t + (r_{t-1} - \pi_t) d_{t-1} + (s_{t-1} - p_{t-1}) \Lambda_{t-1} \\ = c_t + d_t + (s_{t-1} - p_{t-1}) \Lambda_t + (\rho_{t-1} - \pi_t) l_{t-1}. \end{aligned} \tag{A17}$$

Households' demand for stock is defined by:

$$\begin{aligned} \Lambda_t = [c_{\Lambda,y} y_t - c_{\Lambda,r} r_t - c_{\Lambda,s}(s_t - p_t)] \\ + \left[\omega_t^{s,c} D_t^c + \left(1 - \omega_t^{s,c}\right) D_t^f\right], \end{aligned} \tag{A18}$$

where D_t^c is the net demand of chartists and is given by:

$$\begin{aligned} D_t^c &= E_t^c s_{t+1} - s_{t-1} \\ &= s_{t-1} - s_{t-1} \\ &= 0 \end{aligned} \tag{A19}$$

and D_t^f is the net demand of fundamentalists and is given by:

$$\begin{aligned} D_t^f &= E_t^f s_{t+1} - s_{t-1} \\ &= 0 - s_{t-1} \\ &= -s_{t-1} \end{aligned} \tag{A20}$$

Substitute c_t and Λ_t in Equation A17 with Equations A10 and A18 respectively, then plug in the Taylor rule, the market expectations as well as the net demand of chartists and fundamentalists to reach the *third state equation*:

$$\begin{aligned} d_t = &\left[-d_{t-1} + c_{\Lambda,r} s_{t-1} \phi_\pi - \sum \pi_{t-1} c_{\Lambda,r} \phi_\pi + c_{\Lambda,s} \sum \pi_{t-1} \right. \\ &\left. - c_\Lambda, s s_{t-1} + l_{t-1} - d_3 \phi_\pi \right] \pi_t - \left[-1 + s_{t-1} c_{\Lambda,s} \right. \\ &- c_{\Lambda,r} s_{t-1} \phi_y - \sum \pi_{t-1} c_{\Lambda,y} + \phi_y \sum \pi_{t-1} c_{\Lambda,r} + d_1 \\ &\left. + \phi_y d_3 \right] y_t - \left[-c_{\Lambda,r} \phi_s - c_{\Lambda,s} s_{t-1} + \sum \pi_{t-1} c_{\Lambda,r} \phi_s \right. \\ &\left. + c_{\Lambda,s} \sum \pi_{t-1} + d_3 \phi_s \right] s_t + \left[d_3 \omega_t^{\pi,c} + d_4 \omega_t^{\pi,c} \right] \pi_{t-1} \\ &- d_2 \omega_t^{c,y} y_{t-1} + r_{t-1} d_{t-1} + \left[\Lambda_{t-1} - c_{\Lambda,s} \sum \pi_{t-1} \right. \\ &+ s_{t-1} \omega_t^{f,s} - \omega_t^{f,s} \sum \pi_{t-1} - d_4 \omega_t^{c,s} + c_{\Lambda,r} \phi_r r_{t-1} \\ &\left. + c_{\Lambda,r} \epsilon_t^r \right] s_{t-1} - \sum \pi_{t-1} \Lambda_{t-1} - \sum \pi_{t-1} c_{\Lambda,r} \epsilon_t^r \\ &- \sum \pi_{t-1} c_{\Lambda,r} r_{t-1} \phi_r + c_{\Lambda,s} \left[\sum \pi_{t-1} \right]^2 - \rho_{t-1} l_{t-1} \\ &- d_3 \phi_r r_{t-1} - d_3 \epsilon_t^r \end{aligned} \tag{A21}$$

Banking

The banking sector faces the following maximization problem:

$$\max_{l_t} \chi_t l_t - \frac{\kappa}{2}(l_t - d_t - \nu^* l_t)^2.$$

take derivative with respect to l_t:

$$\begin{aligned} &\chi_t - \kappa(1-\nu^*)((1-\nu^*)l_t - d_t) = 0 \\ &\chi_t - \kappa(1-\nu^*)^2 l_t + \kappa(1-\nu^*)d_t = 0 \\ &\kappa(1-\nu^*)^2 l_t = \chi_t + \kappa(1-\nu^*)d_t \\ &l_t = \frac{1}{\kappa(1-\nu^*)^2}\chi_t + \frac{1}{1-\nu^*}d_t. \end{aligned} \tag{A22}$$

Assume $\frac{1}{\kappa(1-\nu^*)^2} = \eta$. Equation A22 becomes:

$$l_t = \eta\chi_t + \kappa\eta(1-\nu^*)d_t, \tag{A23}$$

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:

$$\begin{aligned} &i_t = l_t \\ &e_1\omega_t^{y,c}y_{t-1} + e_2 r_t - e_2\omega_t^{\pi,c}\pi_{t-1} + e_2\chi_t = \eta\chi_t + \kappa\eta(1-\nu^*)d_t. \end{aligned} \tag{A24}$$

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

$$(e_2-\eta)\chi_t = \begin{aligned} &-e_2\phi_\pi\pi_t - e_2\phi_y y_t + \kappa\eta(1-\nu^*)d_t \\ &+ e_2\omega_t^{\pi,c}\pi_{t-1} - e_1\omega_t^{y,c}y_{t-1} - e_2\epsilon_t^r \\ &- e_2\phi_r r_{t-1} - e_2\phi_s s_t. \end{aligned} \tag{A25}$$

