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Interest rate rules under financial dominance

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Interest Rate Rules under Financial Dominance*

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Abstract

In our dynamic stochastic general equilibrium model, capital-constrained entrepreneurs finance risky projects by borrowing from banks. Banks make loans using equity and deposits. Because financial contracts are non-state-contingent, bank balance sheets are exposed to entrepreneurial defaults. Macroprudential policy imposes a positive response of the bank capital ratio to lending. Our main result is that the Taylor Principle is violated when this response is too weak. Then macroprudential policy is ineffective in stabilising debt and monetary policy is subject to 'financial dominance'. Under a constant bank capital requirement, a strong reaction of the interest rate to inflation destabilises the financial sector.

Keywords: bank capital, financial dominance, interest rate rule, macro-prudential policy, Taylor Principle

JEL classification: E32, E44, E52, E58, E61

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1 Introduction

A new policy domain has emerged in response to the financial crisis, that of macroprudential policy with the aim of safeguarding the stability of the financial system as a whole. Its transmission, effectiveness and interdependence with other policy areas is not yet fully understood. This paper sheds light on the implications of bank capital requirements for the conduct of monetary policy.

Smets (2014) summarises three views on the interaction of monetary policy and financial stability. One view separates the two policy areas, their instruments and objectives completely. Another regards the two policies as indistinguishable.[1] Between these two extremes, a more moderate view is that monetary policy may be affected by the stance of macroprudential policy and that it should take into account financial stability concerns if macroprudential tools prove ineffective. The model presented here supports the moderate view. It shows that, when macroprudential policy is too lax and the financial sector does not absorb losses to a sufficient degree, monetary policy may be forced to become too accommodating so as to reduce private sector debt and shore up bank balance sheets. This is what we mean by 'financial dominance', a term that appears in speeches by policy makers (Hannoun, 2012; Weidmann, 2013), and in the academic literature (Brunnermeier and Sannikov, 2013; Leeper and Nason, 2014).

We derive a dynamic stochastic general equilibrium (DSGE) model with a banking sector where entrepreneurs are subject to default risk. Borrowing by firms entails a financial accelerator mechanism as in Bernanke, Gertler and Gilchrist (1999), henceforth BGG (1999). Entrepreneurs operate under limited liability and have to finance their projects by borrowing from banks. Since they are subject to default risk, external finance is costly. Differently from BGG (1999), however, debt contracts are non-state-contingent and as a result, bank balance sheets are impaired by entrepreneurial defaults. This model feature is similar to Zhang (2009), Benes and Kumhof (2011), and Clerc et al (2014). Since banks are no longer perfectly insured against bad shocks, there is a role for macroprudential policy to guard against bank defaults by imposing a minimum ratio of bank capital to assets.

Figure 1 provides an overview of the model.

[insert Figure 1 here]

Our model allows us to reassess monetary policy as a stabilisation tool in the presence of macroprudential instruments. In particular, the macroprudential authority imposes a capital requirement on banks in the form of a minimum ratio of equity capital to

[1]For a paper representing the first view, see Collard, Dellas, Diba and Loisel (2014). An example of the second view is Brunnermeier and Sannikov (2013).

assets. This capital ratio forces banks to partly finance loans to entrepreneurs using equity, which is more costly to banks than using deposit funding. A capital requirement rule links the capital ratio to the amount of borrowing. We represent monetary policy as a simple interest rate feedback rule as proposed by Taylor (1993). A loose monetary policy stance implies, on the one hand, a fall in the return on deposits that *boosts* bank profits and therefore bankers' net worth. On the other hand, the ensuing rise in inflation acts to *reduce* the real value of bank profits and thus bankers' net worth. Therefore, a monetary policy that aims at stabilising banker's equity and borrowing actually needs to move interest rates less than one-for-one in response to inflation. The interest rate rule coefficient on inflation that guarantees a unique model solution is shown to depend critically on the calibration of the macroprudential instrument. If, for instance, the capital ratio is held constant, the task of stabilising borrowing falls onto monetary policy, which is forced to be more accommodating than is warranted to stabilise inflation.

In the standard three-equation New Keynesian model, the well-known 'Taylor Principle' (see e.g. Woodford, 2001) is a necessary and sufficient condition for a unique solution. In particular, the monetary authority should raise its policy instrument, the nominal short term interest rate, by more than one percentage point if inflation increases by one percentage point. Intuitively, if policy makers do not respond 'enough' to interest rate movements, i.e. the coefficient on inflation in the Taylor rule is below unity, the real interest rate falls in response to increased inflation. As a consequence, demand increases as well as marginal costs, such that inflation continues to rise. In the standard framework, the monetary authority stabilises inflation by following the Taylor Principle.

However, suppose instead that credit frictions result in the existence of debt contracts, and that these debt contracts are in nominal terms. Then any rise in inflation acts to reduce the real value of outstanding debt, and as such can have a stabilising effect on debt dynamics. In that case, the Taylor Principle can be destabilising as it leads to accelerating debt dynamics through the Fisher (1933) debt-deflation channel. This has been shown by Leeper (1991) for the case of 'fiscal dominance' when borrowing is done by the government and fiscal policy is ineffective in stabilising public debt.

In our model with borrowing by firms and a bank capital requirement rule, we obtain a similar result for the case of 'financial dominance', i.e. when the macroprudential policy is ineffective in stabilising private debt. If the bank is not required to raise sufficient new equity in response to a rise in credit demand, it ends up granting too much credit to entrepreneurs and bank loans can be on an unstable path. In such a situation, inflation can help to reduce real debt levels and make debt dynamics sustainable. In other words: a violation of the Taylor Principle is warranted.

Our contribution to the literature is a determinacy analysis under the joint setting of monetary and macroprudential policy to achieve the dual objectives of price stability and financial stability. The paper's main finding, a novel result in the literature, mirrors the fiscal dominance result pointed out by Leeper (1991), according to which an active fiscal policy necessitates a passive monetary policy (and vice versa). Chari, Christiano and Kehoe (1991) show that, if the government can issue only nominal debt, inflation can be used as a policy instrument in order to make the real value of debt state-contingent. In this way, monetary policy can stabilise government debt when the appropriate fiscal instruments are absent. Brunnermeier and Sannikov (2013) show that price stability, fiscal sustainability and financial stability are intimately intertwined. Kumhof et al (2010) abstract from financial frictions and analyse the link between fiscal sustainability and price stability focussing on fiscal dominance. Here, we abstract from fiscal sustainability issues by assuming that lump sum taxes are set to satisfy the government budget constraint and analyse the link between financial stability and price stability, focussing on financial dominance. Our result resembles that of Svensson (2013), who finds that a policy of "leaning against the wind" is counterproductive in that it raises debt ratios instead of reducing them.

The remainder of the paper is structured as follows. In the following section, we outline the model. Section 3 discusses the interdependence of macroprudential and monetary policies. Section 4 presents a welfare analysis. Section 5 concludes.

2 Model

We consider a monetary business cycle model with a financial accelerator framework as in BGG (1999). That is, entrepreneurs have insufficient net worth to buy capital and thus demand loans from banks. Due to the fact that entrepreneurs are subject to idiosyncratic default risk, there exists a costly state verification problem whereby banks incur monitoring costs when an entrepreneur declares default. In BGG, the financial intermediary is a veil and its balance sheet plays no role. This is because debt contracts specify a loan repayment that is contingent on the aggregate state of the economy. Here, in contrast, nominal debt contracts are not contingent on the aggregate state of the economy and, therefore, banks suffer balance sheet losses as a result of higher-than-expected entrepreneurial defaults. Banks are required to finance a minimum fraction of their assets in terms of equity capital.

2.1 Households

Households are infinitely lived and maximise lifetime utility as follows,

$$\max_{c_t,l_t,d_t} \mathbb{E}_t \sum_{s=0}^{\infty} \beta^{t+s} \left[\ln c_{t+s} - \varphi \frac{l_{t+s}^{1+\eta}}{1+\eta} \right], \tag{1}$$

where $0 < \beta < 1$ is the discount factor, c_t is consumption, l_t is labour supply, φ is the weight on labour disutility and $\eta \geq 0$ is the inverse Frisch elasticity of labour supply. The household chooses c_t, l_t and bank deposits d_t to maximise utility (1) subject to the period budget constraint

$$c_t + d_t + t_t \leq w_t l_t + \frac{R_t^D d_{t-1}}{\Pi_t} + \Xi_t^K, \tag{2}$$

where t_t are lump sum taxes (in terms of the final consumption good), w_t is the real wage, R_t^D is the gross interest rate on deposits paid in period t, $\Pi_t = P_t/P_{t-1}$ is the gross inflation rate and Ξ_t^K are capital producers' profits that are redistributed to households. The household's first order optimality conditions can be simplified to a labour supply equation and a consumption Euler equation,

$$w_t = \frac{\varphi_t l_t^{\eta}}{\Lambda_t}, \tag{3}$$

$$1 = \mathbb{E}_t \left\{ \beta_{t,t+1} \frac{R_{t+1}^D}{\Pi_{t+1}} \right\}, \tag{4}$$

where $\beta_{t,t+s} = \beta^{t+s} \frac{\Lambda_{t+s}}{\Lambda_t}$ is the household's stochastic discount factor and the Lagrange multiplier on the budget constraint (2), $\Lambda_t = 1/c_t$ captures the shadow value of household wealth in real terms.

2.2 Production

Within the production sector we distinguish final goods producers, intermediate goods producers, and capital goods producers. Final goods producers are perfectly competitive. They create consumption bundles by combining intermediate goods using a Dixit-Stiglitz technology and sell them to the household sector. Intermediate goods producers use capital and labour to produce the goods used as inputs by the final goods producers. They set prices subject to quadratic adjustment costs, which introduces the New Keynesian Phillips curve in our model. Finally, capital goods producers buy the consumption good and convert it to capital which they sell to the entrepreneurs.

Final Goods

A final goods firm bundles the differentiated industry goods Y_{it}, with $i \in (0,1)$, taking as given their price P_{it}, and sells the output Y_t at the competitive price P_t. The optimisation problem of the final goods firm is to choose the amount of inputs that maximise profits, i.e. it solves:

$$\max_{Y_{it}} \left\{ P_t Y_t - \int_0^1 Y_{it} P_{it} \mathrm{d}i \right\},$$

subject to the CES production function,

$$Y_t = \left(\int_0^1 Y_{it}^{\frac{\varepsilon-1}{\varepsilon}} \mathrm{d}i \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{5}$$

where $\varepsilon > 1$ is the elasticity of substitution between industry goods. From the first order condition we derive the demand for industry goods,

$$Y_{it}^d = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon} Y_t. \tag{6}$$

Substituting Y_{it} in the production function using (6) yields the price of final output, which we interpret as an aggregate price index,

$$P_t = \left(\int_0^1 P_{it}^{1-\varepsilon} \mathrm{d}i \right)^{\frac{1}{1-\varepsilon}}.$$

In a symmetric equilibrium, the price of a variety and the price index coincide, $P_t = P_{it}$.

Intermediate Goods

Firms use capital and labour to produce wholesale output according to a constant returns to scale (CRS) production function. BGG (1999) assume that the production function is Cobb-Douglas. The CRS assumption is important; it allows us to write the production function as an aggregate relationship. There is a continuum of intermediate goods producers indexed by $i \in (0,1)$. Each of them produces a differentiated good using

$$Y_{it} = A_t K_{it}^{\alpha} l_{it}^{1-\alpha}, \tag{7}$$

where $0 < \alpha < 1$ is the capital share in production, A_t is aggregate technology, K_{it} are capital services and l_{it} is labour input. The logarithm of technology follows a stationary AR(1) process,

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_t^A,$$

where $0 < \rho_A < 1$ and ε_t^A is an *iid* shock with mean zero and variance σ_A^2. Intermediate goods firms maximise profits,

$$\frac{P_{it}Y_{it}}{P_t} - r_t^K K_{it} - w_t l_{it},$$

where r_t^K is the real rental rate on capital and w_t is the real wage, subject to the technological constraint (7) and the demand constraint (6). The demand for capital and labour is given by

$$w_t = (1-\alpha)s_t \frac{Y_{it}}{l_{it}} \tag{8}$$

and

$$r_t^K = \alpha s_t \frac{Y_{it}}{K_{it}}, \tag{9}$$

respectively.

We compute the capital-labour ratio by combining capital demand (9) and labour demand (8),

$$\frac{K_{it}}{l_{it}} = \frac{\alpha}{1-\alpha}\frac{w_t}{r_t^K}.$$

Substituting the capital labour ratio in equation (8) yields

$$s_t = \frac{w_t^{1-\alpha}(r_t^K)^\alpha}{\alpha^\alpha(1-\alpha)^{1-\alpha}}\frac{1}{A_t},$$

where the Lagrange multiplier on the demand constraint, s_t, represents real marginal costs.

Price Setting

Firms set prices P_{it} to maximise profits, subject to the demand constraint (6) and to price adjustment costs PAC_{it}, to be defined below. Firm i's problem is

$$\max_{P_{it}} \mathbb{E}_t \sum_{s=0}^{\infty} \beta_{t,t+s} \left\{ \frac{P_{it+s}Y_{it+s}^d}{P_{t+s}} - PAC_{it+s} + s_{t+s}\left(Y_{it+s} - Y_{it+s}^d\right) \right\}, \tag{10}$$

Price adjustment costs are proportional to firm revenues,

$$PAC_{it} = \frac{\kappa_p}{2}\left(\frac{P_{it}}{P_{it-1}\Pi} - 1\right)^2 \frac{P_{it}Y_{it}^d}{P_t}, \tag{11}$$

where $\kappa_p > 0$ measures the degree of price rigidity. Perfectly flexible prices are given by $\kappa_p \to 0$. Price adjustment costs are a function of the ratio of the firm's price change P_{it}/P_{jt-1} to steady-state inflation. Under symmetry, all firms produce the same amount of output, and the firm's price P_{it} equals the aggregate price level P_t, such that the price setting condition is

$$\kappa_p \frac{\Pi_t}{\Pi}\left(\frac{\Pi_t}{\Pi}-1\right) = s_t \varepsilon - (\varepsilon - 1)\left[1-\frac{\kappa_p}{2}\left(\frac{\Pi_t}{\Pi}-1\right)^2\right] + \kappa_p \beta \mathbb{E}_t \left\{\frac{\Lambda_{t+1}}{\Lambda_t}\frac{\Pi_{t+1}}{\Pi}\left(\frac{\Pi_{t+1}}{\Pi}-1\right)\frac{Y_{t+1}}{Y_t}\right\}. \tag{12}$$

Capital Goods

Perfectly competitive capital producers buy consumption goods at price P_t, convert them into capital goods and sell those capital goods to entrepreneurs at real price q_t. Capital accumulation is subject to quadratic adjustment costs of the form

$$\frac{\kappa_k}{2}\left(\frac{I_t}{K_t}-\delta\right)^2 K_t.$$

Notice that adjustment costs and their first derivative are equal to zero in steady state. The introduction of capital adjustment costs yields a variable price of capital. Capital goods firms are owned by households. The capital producers' problem has the following first order condition,

$$q_t = 1 + \kappa_k \left(\frac{I_t}{K_t}-\delta\right). \tag{13}$$

The law of motion for capital is

$$K_{t+1} = (1-\delta) K_t + I_{t+1}. \tag{14}$$

where δ is the capital depreciation rate.

2.3 Entrepreneurs

Entrepreneurs are indicated by a superscript 'E', there is a continuum of entrepreneurs on the unit interval and they are indexed by $j \in (0,1)$. They are assumed to live for two periods (overlapping generations) and they are risk neutral.[2] They purchase capital from the capital production sector and, together with depreciated capital from previous entrepreneurs, they rent it to the consumption goods producers.

Wealth Allocation

In period 2, entrepreneurs have to decide which fraction of their (real) wealth $\mathcal{W}^E_{t+1}$ they allocate to consumption c^E_{t+1} and which fraction they leave as a bequest n^E_{t+1} for the next generation of entrepreneurs. Entrepreneur j's preferences with respect to consumption

[2] We follow Clerc et al (2014) by assuming an overlapping generations structure for entrepreneures and bankers, rather than a constant survival rate as in BGG (1999). The wealth accumulation equation looks similar under the two assumptions.

and bequests are described by the following utility function

$$\max_{c_{t+1}^{Ej},n_{t+1}^{Ej}} (c_{t+1}^{Ej})^{\chi^E}(n_{t+1}^{Ej})^{1-\chi^E},$$

subject to

$$c_{t+1}^{Ej} + n_{t+1}^{Ej} \leq \mathcal{W}_{t+1}^{Ej}.$$

At the optimum, a constant fraction of an entrepreneur's wealth is allocated to consumption while the remainder is left as bequest,

$$c_{t+1}^{E} = \chi^E \mathcal{W}_{t+1}^{E}, \tag{15}$$

$$n_{t+1}^{E} = (1-\chi^E)\mathcal{W}_{t+1}^{E}. \tag{16}$$

In period 1, the entrepreneur j is born with an amount n_t^{Ej} obtained from the previous generation. Aggregate entrepreneurial wealth in period $t+1$ is given by the value of their capital stock bought in the previous period, $q_t K_t^j$, multiplied by the ex-post rate of return on capital R_{t+1}^E, multiplied by the fraction of returns which are left to the entrepreneur $1-\Gamma_{t+1}^E$, discounted by the gross rate of inflation,

$$\mathcal{W}_{t+1}^{Ej} = \left(1-\Gamma_{t+1}^E\right)\frac{R_{t+1}^E q_t K_t^j}{\Pi_{t+1}}. \tag{17}$$

Note that the discussion of the contracting problem between entrepreneurs and banks below contains a derivation of Γ_{t+1}^E.

Borrowing

Entrepreneur j chooses the level of capital K_{t+1}^j which has a real price q_t per unit. Capital is chosen at t and used for production at $t+1$. It has an ex post gross return $\omega_{t+1}^{Ej} R_{t+1}^E$, where R_{t+1}^E is the aggregate return on capital and ω_{t+1}^{Ej} is an idiosyncratic (entrepreneur-specific) disturbance, the latter being *iid* log-normally distributed with mean $\mathbb{E}\{\omega_{t+1}^{Ej}\} = 1$. The probability of entrepreneur's default is defined by the respective cumulative distribution function evaluated at $\overline{\omega}_{t+1}^{Ej}$

$$F_{t+1}^E = F^E(\overline{\omega}_{t+1}^{Ej}) = \int_0^{\overline{\omega}_{t+1}^{Ej}} f^E(\omega_{t+1}^{Ej})\mathrm{d}\omega_{t+1}^{Ej},$$

where $f^E(\cdot)$ is the respective probability density function. The entrepreneur has net worth n_t^{Ej}, which she carries over into period $t+1$, and faces expenditures on capital goods $q_t K_t^j$. She borrows the remainder,

$$b_t^j = q_t K_t^j - n_t^{Ej}, \tag{18}$$

from the bank. The entrepreneur receives a loan from the bank which, in turn, obtains funds from households and bankers. The lender must pay a monitoring cost in order to observe the entrepreneur's realised return on capital. This cost is a proportion μ^E of the realised gross payoff to the firms, i.e. $\mu^E \omega_{t+1}^{Ej} R_{t+1}^E q_t K_t^j$ and is incurred in the case of default.

2.4 Financial Contract

The bank enters into a financial contract with the entrepreneurs. Depending on the realisation of the idiosyncratic productivity shock, some entrepreneurs will declare default while others continue operating. A productivity threshold $\overline{\omega}_{t+1}^{Ej}$ is defined such that for realizations of ω_{t+1}^{Ej} smaller than the threshold the entrepreneur is able to repay her loan in full, i.e. the entrepreneur declares default, while for values greater than the treshold the entrepreneur will honour her contractual obligation by paying the bank $Z_t^{Ej} b_t^j$, i.e.

$$\overline{\omega}_{t+1}^{Ej} R_{t+1}^E q_t K_t^j = Z_t^{Ej} b_t^j, \tag{19}$$

where Z_t^{Ej} is the contractual repayment rate. We rewrite the above condition as follows,

$$\overline{\omega}_{t+1}^{Ej} = \frac{x_t^{Ej}}{R_{t+1}^E},$$

where we define the entrepreneur's leverage as $x_t^{Ej} \equiv Z_t^{Ej} b_t^j / (q_t K_{t+1}^j)$. Unlike BGG (1999), the cutoff productivity level $\overline{\omega}_{t+1}^{Ej}$ is not contingent on the realisation of the aggregate state R_{t+1}^Ebut on its expected value.[3] This assumption is important since it introduces the possibility of firm defaults impinging on bank balance sheets in the model.

The entrepreneur is risk-neutral and cares only about the mean return on his wealth. However, the bank bears some of the losses stemming from aggregate risk, as in Zhang (2009), Benes and Kumhof (2011) and Clerc et al (2014). The expected real return to the entrepreneur is given by the expected project return net of loan repayments which realise if the entrepreneur does not default,

$$\mathbb{E}_t \int_{\overline{\omega}_{t+1}^{Ej}}^{\infty} \omega_{t+1}^{Ej} R_{t+1}^E q_t K_t^j f^E(\omega_{t+1}^{Ej}) \mathrm{d}\omega_{t+1}^{Ej} - [1 - F^E(\overline{\omega}_{t+1}^{Ej})] Z_t^{Ej} b_t^j, \tag{20}$$

where the expectation is taken with respect to the random variable R_{t+1}^E. As noted above, the random variable ω_{t+1}^{Ej} follows a log-normal distribution with mean one and a standard

[3] If instead the cutoff productivity level $\overline{\omega}_{t+1}^{Ej}$ is made contingent on the aggregate state given by R_{t+1}^E as in BGG (1999), the entrepreneur bears all the aggregate risk, and the bank is perfectly insulated from any losses stemming from defaulting entrepreneurs.

deviation $\sigma_t^E = \sigma^E \varsigma_t$, which introduces time variability of firm risk via an AR(1) process,

$$\ln \varsigma_t = \rho_\varsigma \ln \varsigma_{t-1} + \varepsilon_t^\varsigma,$$

such that $0 < \rho_\varsigma < 1$ and σ^ς denotes the standard deviation of the *iid* normal shock ε_t^ς.

In the case where $\omega_{t+1}^{Ej} < \overline{\omega}_{t+1}^{Ej}$, the entrepreneur is not able to fully repay her loan. In this case, the entrepreneur has to pay the whole return $\omega_{t+1}^{Ej} R_{t+1}^E q_t K_t^j$ to the bank. In the non-default case the bank receives only the contractural agreement $\overline{\omega}_{t+1}^{Ej} R_{t+1}^E q_t K_t^j$. The remainder, $(\omega_{t+1}^{Ej} - \overline{\omega}_{t+1}^{Ej}) R_{t+1}^E q_t K_t^j$, is left for the residual claimant, the entrepreneur. Consequently, if the entrepreneur does not default, the payment is independent of the realisation of the random variable but depends solely on the threshold value. The difference to BGG (1999) is that the threshold productivity is outside the expectations operator, as shown in Zhang (2009). Substituting out $Z_t^{Ej} b_t^j$ in (20) using (19), and using our assumption that $\mathbb{E}_t(\omega_{t+1}^{Ej}) = 1$, allows us to rewrite the expression for the expected real return as

$$\left(1 - \Gamma_{t+1}^E\right) R_{t+1}^E q_t K_t^j, \tag{21}$$

where we define

$$\Gamma_{t+1}^E = \Gamma^E(\overline{\omega}_{t+1}^{Ej}) \equiv \int_0^{\overline{\omega}_{t+1}^{Ej}} \omega_{t+1}^{Ej} f(\omega_{t+1}^{Ej}) \mathrm{d}\omega_{t+1}^{Ej} + [1 - F^E(\overline{\omega}_{t+1}^{Ej})]\overline{\omega}_{t+1}^{Ej},$$

such that $1 - \Gamma_{t+1}^E$ represents the share of the return which is left for the entrepreneur. Equation (21) represents entrepreneur j's expected profits which she seeks to maximise when negotiating the credit contract with the bank.