The stock market

$$s_t = s_{t-1} + \left(1-\omega_t^{s,c}\right)D_t^f + \omega_t^{s,c}D_t^c + c_{\Lambda,y}y_t - c_{\Lambda,r}r_t - c_{\Lambda,s}s_t + \epsilon_t^s. \tag{A26}$$

Plug in Taylor rule, substitute D_t^c and D_t^f for Equations A19 and A20 respectively and rearrange to reach the *fifth state equation*:

$$\begin{aligned} [1 + c_{\Lambda,s} + c_{\Lambda,r}\phi_s]s_t = &\left[1 - \left(1-\omega_t^{s,c}\right)\right]s_{t-1} + \epsilon_t^s \\ &+ \left[c_{\Lambda,y} - c_{\Lambda,r}\phi_y\right]y_t - c_{\Lambda,r}\phi_\pi\pi_t - c_{\Lambda,r}\epsilon_t^r \\ &- c_{\Lambda,r}\phi_r r_{t-1} \end{aligned} \tag{A27}$$

The state space representation

The state space representation then reads:

$$\begin{pmatrix} \pi_t \\ y_t \\ d_t \\ \chi_t \\ s_t \end{pmatrix} = \mathbf{A}_t^{-1}\mathbf{B}_t \begin{pmatrix} \pi_{t-1} \\ y_{t-1} \\ d_{t-1} \\ \chi_{t-1} \\ s_{t-1} \end{pmatrix} + \mathbf{A}_t^{-1}\mathbf{C}_t, \tag{A28}$$

where:

$$A_t = \begin{pmatrix} 1 & -b_2 & 0 & 0 & 0 \\ -(d_3+e_2)\phi_\pi & 1-d_1-\phi_y d_3-\phi_y e_2 & 0 & -e_2 & -d_3\phi_s - e_2\phi_s \\ A_{3,1} & A_{3,2} & 1 & 0 & A_{3,5} \\ \phi_\pi e_2 & \phi_y e_2 & -\kappa\eta(1-\nu^*) & e_2-\eta & e_2\phi_s \\ c_{\Lambda,r}\phi_\pi & c_{\Lambda,r}\phi_y - c_{\Lambda,y} & 0 & 0 & 1+c_{\Lambda,s}+c_{\Lambda,r}\phi_s \end{pmatrix},$$

where

$$\begin{aligned} A_{3,1} = &d_{t-1} - c_{\Lambda,r}s_{t-1}\phi_\pi + \sum \pi_{t-1}c_{\Lambda,r}\phi_\pi - c_{\Lambda,s}\sum \pi_{t-1} \\ &+ c_{\Lambda,s}s_{t-1} - l_{t-1} + d_3\phi_\pi, \end{aligned}$$

$$\begin{aligned} A_{3,2} = &-1 + s_{t-1}c_{\Lambda,s} - c_{\Lambda,r}s_{t-1}\phi_y - \sum \pi_{t-1}c_{\Lambda,y} \\ &+ \phi_y \sum \pi_{t-1}c_{\Lambda,r} + d_1 + \phi_y d_3 \end{aligned}$$

and

$$\begin{aligned} A_{3,5} = &-c_{\Lambda,r}\phi_s - c_{\Lambda,s}s_{t-1} + \sum \pi_{t-1}c_{\Lambda,r}\phi_s + c_{\Lambda,s}\sum \pi_{t-1} \\ &+ d_3\phi_s. \end{aligned}$$

$$B_t = \begin{pmatrix} b_1 * \omega_t^{\pi,c} & 00 & 00 & \\ -(d_3+e_2+d_4)\omega_t^{\pi,c} & (d_2+e_1)\omega_t^{y,c} & 00 & d_4\omega_t^{s,c} \\ d_3\omega_t^{\pi,c} + d_4\omega_t^{\pi,c} & -d_2\omega_t^{c,y} & r_{t-1} & 0B_{3,5} \\ e_2\omega_t^{\pi,c} & -e_1\omega_t^{y,c} & 00 & 0 \\ 0 & 00 & 01-\omega_t^{s,f} & \end{pmatrix},$$

where

$$\begin{aligned} B_{3,5} = &\Lambda_{t-1} - c_{\Lambda,s}\sum \pi_{t-1} + s_{t-1}\omega_t^{f,s} - \omega_t^{f,s}\sum \pi_{t-1} - d_4\omega_t^{c,s} \\ &+ c_{\Lambda,r}\phi_r r_{t-1} + c_{\Lambda,r}\epsilon_t^r \end{aligned}$$

and

$$C_t = \begin{pmatrix} \epsilon_t^{\pi} \\ (d_3+e_2)\phi_r r_{t-1} + (d_3+e_2)\epsilon_t^r \\ -\sum \pi_{t-1}\Lambda_{t-1} - \sum \pi_{t-1} c_{\Lambda,r}\epsilon_t^r - \sum \pi_{t-1} c_{\Lambda,r} r_{t-1}\phi_r + c_{\Lambda,s}[\sum \pi_{t-1}]^2 - \rho_{t-1} l_{t-1} - d_3\phi_r r_{t-1} - d_3\epsilon_t^r \\ -e_2\epsilon_t^r - e_2\phi_r r_{t-1} \\ \epsilon_t^s - c_{\Lambda,r}\epsilon_t^r - c_{\Lambda,r}\phi_r r_{t-1} \end{pmatrix}.$$

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 $\epsilon_{50}^r/\epsilon_{50}^s$ increased by 0.5. 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 $+ 0.5$.
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 10,000 times.