In order for the bank to agree on the contract, the return which the bank earns from lending funds to the entrepreneur (left hand side) must be equal to or greater than the return the bank would obtain from investing its equity in the interbank market (right hand side),

$$\mathbb{E}_t\{\left(1 - \Gamma_{t+1}^F\right) [(1-F_{t+1}^E)\overline{\omega}_{t+1}^{Ej} + (1-\mu^E) \int_0^{\overline{\omega}_{t+1}^{Ej}} \omega_{t+1}^{Ej} f^E(\omega_{t+1}^{Ej}) \mathrm{d}\omega_{t+1}^{Ej}] R_{t+1}^E q_t K_t^j\} \geq \mathbb{E}_t\{R_{t+1}^B n_t^B\}, \tag{22}$$

where

$$\Gamma_{t+1}^F = \frac{R_{t+1}^D d_t}{R_{t+1}^F b_t},$$

and $1 - \Gamma_{t+1}^F$ is thus the share of loan return to the banker after the bank has made interest payments to the depositors. Banks finance loans using equity and deposits. They are subject to the following capital constraint,

$$n_t^B \geq \phi_t b_t, \tag{23}$$

which says that equity must be at least a fraction ϕ_t of bank assets. As ϕ_t rises, banks hold more internal equity; as ϕ_t falls, the fraction of external funds increases. It can be shown that (23) holds with equality in equilibrium such that $n_t^B = \phi_t b_t$. Aggregating capital holdings and net worth over each group of entrepreneurs, we define $K_t = \int_j K_t^j \mathrm{d}j$ and $n_t^E = \int_j n_t^{Ej} \mathrm{d}j$, such that

$$b_t = q_t K_t - n_t^E \tag{24}$$

are the total loans that the bank provides to entrepreneurs. Replacing b_t in (23), we obtain $n_t^B = \phi_t(q_t \int_j K_t^j \mathrm{d}j - n_t^E)$ and the bank's participation constraint (22) becomes

$$\mathbb{E}_t\{\left(1 - \Gamma_{t+1}^F\right)(\Gamma_{t+1}^E - \mu^E G_{t+1}^E) R_{t+1}^E q_t K_t^j\} \geq \phi_t \mathbb{E}_t\{R_{t+1}^B (q_t \int_j K_t^j \mathrm{d}j - n_t^E)\}, \tag{25}$$

where we define the share of returns subject to firm default as follows,

$$G_{t+1}^E = G^E(\overline{\omega}_{t+1}^{Ej}) \equiv \int_0^{\overline{\omega}_{t+1}^{Ej}} \omega_{t+1}^{Ej} f^E(\omega_{t+1}^{Ej}) \mathrm{d}\omega_{t+1}^{Ej}.$$

Using the above results we are able to derive the financial contract. The entrepreneur's objective is given by

$$\max_{x_t^{Ej}, K_{t+1}^j} \mathbb{E}_t \left\{ \left[1 - \Gamma^E \left(\frac{x_t^{Ej}}{R_{t+1}^E} \right) \right] R_{t+1}^E q_t K_t^j \right\}, \tag{26}$$

subject to the bank's participation constraint,

$$\mathbb{E}_t \left(1 - \Gamma_{t+1}^F\right) \left[\Gamma^E \left(\frac{x_t^{Ej}}{R_{t+1}^E} \right) - \mu^E G^E \left(\frac{x_t^{Ej}}{R_{t+1}^E} \right) \right] R_{t+1}^E q_t K_t^j = \phi_t \mathbb{E}_t\{R_{t+1}^B (q_t \int_j K_t^j \mathrm{d}j - n_t^E)\}. \tag{27}$$

The optimality conditions of the contracting problem are

$$\mathbb{E}_t\{-\Gamma_{t+1}^{E\prime} + \xi_t^{Ej} \left(1 - \Gamma_{t+1}^F\right) \left(\Gamma_{t+1}^{E\prime} - \mu^E G_{t+1}^{E\prime}\right)\} = 0,$$

$$\mathbb{E}_t\{\left(1 - \Gamma_{t+1}^E\right) R_{t+1}^E + \xi_t^{Ej} \left[\left(1 - \Gamma_{t+1}^F\right) \left(\Gamma_{t+1}^E - \mu^E G_{t+1}^E\right) R_{t+1}^E - \phi_t R_{t+1}^B\right]\} = 0,$$

where ξ_t^{Ej} is the Lagrange multiplier with respect to the bank participation constraint (27).

2.5 Bankers

Banks obtain equity from bankers who face a trade-off between consuming and leaving a bequest for following generations. Each banker lives for two periods. In period 2, bankers have to decide which fraction of their real wealth $\mathcal{W}_{t+1}^B$ they allocate to consumption c_{t+1}^B

and which fraction they want to invest as bank equity n^B_{t+1} which yields a return R^B_{t+1}. Their preferences with respect to consumption and bequests are described by the following utility function:

$$\max_{c^B_{t+1}, n^B_{t+1}} \left(c^B_{t+1}\right)^{\chi^B} \left(n^B_{t+1}\right)^{1-\chi^B},$$

subject to

$$c^B_{t+1} + n^B_{t+1} \leq \mathcal{W}^B_{t+1}.$$

Analogous to the wealth allocation problem of entrepreneurs, the optimality conditions of bankers with respect to consumption and bequests are, respectively,

$$c^B_{t+1} = \chi^B \mathcal{W}^B_{t+1}, \tag{28}$$

$$n^B_{t+1} = (1 - \chi^B)\mathcal{W}^B_{t+1}. \tag{29}$$

In period 1, the banker is born with real net worth n^B_t which she inherits from the previous generation. The only investment opportunity of the banker is to provide equity to the bank. Bankers obtain an ex post aggregate return of R^B_{t+1} on their investment, which determines their wealth in period 2,

$$\mathcal{W}^B_{t+1} = \frac{R^B_{t+1} n^B_t}{\Pi_{t+1}}. \tag{30}$$

2.6 Banks

The bank obtains deposits from households and raises equity from bankers. Its assets are the loans which it provides to the entrepreneurs. Consequently, the bank's balance sheet reads

$$n^B_t + d_t = b_t. \tag{31}$$

Bank profits in period $t + 1$ are the difference between the return from loans to the entrepreneurs and the interest payments on household deposits,

$$\Xi^F_{t+1} = R^F_{t+1} b_t - R^D_{t+1} d_t. \tag{32}$$

where R^F_{t+1} is the bank's realised return on loans to entrepreneurs.[4]

[4] We verify numerically that bank profits are non-negative in all states and at all dates.

2.7 Realised Rates of Return

The ex-post gross rate of return on a banker's equity R^B_{t+1} is given by the ratio of bank profits to banker net worth, Ξ^F_{t+1}/n^B_t, or using (32),

$$R^B_{t+1} = \frac{R^F_{t+1}b_t - R^D_{t+1}d_t}{n^B_t} = \frac{\left(1-\Gamma^F_{t+1}\right)R^F_{t+1}b_t}{n^B_t}. \tag{33}$$

In turn, the return on bank loans in (36), R^F_{t+1}, is derived as the payoff to the bank on loans in $t+1$, which is given by $\left(\Gamma^E_{t+1} - \mu^E G^E_{t+1}\right) R^E_{t+1} q_t K_t$, divided by the volume of loans b_t. That is,

$$R^F_{t+1} = \Phi^E_{t+1}\frac{R^E_{t+1}q_tK_t}{b_t}. \tag{34}$$

where $\Phi^E_{t+1} = \Gamma^E_{t+1} - \mu^E G^E_{t+1}$. The nominal gross return to entrepreneurs of holding a unit of capital from t to $t+1$ is given by the rental rate on capital, plus the capital gain net of depreciation, $(1-\delta)\,q_{t+1}$, divided by the real price of capital, in period t,

$$R^E_{t+1} = \frac{r^K_{t+1} + (1-\delta)\,q_{t+1}}{q_t}\Pi_{t+1}. \tag{35}$$

It is useful to derive the real return on equity as a function of the policy instruments R^D_t and ϕ_t. Combining the return on equity (33) with the loan return (34), we have

$$R^B_{t+1} = \Phi^E_{t+1}R^E_{t+1}q_tK_t - R^D_{t+1}\frac{d_t}{n^B_t}, \tag{36}$$

Using the definition of the capital ratio (23) to replace d_t/n^B_t and the return on capital (35) to replace R^E_{t+1}, and dividing by inflation Π_{t+1}, this becomes

$$\frac{R^B_{t+1}}{\Pi_{t+1}} = \Phi^E_{t+1}\left[r^K_{t+1} + (1-\delta)\,q_{t+1}\right]K_t - \frac{R^D_{t+1}}{\Pi_{t+1}}\frac{1-\phi_t}{\phi_t}. \tag{37}$$

Two things can be observed from (37). First, the effective real equity return is a positive function of the capital requirement ϕ_t, ceteris paribus. When the bank is required to finance a larger fraction of loans using equity, this raises the real return on equity earned by bankers. Second, the effective real equity return is a negative function of the effective real interest rate R^D_{t+1}/Π_{t+1}. The higher the rate of return that the bank has to pay depositors, the lower is the bank's profit and therefore the lower is the return accruing to equity holders.

2.8 Market Clearing and Equilibrium

Consumption goods produced must equal goods demanded by households, entrepreneurs and bankers; goods used for investment, resources lost when adjusting investment, and resources lost in the recovery of funds associated with entrepreneur defaults,

$$Y_t = c_t + \chi^E \mathcal{W}^E_{t+1} + \chi^B \mathcal{W}^B_{t+1} + \frac{\kappa_k}{2}\left(\frac{I_t}{K_t} - \delta\right)^2 K_t + \mu^E G^E_t \frac{R^E_t q_{t-1} K_t}{\Pi_t}.$$

Firms' labour demand must equal labour supply.

$$(1-\alpha)\, s_t \frac{Y_t}{l_t} = \frac{\varphi_t l_t^\eta}{\Lambda_t}.$$

The model is closed with a monetary policy rule that governs the policy rate R_t and a macroprudential rule that governs the capital ratio, ϕ_t. Notice that because of full deposit insurance, the policy rate is identical to the risk-free deposit rate, $R_t = R^D_t$.

We are now ready to provide a formal definition of equilibrium in our economy.

Definition 1 *An equilibrium is a set of allocations* $\{l_t,\ K_t,\ I_t,\ c_t,\ Y_t,\ n^E_t,\ b_t,\ n^B_t,\ d_t,\ x^E_t\}_{t=0}^\infty$*, prices* $\{w_t,\ r^K_t,\ q_t,\ \Pi_t,\ s_t\}_{t=0}^\infty$ *and rates of return* $\{R^E_t,\ R^F_t,\ R^B_t\}_{t=0}^\infty$ *which, given the monetary and macroprudential policies* $\{R_t,\ \phi_t\}_{t=0}^\infty$ *and shocks to technology and firm risk* $\{A_t,\ \varsigma_t\}_{t=0}^\infty$ *satisfy the set of equations summarised in Table 1.*

[insert Table 1 here]

We derive the deterministic zero-inflation steady state. To this end, we first set gross inflation and technology to unity in steady state as a normalisation, $\Pi = A = 1$. Second, we solve numerically for labour l, firm leverage x^E, the share of the loan return going to depositors Γ^F, and the return on capital, R^E. Given initial values for those steady state parameters, we can solve for the remaining steady state variables recursively. The recursive steady state equations are provided in Table 2.

2.9 Calibration and Steady State

We calibrate the model to a quarterly frequency. The calibration of our model parameters is summarised in Table 3. Most of the structural parameters have standard values. The subjective discount factor β is set to 0.99, implying a quarterly risk-free (gross) interest rate of 1.01 or a real annual (net) interest rate of roughly 4%, given that steady state gross inflation is set to unity, $\Pi = 1$. The inverse Frisch elasticity of labour supply is set to $\eta = 0.2$, which is common for macroeconomic models. The capital share in production is set to $\alpha = 0.3$, the substitution elasticity between goods varieties is $\varepsilon = 6$, implying a gross steady state markup of $\varepsilon/(\varepsilon - 1) = 1.2$. The Rotemberg price adjustment cost parameter is $\kappa_p = 20$. Capital depreciation in steady state is $\delta = 0.025$ per quarter, while the capital adjustment cost parameter is set to $\kappa_k = 2$.

[insert Table 3 here]

We now turn to the financial parameters. The share of wealth that is consumed by the old generation is set to 6% for both entrepreneurs and bankers, i.e. $\chi^E = \chi^B = 0.06$. Monitoring costs are the fraction of the return that is lost when a debtor declares default. This parameter is set to $\mu^E = 0.3$. The size of the idiosyncratic shock hitting entrepreneurs is $\sigma^E = 0.12$. The steady state capital requirement for banks, i.e. the ratio of equity to loans, is set to 8%, that is $\phi = 0.08$.

The implied steady state values of several model variables are shown in Table 2 below. We first discuss the ranking of the various interest rates and spreads in steady state, before turning to the default probability of entrepreneurs.

[insert Table 2 here]

The risk-free rate corresponds to the deposit rate R^D and to the policy rate R in steady state. The realised return on loans to entrepreneurs is $R^F = 1.0144$. This return contains a discount which is related to the monitoring cost μ^E that the bank must incur when an entrepreneur declares default. The next higher rate of return is the return on capital, $R^E = 1.0284$. The return on capital is yet higher than the realised loan return R^F, because it needs to compensate the entrepreneur for running the risk of default while it is not reduced by the monitoring cost. Finally, the return on equity earned by bankers R^B exceeds the realised loan return, because it contains a compensation to bankers (or equity holders) for the risk of bank default. In addition, the loan return is a decreasing function of the capital requirement ϕ_t; the higher is the capital requirement, the more equity banks will hold, and hence the lower is the implied return on equity, R^B. Table 2 also shows the annualised return spreads on bank loans (1.7%), on entrepreneurial capital (7.3%) and on equity (21.5%). The quarterly default probability of entrepreneurs is 0.66%, which corresponds to an annual default rate of 2.6%.

In our welfare analysis below, we simulate the model under autoregressive processes for the technology shock, $\ln A_t$, and the firm risk shock, $\ln \varsigma_t$. Both shocks are assumed to have persistence 0.9. The size of the technology shock is set to 0.0046 and the size of the firm risk shock is set to 0.07 following Christiano, Motto and Rostagno (2014).

3 Macroprudential and Monetary Policy

We now analyse the interaction of monetary and macroprudential policy in the form of simple rules. We follow the approach in Kumhof, Nunes and Yakadina (2010), who focus on simple monetary rules under *fiscal* dominance. Kumhof et al (2010) define fiscal dominance as a situation where fiscal policy is "unable or unwilling to adjust primary surpluses to stabilize government debt". In the standard New Keynesian model, lump sum taxes are used to satisfy the government budget constraint, and hence fiscal policy is passive in the sense that it reacts at most weakly to government debt. Then, an aggressive monetary policy reaction to inflation, i.e. an adherence to the Taylor Principle, is required for determinacy.

In our model, we define macroprudential policy as being either active or passive in a way analogous to Leeper (1991). We refer to 'financial dominance' as a situation where macroprudential policy is unable or unwilling to adjust its instrument - the bank capital ratio - sufficiently in response to private sector debt.[5] This is the case when the coefficient in the macroprudential rule, ζ_b is too low and macroprudential policy is therefore 'active'. Our result mirrors that in Kumhof et al (2010): in the absence of *financial* dominance the Taylor Principle is re-established. For this to happen, the macroprudential instrument must respond sufficiently to lending such that macroprudential policy becomes passive. However, if bank capital ratios imposed by the macroprudential regulator are constant or respond too little to credit, an aggressive monetary policy stance can lead to indeterminacy.

We proceed as follows. We first analyse the determinacy properties of the model, i.e. the conditions under which a unique stable equilibrium solution to the model exists. Second, we take into account the zero lower bound (ZLB) constraint by comparing the standard deviation of the interest rate under various combinations of the policy coefficients with its steady state level. Parameter combinations that imply a violation of the ZLB constraint more than 5% of the time are discarded. Finally, we compute the implied volatility of inflation and bank lending for all parameter combinations that produce a unique equilibrium and perform a welfare analysis which provides information about preferred values of policy coefficients in which the ZLB is not violated too often.

3.1 Interest Rate Rule and Capital Requirement Rule

We consider a monetary policy rule by which the central bank may adjust the policy rate in response to inflation and lending. The respective feedback coefficients are τ_Π and τ_b, such that:

$$\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{\tau_\Pi} \left(\frac{b_t}{b}\right)^{\tau_b}. \tag{38}$$

The response of the interest rate to lending, the second term in the monetary policy rule (38), has been called "Leaning Against The Wind" (LATW) in the literature.[6] Similar

[5]Brunnermeier and Sannikov (2013) define financial dominance more generally as the "inability or unwillingness of the financial sector to absorb losses".

[6]LATW may also refer to an augmented monetary policy rule where the interest rate responds to assets prices, see e.g. Cecchetti et al (2000) and Bernanke and Gertler (2001). We do not consider this

specifications can be found in many papers, for instance in Benes and Kumhof (2011) or in Lambertini, Mendicino and Punzi (2013). The idea behind a positive coefficient on borrowing, $\tau_b > 0$, is that monetary policy may want to dampen financial cycles by varying the interest rate, even if inflation is subdued.

Macroprudential policy is given by a rule for how the bank capital requirement should be set in response to changes in lending,

$$\frac{\phi_t}{\phi} = \left(\frac{b_t}{b}\right)^{\zeta_b}. \tag{39}$$

The capital requirement rule in (39) has been used in this form in other studies, e.g. in Benes and Kumhof (2011) and in Clerc et al (2014). It is a natural specification that lets the policy instrument (the capital ratio) react to deviations of the debt level from its steady state value with a coefficient ζ_b. Fiscal policy rules are often specified in a similar way: the fiscal instrument, e.g. the tax rate, responds with a certain coefficient to deviations of the public debt level from its steady state (or target) level, see e.g. Kumhof et al (2010).

The parametrizations of the policy rules is the focus of our analysis below.

3.2 Determinacy Analysis

We characterise the determinacy region for two cases. First, we consider two separate rules for monetary and macroprudential policy in our benchmark model. Second, we use a model variant with a constant bank capital requirement and a reaction in the interest rate rule to lending.

Macroprudential Stabilisation

We analyse determinacy for different combinations of the coefficient on inflation in the interest rate rule and the coefficient on lending in the bank capital rule. By setting the coefficient on lending in the interest rate rule (τ_b) to zero, we consider a variant of the so-called Taylor Rule, see Taylor (1993),

$$\tau_\Pi \neq 0, \quad \tau_b = 0, \quad \zeta_b \neq 0.$$

The result of this exercise is depicted in Figure 2. The horizontal axis shows the coefficient in the macroprudential rule (ζ_b), varying between 0 and 25, while the vertical axis shows the coefficient on inflation in the Taylor Rule (τ_Π), varying between -1 and 3. Even though we do not consider a negative inflation coefficient as economically meaningful, we

type of rule here.

do not want to impose any priors at this point of the analysis. See also the exercise in Kumhof et al (2010).

Result 1: *Under a macroprudential policy rule which sets a bank capital requirement in response to the volume of lending, there is a threshold coefficient* $\overline{\zeta}_b$ *below which the Taylor Principle is violated.*

We notice that the figure is divided into quadrants, two of which correspond to parameter regions with a unique solution (determinacy regions): the lower left and upper right quadrants. This means that the model is determinate if the coefficient on inflation in the interest rate rule and the coefficient on borrowing in the macroprudential rule are either both low or both high. In other words, both policies have to be similarly accommodating or aggressive.

[insert Figures 2 and 3 here]

What is the intuition for this result? If macroprudential policy is active, such that ζ_b is (too) low, banks do not raise capital holdings adequately in response to rises in debt: the economy suffers from financial dominance.

In the *upper left* quadrant, monetary policy follows the Taylor Principle - as it should in the New Keynesian model without financial frictions. The coefficient on inflation in the interest rate rule is greater than unity, $\tau_\Pi > 1$. The resulting Fisher debt-deflation effect increases the real value of outstanding debt. As a result, debt becomes unsustainable and the model features an explosive solution.

Determinacy is instead achieved in the *lower left* quadrant. The ineffectiveness of macroprudential regulation in stabilising borrowing forces the monetary authority to take on a more accommodative stance than in the absence of financial stability concerns. More precisely, the central bank must move the interest rate less than one-for-one in response to inflation in order to attain a determinate equilibrium. By violating the Taylor Principle, monetary policy allows financial stability concerns to override its price stability objective.

If the macroprudential rule features a strong response of the capital requirement to borrowing, i.e. a high ζ_b, determinacy requires that the Taylor Principle be satisfied, such that $\tau_\Pi > 1$, see the *upper right* quadrant in Figure 2. In that case, the debt-deflation effect which jeopardises financial stability in a downturn is sufficiently compensated for by increases in the bank capital ratio, such that debt does not spiral out of control and the system displays a unique solution. Finally, in the *lower right* quadrant, the capital requirement ratio is strongly procyclical with respect to borrowing, but monetary policy is passive in the sense that it does not move the interest rate by more than the change in inflation. The result of this parameter constellation is indeterminacy.

Indeterminacy opens up the possibility of sunspot equilibria. Suppose that entrepreneurs expect a high future return on their investment. They want to invest more and raise their demand for capital. Given their net worth, this implies that they need to borrow more from banks. In the lower right quadrant of Figure 2, the macroprudential rule (39) requires the bank capital ratio to be raised strongly along with borrowing (ζ_b is high). Therefore, an investment boom triggers a rise in bank capital ϕ_t, which by equation (37) boosts the real return on equity, R^B_{t+1}/Π_{t+1}. The rates of return on equity and on entrepreneurial capital are related, see (36). Thus, the return on risky investment rises and the entrepreneurs' expectation becomes a self-fulfilling prophecy.

Leaning Against the Wind

In a second model variant, we assume an augmented monetary policy rule, according to which the interest rate reacts to inflation and borrowing, coupled with a constant capital requirement. In particular, the policy rule coefficients are given by

$$\tau_\Pi \neq 0, \quad \tau_b \neq 0, \quad \zeta_b = 0. \tag{40}$$

We proceed in the same way as above and analyse determinacy and the transmission mechanism in this variant of the model. We let the inflation coefficient τ_Π range from -1 to 3 as above, and we let the 'leaning against the wind' coefficent τ_b range from -0.5 to 1.

Result 2: *Under a 'leaning against the wind' policy with a constant capital requirement and an interest rate rule that reacts to inflation and lending, the Taylor Principle is violated for plausible values of policy rule coefficient on lending,* τ_b.

Figure 3 displays the determinacy regions corresponding to the augmented Taylor Rule model. We notice that on the entire support of τ_b, determinacy is achieved when the Taylor Principle is violated. The central bank is therefore forced to take on an accommodative stance in order to select a unique equilibrium. This result is due to the fact that there is no instrument that effectively stabilises lending b_t. Therefore, the Fisher debt-deflation channel, which is active under the Taylor Principle, leads to a snowballing of debt and thus explosive dynamics.

The above analysis has shown that the absence of a separate macroprudential instrument necessitates a passive monetary policy rule. Put differently, an active monetary policy rule, i.e. one that satisfies the Taylor Principle, can only be combined with a *separate* macroprudential instrument, which is effective in stabilising lending. Such an active monetary policy cannot be combined with a policy of 'leaning against the wind' by raising interest rates in response to changes in lending volumes.

3.3 Discussion and Sensitivity Analysis

To better understand the main result presented in the previous section, we derive the dynamic equation which is crucial in the determination of the equilibrium dynamics: the banker's net worth equation. We combine banker bequests (29) and banker wealth (30) to obtain,

$$n_{t+1}^{B} = \left(1-\chi^{B}\right)\left(\frac{R_{t+1}^{B}}{\Pi_{t+1}}\right) n_{t}^{B}. \tag{41}$$

The stability of this process depends on the properties of the terms in front of n_t^B. First, it depends on the degree of altruism of the bankers, $1-\chi^B$, i.e. on the fraction of their wealth that they leave as bequests to the next generation. Second, it depends on the real effective return on equity in excess of the riskfree real rate, $(R_{t+1}^B - R_{t+1}^D)/\Pi_{t+1}$. The latter, derived in (37), is repeated here for convenience,

$$\frac{R_{t+1}^{B}-R_{t+1}^{D}}{\Pi_{t+1}} = \Phi_{t+1}^{E}\left[r_{t+1}^{K}+\left(1-\delta\right)q_{t+1}\right]K_{t} - \frac{R_{t+1}^{D}}{\Pi_{t+1}}\frac{1}{\phi_{t}}. \tag{42}$$

This relation makes it clear that stability of the banker's net worth depends positively on macroprudential policy, which affects the capital requirement, ϕ_t, and negatively on monetary policy, which affects the effective real interest rate, R_{t+1}^D/Π_{t+1}. In particular, we can combine the excess return on equity (42) with the monetary policy rule (38) and the macroprudential rule (39), to find

$$\frac{R_{t+1}^{B}-R_{t+1}^{D}}{\Pi_{t+1}} = \Phi_{t+1}^{E}\left[r_{t+1}^{K}+\left(1-\delta\right)q_{t+1}\right]K_{t} - \frac{1}{\beta\phi}\left(\frac{\Pi_{t+1}}{\Pi}\right)^{\tau_{\Pi}-1}\left(\frac{b_{t+1}}{b}\right)^{\tau_{b}-\zeta_{b}}. \tag{43}$$

Equation (43) shows that, ceteris paribus, the excess return on equity is increasing in the macroprudential policy coefficient ζ_b and decreasing in the inflation coefficient τ_Π and in the leaning-against-the-wind coefficient τ_b.

The determinacy analysis of the previous section relied on a particular calibration of the model parameters. We now investigate the sensitivity of our results to perturbations in selected parameter values. In particular, the banker's net worth equation (41) and the excess equity return (43) suggest that the following parameters are crucial in determining the stability of n_t^B: the steady state bank capital requirement ϕ, the banker's propensity to consume χ^B, and steady state firm risk σ^E.

First, let us consider the steady state bank capital requirement ϕ. We make macroprudential policy more stringent by raising ϕ from 0.08 to 0.1 and carrying out the same determinacy analysis as above. The result of this exercise is shown in Figure 5. We can see from the figure that the threshold value $\overline{\zeta}_b$ below which the Taylor Principle is violated shifts to the left. As a result, the determinacy region associated with financial dominance, the lower left quadrant, shrinks.

[insert Figures 4 and 5 here]

The intuition for this finding is that the excess equity return is positively related to both the bank capital requirement ϕ and the macroprudential coefficient ζ_b. To keep the excess equity return stable, a higher capital requirement therefore allows for a lower response coefficient on lending in the macroprudential rule. Note that we do not consider a steady state capital requirement of zero, $\phi = 0$. The reasons for this are threefold. The first reason is that the regulatory requirement as specified in the Basel Agreements stipulates a (constant) capital ratio of 8%.[7] The case of $\phi = 0$ therefore does not appear empirically relevant. The second reason is that the bank has no incentive to hold capital in this model, because capital is the more expensive form of financing loans relative to deposit funding. Therefore, without a positive steady state capital requirement, the macroprudential authority would not be able to use the capital ratio in a symmetric manner, raising ϕ_t when debt levels are high and lowering ϕ_t when they are low, because the capital ratio cannot go negative. Finally, Clerc et al (2014) show - in a more elaborate model with household and bank defaults, and less than perfect deposit insurance - that the welfare-optimising steady state capital ratio is positive.

Second, we alter the banker's propensity to consume, χ^B. Recall that this parameter captures the fraction of wealth that is consumed by the old generation of bankers, while the remainder is left as a bequest to the young generation. We can make bankers more selfish (less altruistic) by raising χ^B. Again, the threshold value $\overline{\zeta}_b$ shifts to the left (not shown). The reason is that more selfish bankers consume more of their wealth each period, such that their wealth accumulates more slowly.

Finally, we increase the size of the firm-risk shock, σ^E, from 0.12 to 0.24. This doubling of steady state firm risk lowers the expected share of the return on the entrepreneur's investment that accrues to the bank, Φ^E_{t+1}. Therefore, the excess equity return $(R^B_{t+1} - R^D_{t+1})/\Pi_{t+1}$ increases by less and the net worth of bankers becomes more stable. As in the above exercise, the threshold $\overline{\zeta}_b$ moves to the left and the explosive region becomes smaller. The corresponding figure resembles Figure 5 and is not shown here.

3.4 Effect of the Zero Lower Bound

Considering different monetary policy regimes raises the question whether the proposed parameter choices are attainable. In this respect monetary policy faces a minimum constraint on its policy instrument which limits its ability to appropriately react to inflation. In order to take the zero lower bound into consideration, we follow the approach of

[7] At the time of writing, countercyclical capital buffers are being developed but are operational only in a small number of countries.

Schmitt-Grohé and Uribe (2007). Among all policy combinations which yield a unique and stable solution, we rule out those which violate our zero lower bound condition. In particular, in order for the interest rate not to hit the zero lower bound we require that twice the standard deviation of the policy instrument is no greater than the logarithm of the steady state gross policy interest rate,

$$2\sigma_R \leq \ln(R),$$

where R and σ_R denote, respectively, the steady state and the standard deviation of the policy rate. Assuming a normally distributed random variable, this condition places a corridor around the steady state which contains the actual interest rate with probability 0.95. If this interval does not contain zero, central bank's risk of hitting the lower bound is assumed to be sufficiently small. If the policy instrument is volatile, a binding constraint becomes more likely, given a steady state value $R = 1/\beta$.

[insert Figures 6 and 7 here]

In Figure 6 we depict in blue the regions attainable given certain combinations of the macroprudential and monetary policy rule coefficients. The white regions correspond to situations where either no unique and stable equilibrium is obtained or where the zero lower bound is violated. The upper right region is not affected by the zero lower bound, while the lower left region features cases which are not attainable since the risk of hitting the bound becomes relevant.

Figure 7 repeats the exercise for the "Leaning-against-the-wind"-case. Notice that the zero lower bound shrinks the determinacy region in the model variant with LATW. The highest inflation coefficient required for a unique and stable equilibrium is reduced and appears to fall as we increase the coefficient on borrowing in the bank capital rule. This exacerbates the violation of the Taylor Principle.

4 Optimal Simple Policy Rules

Our results show that the specific choice of policy rule parameter values is critical for the existence of a unique bounded solution. Now, the question arises which of the remaining parameter combinations delivers the 'best outcome' in our model economy. In order to answer this question, we perform a welfare analysis of how different coefficients in our monetary and macroprudential policy rules affect household welfare when the economy is subject to two types of shocks: technology shocks and firm risk shocks.

We first discuss the derivation of the welfare measure we use to evaluate the determinate model equilibria. We employ the method developed in Schmitt-Grohé and Uribe

(2007) and therefore follow their exposition closely. Let us define the reference policy as a combination of the policy parameters in the monetary and the macroprudential policy rule. This policy is associated with a particular conditional lifetime utility level as of period zero, V_0^r, which represents reference policy welfare in our model economy,

$$V_0^r = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln c_t^r - \varphi \frac{(l_t^r)^{1+\eta}}{1+\eta} \right].$$

We define the reference policy as the one that delivers the maximum lifetime utility within the space of policy parameters considered. Similarly, we define utility associated with alternative policy rule parameters being of the same functional form,

$$V_0^a = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln c_t^a - \varphi \frac{(l_t^a)^{1+\eta}}{1+\eta} \right].$$

In general, an alternative policy regime is not optimal in terms of utility. Given an optimal reference policy, i.e. $V_0^r \geq V_0^a$, it is possible to reduce the amount of reference consumption by a fraction λ such that we obtain the same utility level as for the alternative policy. More technically, there exists a λ such that

$$V_0^a = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln \left[(1-\lambda) \, c_t^r \right] - \varphi \frac{(l_t^r)^{1+\eta}}{1+\eta} \right\}.$$

We can rewrite the above expression in terms of the reference policy utility level V_0^r,

$$V_0^a = \frac{\ln(1-\lambda)}{1-\beta} + V_0^r.$$

Solving this expression for λ, we obtain

$$\lambda = 1 - \exp\left[(1-\beta)(V_0^a - V_0^r) \right].$$

The resulting expression represents the percentage welfare loss relative to the economy operating under a policy rule with optimised coefficients. Note that higher values of λ coincide with less preferable equilibria.

As above, we consider two policy regimes, 'macroprudential stabilisation' and 'leaning against the wind'. In the first regime, monetary policy (with its instrument being the interest rate) reacts to inflation and macroprudential policy (with its instrument being the capital requirement) reacts to lending. In the second regime, the capital requirement is fixed and monetary policy reacts to both inflation and lending. We carry out a grid search over policy coefficients, compute welfare V_0^a for each point on the grid and select the combination of values yielding the highest welfare level, which we call V_0^r. We limit the welfare analysis to regions in the parameter space which deliver a unique and bounded solution and plot indifference curves in order to characterise the welfare surface in the determinacy regions. By comparing the welfare levels under the two regimes, we can state which of the two is preferable.

Definition 2 *The **optimal macroprudential stabilisation policy** is characterised by $\tau_b = 0$ and a pair of policy coefficients τ_Π and ζ_b in the policy rules (38) and (39), which maximise welfare in the economy described by the equilibrium conditions summarised in Table 1.*

Figure 8 shows the welfare loss, relative to the optimised rule, associated with different pairs of policy coefficients τ_Π and ζ_b, where $\tau_\Pi \in [-1, 3]$ and $\zeta_b \in [0, 25]$. More precisely, we are plotting the welfare loss in percentage terms, i.e. $100 \cdot \lambda$.

[insert Figures 8 and 9 here]

The figure shows that a combination of an active macroprudential policy and a passive monetary policy rule, i.e. one that violates the Taylor Principle, is not optimal. The lower left quadrant in the figure, which is associated with low values of both τ_Π and ζ_b result in lower welfare than combinations of coefficients in the upper right quadrant. The optimal policy coefficients are shown as the blue area in the corner of the upper right quadrant; they represent a corner solution where the macroprudential rule coefficient ζ_b, is at its highest admissible value, and the inflation coefficient in the interest rate rule, τ_Π, approaches 1 from above.

Definition 3 *The **optimal leaning against the wind (LATW) policy** is given by $\zeta_b = 0$ and a pair of policy coefficients τ_Π and τ_b in the policy rule (38), which maximise welfare in the economy described by the equilibrium conditions summarised in Table 1.*

Figure 9 shows the percentage welfare loss relative to the optimised rule, $100 \cdot \lambda$, associated with different pairs of policy coefficients τ_Π and τ_b, where $\tau_\Pi \in [-1, 3]$ and $\tau_b \in [-0.5, 1]$. As the figure shows, a higher value of τ_b, i.e. stronger leaning against the wind in the monetary policy rule, leads to ever larger welfare losses. Notice that we can compute welfare only for parameter combinations resulting in a unique model solution, which is the case for low values of τ_Π that violate the Taylor Principle. We find that the optimal coefficient on inflation is below unity, while the optimal coefficient on borrowing is slightly negative. This finding clearly indicates that leaning against the wind, in the form of a positive coefficient on borrowing in an augmented Taylor rule, is a suboptimal policy.

In a model with credit frictions, Lambertini et al (2013) report that leaning against the wind is welfare-improving relative to a standard monetary policy rule. Their model is however, very different from ours: credit flows takes place between borrowing and lending households; demand for credit arises from housing demand; the macroprudential instrument is a loan-to-value ratio. Instead, our finding is consistent with the point made by Svensson (2013), who argues that leaning against the wind can have perverse effects by increasing rather than decreasing the debt-to-GDP ratio. The intuition is that LATW decreases GDP more than debt, such that the debt ratio ultimately rises. Here, an accommodative monetary policy ($\tau_{\Pi} < 1$) coupled with a *negative* (but small) interest rate coefficient on borrowing ($\tau_b < 0$) characterises the optimal simple rule.

5 Conclusion

Financial dominance prevails when macroprudential policy is ineffective in stabilising lending and the financial sector is not willing - or required by macroprudential policy - to absorb losses adequately. As a result, monetary policy is forced to be passive: a violation of the Taylor Principle is necessary to guarantee a unique stable equilibrium. In other words, monetary policy has to allow for higher inflation which improves firms' balance sheet conditions. Equilibrium determinacy is achieved when the monetary and macroprudential policies are either similarly accommodating or similarly aggressive.

The first possibility is the adoption of a passive (in the sense of Leeper, 1991) macroprudential rule, which means that the bank's required capital ratio is increased sufficiently in response to an expansion in corporate lending. Such a policy has a stabilising effect and re-establishes the Taylor Principle, such that the central bank can focus on its primary objective, which is to safeguard price stability.

Second, an active macroprudential and a passive monetary policy yield equilibrium stability. In this case, the capital ratio is kept rather stable, while the interest rate is raised less than one-for-one in response to changes in inflation. Effectively, the monetary authority allows inflation to rise in order to reduce the real value of private sector debt. By assuming some responsibility for financial stability when the macroprudential policy is ineffective, the central bank goes beyond its price stability mandate. Our analysis shows, however, that this policy mix leads to lower household welfare. In addition, in this region of the parameter space, some combinations of policy coefficients are regarded as not implementable since they increase by too much the probability of hitting the zero lower bound.

Finally, an alternative solution is to maintain a constant bank capital requirement whilst following an augmented Taylor-type rule where the interest rate responds not only to inflation but also to bank lending. Under such a policy of 'leaning against the wind', equilibrium determinacy requires violating the Taylor Principle: a stable model solution exists only if the coefficient on inflation is set to a value below unity. Furthermore, leaning against the wind is shown to be clearly suboptimal relative to an active monetary policy rule combined with a capital requirement rule that responds strongly to lending. The latter result is consistent with the Tinbergen Principle according to which each individual policy target requires a separate instrument.

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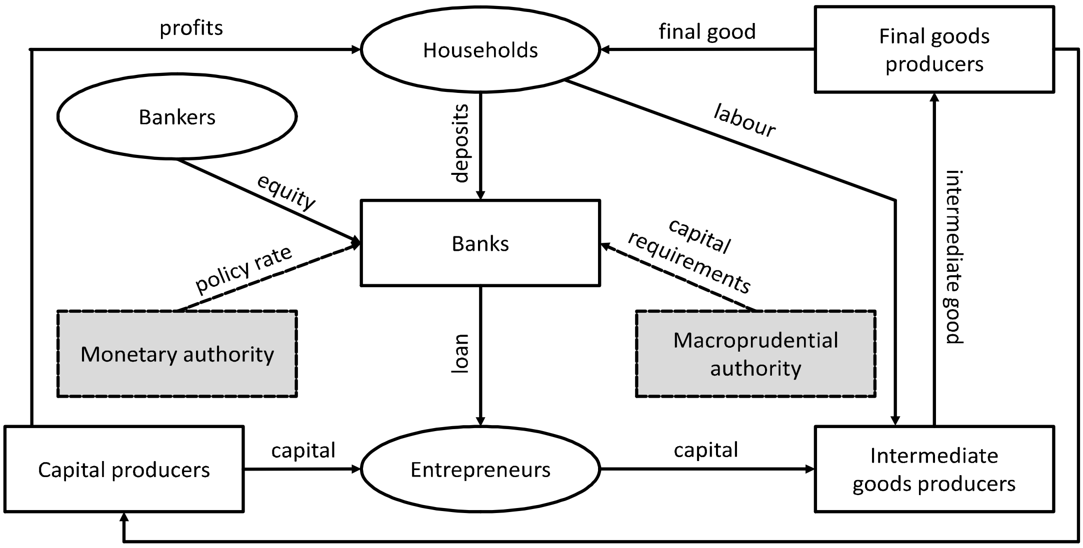
Figure 1: **Illustration of Model**



Note: The flows between the agents in our economy are indicated with solid arrows, while the transmission channels of macroprudential and monetary policy are shown with dashed arrows. The two policy makers are shown as the shaded boxes, while ovals indicate consuming agents (households, entrepreneurs and bankers).

Figure 2: **Determinacy Analysis: Macroprudential Stabilisation**

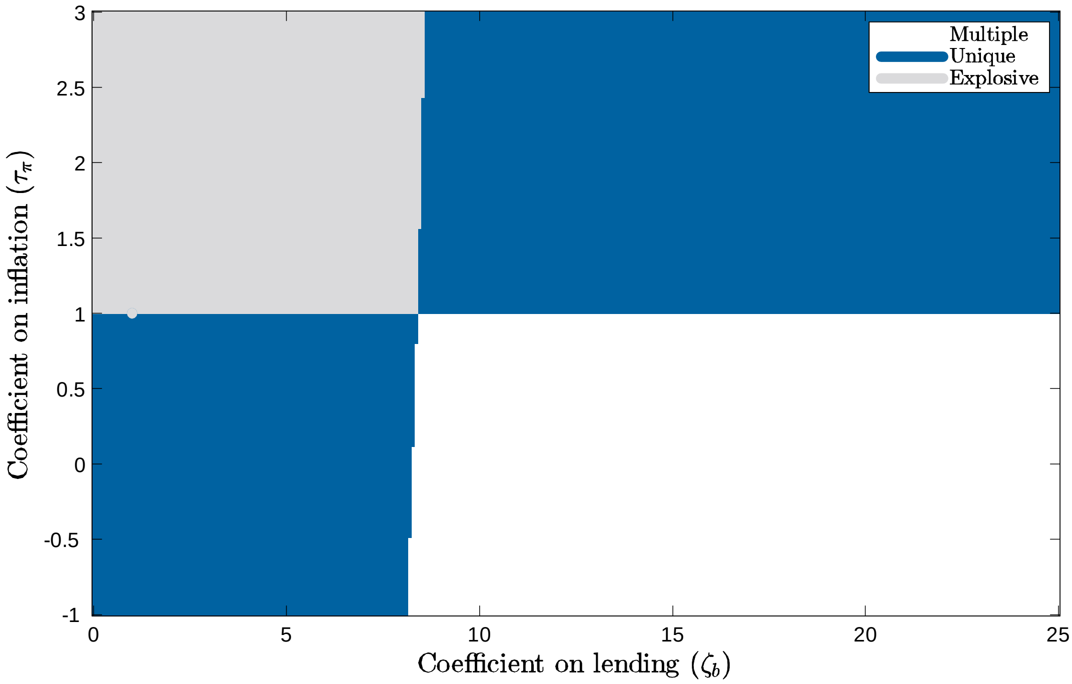
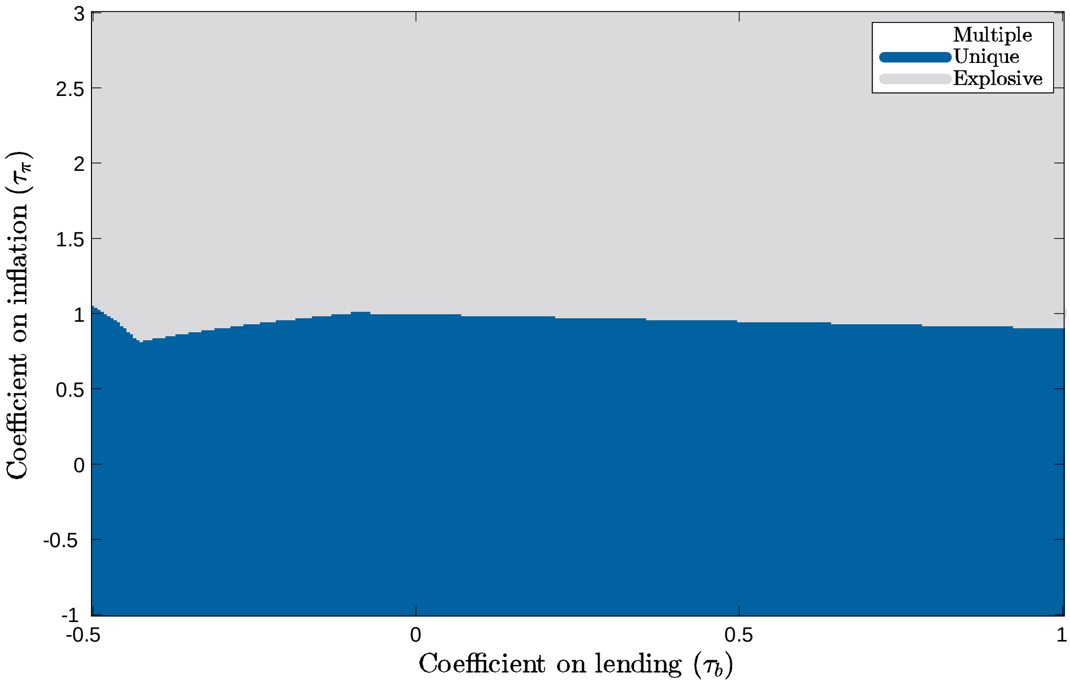


Figure 3: **Determinacy Analysis: Leaning Against the Wind**



Note: These figures show the model's determinacy properties as a function of the respective response coefficients on inflation and borrowing. The upper figure shows the results in the benchmark model with an interest rate rule and a macroprudential rule. The lower figure shows the results in the model variant with an augmented interest rate rule and a constant bank capital requirement.

Figure 4: **Determinacy Analysis: Benchmark Capital Requirement**

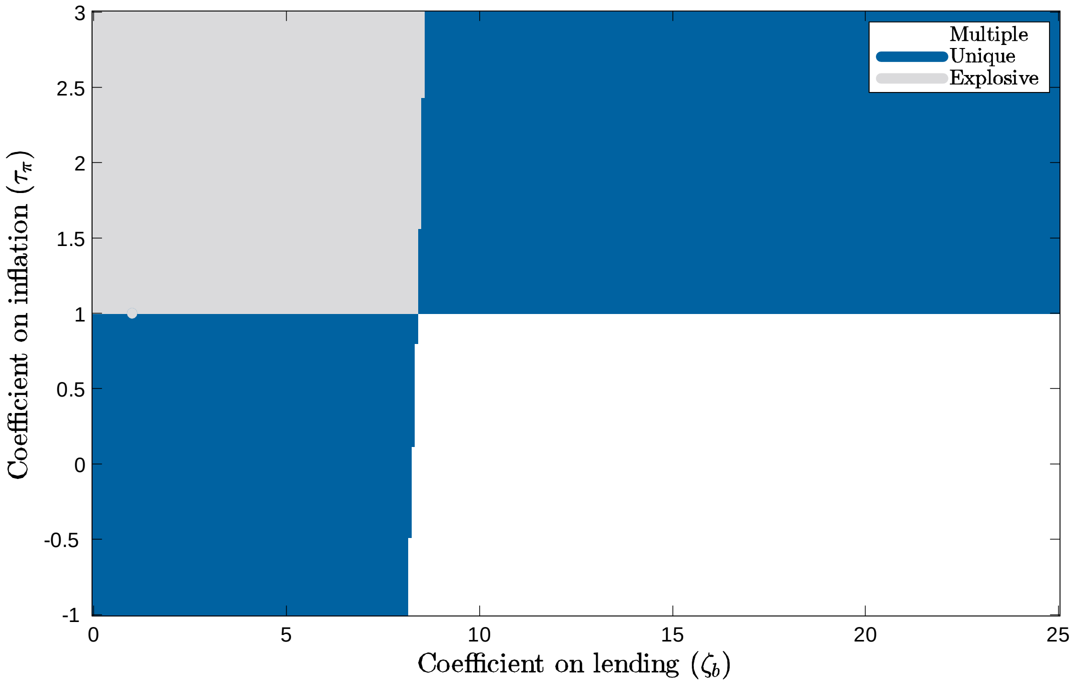
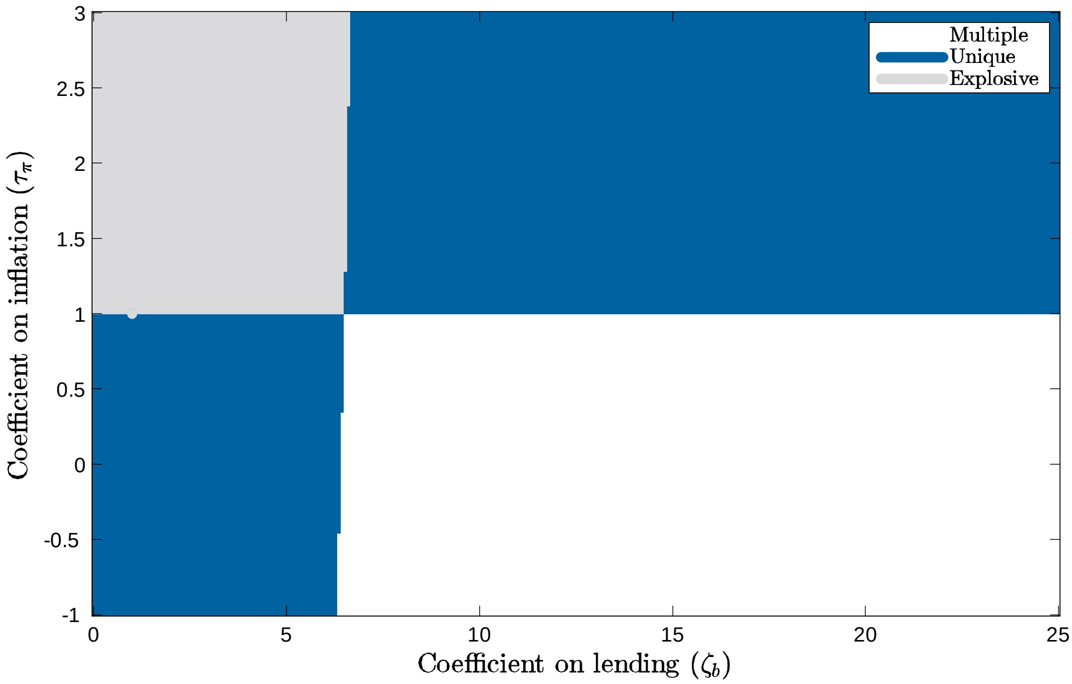


Figure 5: **Determinacy Analysis: Higher Bank Capital Requirement**



Note: These figures show the determinacy properties of the benchmark model with an interest rate rule and a macroprudential rule, as a function of the respective response coefficients on inflation and borrowing. The upper figure shows the results for the benchmark calibration where $\phi = 0.08$. The lower figure shows the results for a higher steady state capital requirement, $\phi = 0.1$.

Figure 6: **Effect of the Zero Lower Bound: Macroprudential Stabilisation**

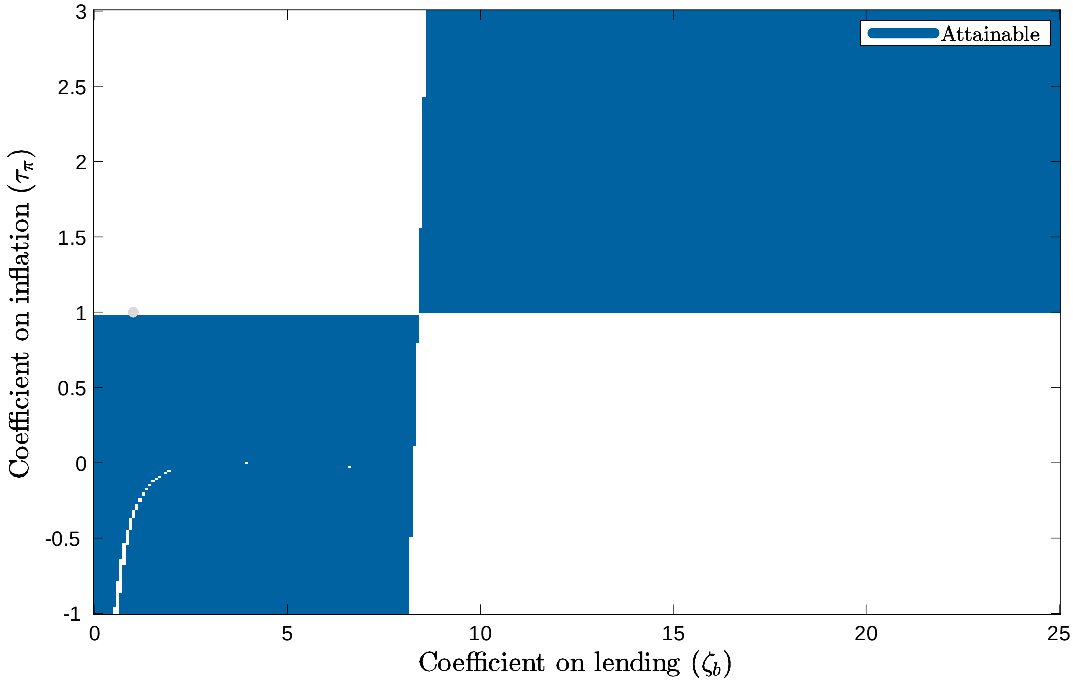
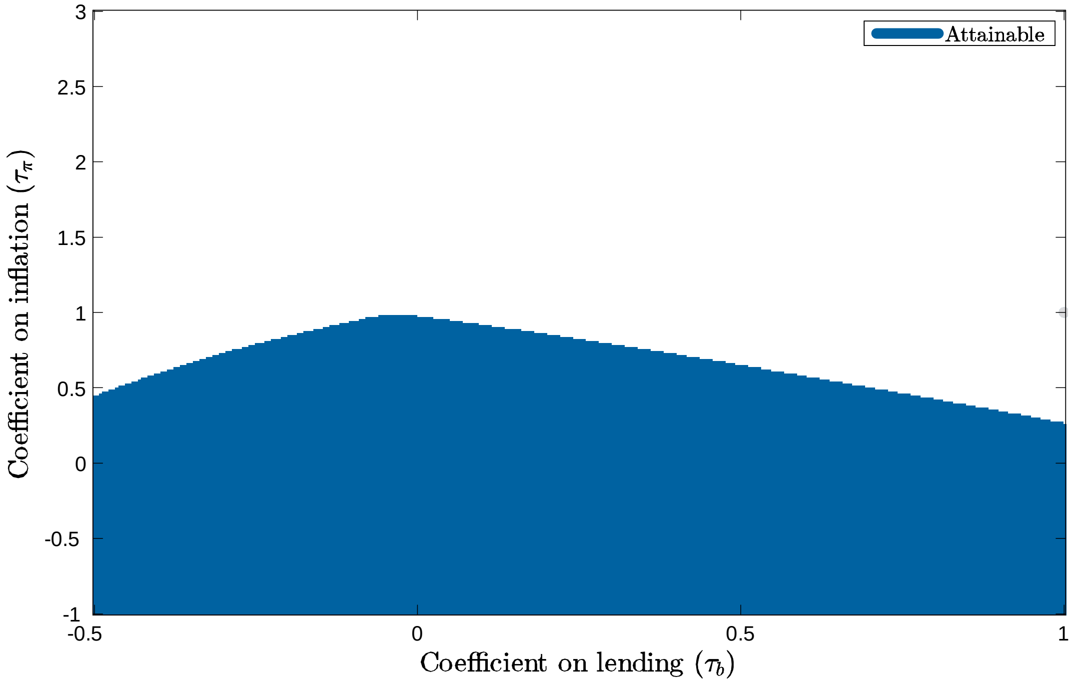


Figure 7: **Effect of the Zero Lower Bound: Leaning against the Wind**



Note: These figures show the model's determinacy properties as a function of the respective response coefficients on inflation and borrowing. The upper figure shows the results in the benchmark model with an interest rate rule and a macroprudential rule; the effect of the ZLB is noticeable as a white area in the bottom left quadrant. The lower figure shows the results in the model variant with an augmented interest rate rule and a constant bank capital requirement. Here, the ZLB reduces by a large amount determinacy region in the model, exacerbating the violation of the Taylor Principle.

Figure 8: **Welfare Analysis: Macroprudential Stabilisation**

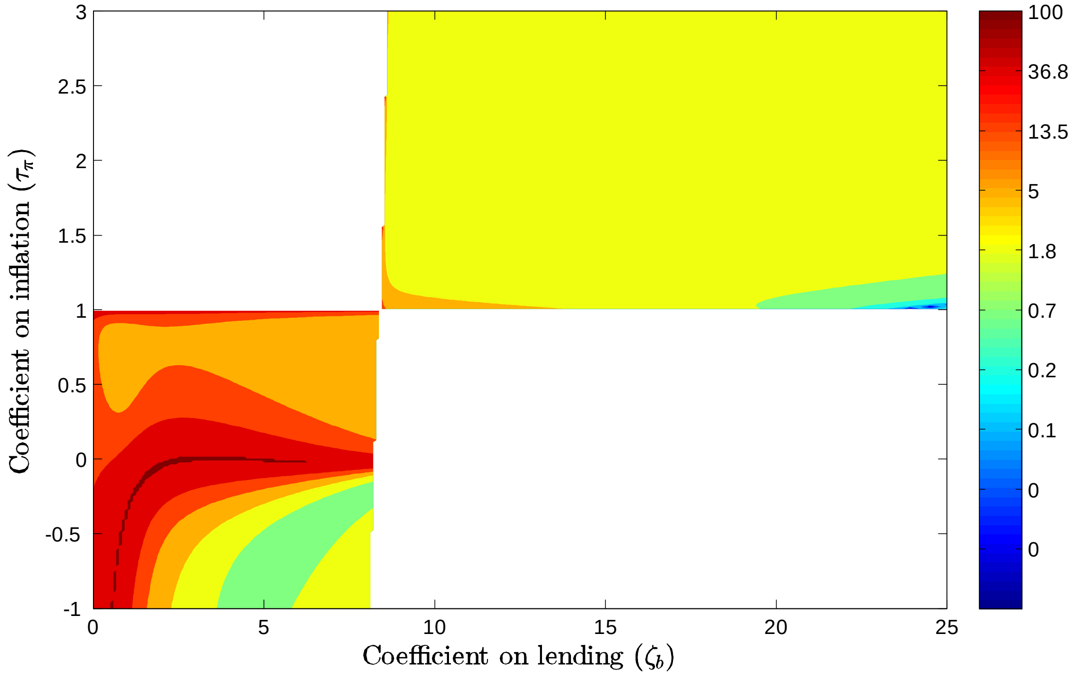
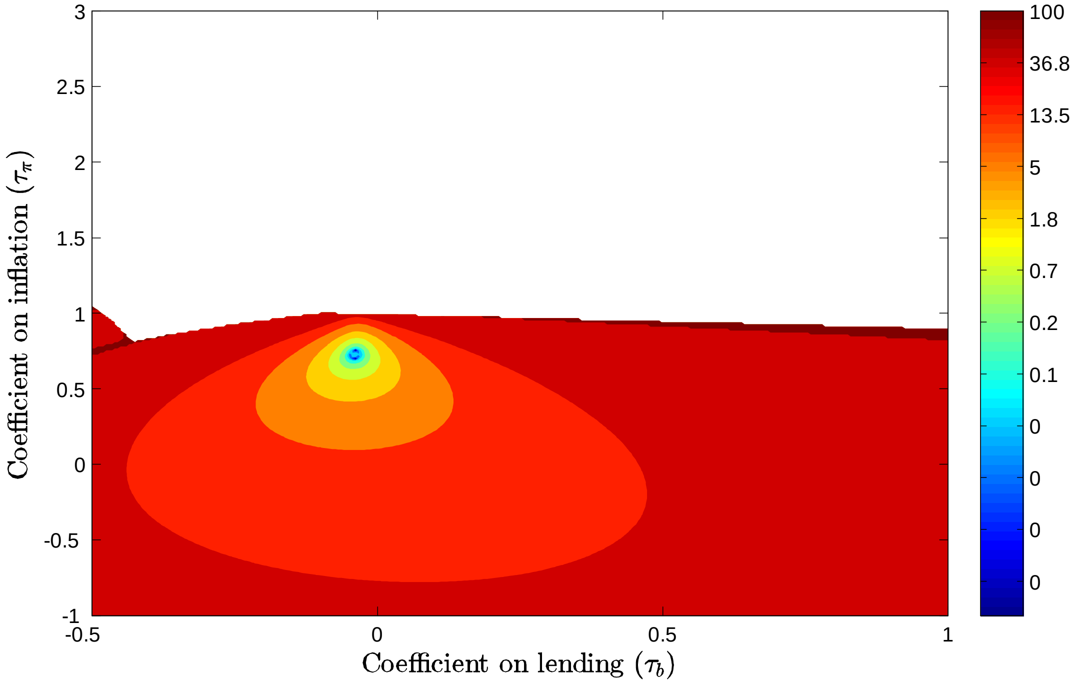


Figure 9: **Welfare Analysis: Leaning against the Wind**



Note: These figures show the welfare loss relative to the optimised policy rule, $100{\cdot}\lambda$, as a function of the respective response coefficients on inflation and borrowing. The upper figure shows the results in the benchmark model with an interest rate rule and a macroprudential rule. The lower figure shows the results in the model variant with an augmented interest rate rule and a constant bank capital requirement.

Table 1: **Summary of Model Equations**

(1)	$w_t = \varphi l_t^{\eta} c_t$
(2)	$1 = \beta \mathbb{E}_t \left\{ \frac{c_t}{c_{t+1}} \frac{R_t^D}{\Pi_{t+1}} \right\}$
(3)	$Y_t = A_t K_{t-1}^{\alpha} l_t^{1-\alpha}$
(4)	$w_t l_t = \frac{1-\alpha}{\alpha} r_t^K K_{t-1}$
(5)	$s_t = \frac{w_t^{1-\alpha} (r_t^K)^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \frac{1}{A_t}$
(6)	$\kappa_p \Pi_t \left(\Pi_t - 1\right) = s_t \varepsilon - (\varepsilon - 1)\left[1 - \frac{\kappa_p}{2}\left(\Pi_t - 1\right)^2\right] + \kappa_p \beta \mathbb{E}_t \left\{ \frac{c_t}{c_{t+1}} \Pi_{t+1} \left(\Pi_{t+1} - 1\right) \frac{Y_{t+1}}{Y_t} \right\}$
(7)	$q_t = 1 + \kappa_k \left(\frac{I_t}{K_{t-1}} - \delta \right)$
(8)	$K_t = I_t + \left(1 - \delta\right) K_{t-1}$
(9)	$n_t^E = \left(1 - \chi^E\right)\left(1 - \Gamma_t^E\right) \frac{R_t^E q_{t-1} K_{t-1}}{\Pi_t}$
(10)	$q_t K_t = n_t^E + b_t$
(11)	$n_t^B = (1 - \chi^B) \frac{R_t^B n_{t-1}^B}{\Pi_t}$
(12)	$b_t = n_t^B / \phi_t$
(13)	$d_t = b_t - n_t^B$
(14)	$Y_t = c_t + \chi^E \left(1 - \Gamma_t^E\right) \frac{R_t^E q_{t-1} K_{t-1}}{\Pi_t} + \chi^B \frac{R_t^B n_{t-1}^B}{\Pi_t} + \frac{\kappa_k}{2} \left(\frac{I_t}{K_{t-1}} - \delta \right)^2 K_{t-1} + \mu^E G_t^E \frac{R_t^E q_{t-1} K_{t-1}}{\Pi_t}$
(15)	$\mathbb{E}_t \left\{ \left(1 - \Gamma_{t+1}^E\right) R_{t+1}^E + \frac{\Gamma_{t+1}^{E\prime}}{(\Gamma_{t+1}^{E\prime} - \mu^E G_{t+1}^{E\prime})(1-\Gamma_t^F)} \left[\left(1 - \Gamma_t^F\right) \left(\Gamma_{t+1}^E - \mu^E G_{t+1}^E\right) R_{t+1}^E - \phi_t R_{t+1}^B \right] \right\} = 0$
(16)	$R_t^E = \frac{r_t^K + (1-\delta) q_t}{q_{t-1}} \Pi_t$
(17)	$R_t^F = (\Gamma_t^E - \mu^E G_t^E) \frac{R_t^E q_{t-1} K_{t-1}}{b_{t-1}}$
(18)	$R_t^B = (1 - \Gamma_t^F) \frac{R_t^F}{\phi_{t-1}}$
(19)	$\overline{\omega}_t^E = \frac{x_{t-1}^E}{R_t^E}$
(20)	$G_t^E = \Phi \left(\frac{\ln \overline{\omega}_t^E - \frac{1}{2}\left(\sigma_t^E\right)^2}{\sigma_t^E} \right)$
(21)	$F_t^E = \Phi \left(\frac{\ln \overline{\omega}_t^E + \frac{1}{2}\left(\sigma_t^E\right)^2}{\sigma_t^E} \right)$
(22)	$\Gamma_t^E = G_t^E + \overline{\omega}_t^E (1 - F_t^E)$
(23)	$G_t^{E\prime} = \frac{1}{\overline{\omega}_t^E \sigma_t^E} \Phi' \left(\frac{\ln \overline{\omega}_t^E - \frac{1}{2}\left(\sigma_t^E\right)^2}{\sigma_t^E} \right)$
(24)	$F_t^{E\prime} = \frac{1}{\overline{\omega}_t^E \sigma_t^E} \Phi' \left(\frac{\ln \overline{\omega}_t^E + \frac{1}{2}\left(\sigma_t^E\right)^2}{\sigma_t^E} \right)$
(25)	$\Gamma_t^{E\prime} = G_t^{E\prime} + (1 - F_t^E) - \overline{\omega}_t^E F_t^{E\prime}$
(26)	$\Gamma_t^F = \left(1 - \phi_{t-1}\right) \frac{R_t^D}{R_t^F}$

The system consists of 26 endogenous variables, l_t, K_t, I_t, c_t, Y_t, n_t^E, b_t, n_t^B, d_t, x_t^E, w_t, r_t^K, q_t, Π_t, s_t, R_t^E, R_t^F, R_t^B, $\overline{\omega}_t^E$, G_t^E, F_t^E, Γ_t^E, $G_t^{E\prime}$, $F_t^{E\prime}$, $\Gamma_t^{E\prime}$, Γ_t^F, two policy variables, R_t, ϕ_t, and two exogenous processes, A_t, ς_t. As can be seen from the table, K_t, q_t, n_t^B, b_t, ϕ_t and x_t^E are endogenous state variables. The functions $\Phi(\cdot)$ and $\Phi'(\cdot)$ denote, respectively, the cumulative distribution function and the probability density function of the standard normal distribution.

Table 2: **Computation of Steady State**

(1)	$q = 1$
(2)	$r^K = [R^E - (1-\delta)]q$
(3)	$s = \frac{\varepsilon - 1}{\varepsilon}$
(4)	$K = \left[\frac{1}{A}\left(\frac{1}{\alpha}\frac{r^K}{s}\right) l^{\alpha-1}\right]^{\frac{1}{\alpha-1}}$
(5)	$I = \delta K$
(6)	$Y = \left(\frac{1}{\alpha}\frac{r^K}{s}\right) K$
(7)	$w = (1-\alpha)\, s\frac{Y}{l}$
(8)	$R^D = \frac{1}{\beta}$
(9)	$c = \frac{w}{\varphi l^{\eta}}$
(10)	$\overline{\omega}^E = \frac{x^E}{R^E}$
(11)	$G^E = \Phi\left(\frac{\ln \overline{\omega}^E - \frac{1}{2}\left(\sigma^E\right)^2}{\sigma^E}\right)$
(12)	$F^E = \Phi\left(\frac{\ln \overline{\omega}^E + \frac{1}{2}\left(\sigma^E\right)^2}{\sigma^E}\right)$
(13)	$\Gamma^E = G^E + \overline{\omega}^E(1 - F^E)$
(14)	$G^{E\prime} = \frac{1}{\overline{\omega}^E \sigma^E}\Phi'\left(\frac{\ln \overline{\omega}^E - \frac{1}{2}\left(\sigma^E\right)^2}{\sigma^E}\right)$
(15)	$F^{E\prime} = \frac{1}{\overline{\omega}^E \sigma^E}\Phi'\left(\frac{\ln \overline{\omega}^E + \frac{1}{2}\left(\sigma^E\right)^2}{\sigma^E}\right)$
(16)	$\Gamma^{E\prime} = G^{E\prime} + (1 - F^E) - \overline{\omega}^E F^{E\prime}$
(17)	$n^E = (1-\chi^E)\left(1-\Gamma^E\right)\frac{R^E qK}{\Pi}$
(18)	$b = qK - n^E$
(19)	$n^B = \phi b$
(20)	$d = b - n^B$
(21)	$R^B = \frac{\Pi}{1-\chi^B}$
(22)	$R^F = \frac{\phi}{1-\Gamma^F} R^B$
(23)	$0 = \Gamma^F - (1-\phi)\frac{R^D}{R^F}$
(24)	$0 = R^F - (\Gamma^E - \mu^E G^E)\frac{R^E qK}{b}$
(25)	$0 = (1-\Gamma^E)R^E + \frac{\Gamma^{E\prime}}{(\Gamma^{E\prime} - \mu^E G^{E\prime})(1-\Gamma^F)}\left[(1-\Gamma^F)(\Gamma^E - \mu^E G^E)R^E - R^B\phi\right]$
(26)	$0 = c + \left(1 - \frac{R^D}{\Pi}\right) d - wl$

Given initial values for Γ^F, l, x^E and R^E, we can compute the 22 parameters q, r^K, s, K, I, Y, w, R^D, c, $\overline{\omega}^E$, G^E, F^E, Γ^E, $G^{E\prime}$, $F^{E\prime}$, $\Gamma^{E\prime}$, n^E, b, n^B, d, R^B and R^F using equations (1) to (22). We then solve the four-equation system consisting of (23)-(26) numerically for Γ^F, l, x^E, and R^E.

Table 3: **Calibration of Model Parameters**

Parameter	Value	Description
Structural Parameters		
β	0.99	Household discount factor
η	0.2	Inverse Frisch elasticity of labour supply
α	0.3	Capital share in production
ε	6	Substitutability between goods
κ_p	20	Price adjustment cost
δ	0.025	Capital depreciation rate
κ_k	2	Capital adjustment cost
Financial Parameters		
χ^E	0.06	Consumption share of wealth entrepreneurs
χ^B	0.06	Consumption share of wealth bankers
μ^E	0.3	Monitoring cost entrepreneurs
σ^E	0.12	Idiosyncratic shock size entrepreneurs
ϕ	0.08	Bank capital requirement
Shock Parameters		
σ^A	0.0046	Size technology shock
ρ^A	0.9	Persistence technology shock
σ^ς	0.07	Size firm risk shock
ρ^ς	0.9	Persistence firm risk shock

Table 4: **Implied Steady State Values**

Variable	Value	Description
Interest Rates		
R	1.0101	Policy rate
R^D	1.0101	Return on deposits (earned by depositors)
R^F	1.0144	Return on loans (earned by banks)
R^E	1.0284	Return on capital (earned by entrepreneurs)
R^B	1.0638	Return on equity (earned by bankers)
Annualised Spreads and Default Probability		
$400{\cdot}(R^F\text{-}R)$	1.7	Loan return spread p.a., in %
$400{\cdot}(R^E\text{-}R)$	7.3	Capital return spread p.a., in %
$400{\cdot}(R^B\text{-}R)$	21.5	Equity return spread p.a., in %
$400{\cdot}F^E$	2.6	Default probability p.a., in %
Leverage		
x^E	0.7583	Leverage entrepreneurs
$1-\phi$	0.92	Leverage banks

Note: All interest rates and rates of return are gross rates.

Table 5: **Summary of Linearised Model Equations**

(1)	$\hat{w}_t = \eta \hat{l}_t + \hat{c}_t$
(2)	$\hat{c}_t + \hat{R}^D_t = \mathbb{E}_t\{\hat{c}_{t+1} + \hat{\Pi}_{t+1}\}$
(3)	$\hat{Y}_t = \hat{A}_t + \alpha \hat{K}_{t-1} + (1-\alpha)\hat{l}_t$
(4)	$\hat{w}_t + \hat{l}_t = \hat{r}^K_t + \hat{K}_{t-1}$
(5)	$\hat{s}_t = (1-\alpha)\hat{w}_t + \alpha \hat{r}^K_t - \hat{A}_t$
(6)	$\hat{\Pi}_t = \frac{\varepsilon-1}{\kappa_p}\hat{s}_t + \beta \mathbb{E}_t\{\hat{\Pi}_{t+1}\}$
(7)	$\hat{q}_t = \kappa_k \delta(\hat{I}_t - \hat{K}_{t-1})$
(8)	$\hat{K}_t = \delta \hat{I}_t + (1-\delta)\hat{K}_{t-1}$
(9)	$\hat{n}^E_t = -\frac{\Gamma^E}{1-\Gamma^E}\hat{\Gamma}^E_t + \hat{R}^E_t + \hat{q}_{t-1} + \hat{K}_{t-1} - \hat{\Pi}_t$
(10)	$\hat{b}_t = \frac{K}{b}(\hat{q}_t + \hat{K}_t) - \frac{n^E}{b}\hat{n}^E_t$
(11)	$\hat{n}^B_t = \hat{R}^B_t + \hat{n}^B_{t-1} - \hat{\Pi}_t$
(12)	$\hat{n}^B_t = \hat{\phi}_t + \hat{b}_t$
(13)	$\hat{b}_t = \frac{n^B}{b}\hat{n}^B_t + \frac{d}{b}\hat{d}_t$
(14)	$Y\hat{Y}_t = c\hat{c}_t + R^E K \Big\{ -\chi^E \Gamma^E \hat{\Gamma}^E_t + \mu^E G^E \hat{G}^E_t$ $+ [\chi^E(1-\Gamma^E) + \mu^E G^E](\hat{R}^E_t + \hat{q}_{t-1} + \hat{K}_{t-1} - \hat{\Pi}_t)\Big\} + \chi^B R^B n^B (\hat{R}^B_t + \hat{n}^B_{t-1} - \hat{\Pi}_t)$
(15)	$\mathbb{E}_t\{\hat{\Gamma}^{E\prime}_{t+1}\} = \hat{\xi}^E_t - \frac{\Gamma^F}{1-\Gamma^F}\mathbb{E}_t\{\hat{\Gamma}^F_{t+1}\} + \frac{\Gamma^{E\prime}}{\Gamma^{E\prime}-\mu^E G^{E\prime}}\mathbb{E}_t\{\hat{\Gamma}^{E\prime}_{t+1}\} - \frac{\mu^E G^{E\prime}}{\Gamma^{E\prime}-\mu^E G^{E\prime}}\mathbb{E}_t\{\hat{G}^{E\prime}_{t+1}\}$
(16)	$\hat{\xi}^E_t = \mathbb{E}_t\{\hat{R}^E_{t+1}\} - \frac{\Gamma^E}{1-\Gamma^E}\mathbb{E}_t\{\hat{\Gamma}^E_{t+1}\} + \frac{\xi^E}{1-\Gamma^E}\Big[\left(\Gamma^E - \mu^E G^E\right)\Gamma^F \mathbb{E}_t\{\hat{\Gamma}^F_{t+1}\}$ $+ \left(1-\Gamma^F\right)\mathbb{E}_t\{(\Gamma^E \hat{\Gamma}^E_{t+1} - \mu^E G^E \hat{G}^E_{t+1})\} - \phi \frac{R^B}{R^E}(\hat{\phi}_t + \mathbb{E}_t\{\hat{R}^B_{t+1}\})\Big]$
(17)	$\hat{R}^E_t = \frac{r^K}{R^E}\hat{r}^K_t + \frac{1-\delta}{R^E}\hat{q}_t + \hat{\Pi}_t - \hat{q}_{t-1}$
(18)	$\hat{R}^F_t = \frac{\Gamma^E}{\Gamma^E-\mu^E G^E}\hat{\Gamma}^E_t - \frac{\mu^E G^E}{\Gamma^E-\mu^E G^E}\hat{G}^E_t + \hat{R}^E_t + \hat{q}_{t-1} + \hat{K}_{t-1} - \hat{b}_{t-1}$
(19)	$\hat{R}^B_t = -\frac{\Gamma^F}{1-\Gamma^F}\hat{\Gamma}^F_t + \hat{R}^F_t - \hat{\phi}_{t-1}$
(20)	$\hat{\omega}^E_t = \hat{x}^E_{t-1} - \hat{R}^E_t$
(21)	$G^E \hat{G}^E_t = \Phi'(\cdot)\left(\frac{1}{\sigma^E}\hat{\omega}^E_t - \frac{\ln \overline{\omega}^E}{\sigma^E}\hat{\sigma}^E_t - \frac{1}{2}\sigma^E \hat{\sigma}^E_t\right)$
(22)	$F^E \hat{F}^E_t = \widetilde{\Phi}'(\cdot)\left(\frac{1}{\sigma^E}\hat{\omega}^E_t - \frac{\ln \overline{\omega}^E}{\sigma^E}\hat{\sigma}^E_t + \frac{1}{2}\sigma^E \hat{\sigma}^E_t\right)$
(23)	$\Gamma^E \hat{\Gamma}^E_t = G^E \hat{G}^E_t + \overline{\omega}^E[(1-F^E)\hat{\omega}^E_t - F^E \hat{F}^E_t]$
(24)	$\overline{\omega}^E \sigma^E G^{E\prime}(\hat{\omega}^E_t + \hat{\sigma}^E_t + \hat{G}^{E\prime}_t) = \Phi''(\cdot)\left(\frac{1}{\sigma^E}\hat{\omega}^E_t - \frac{\ln \overline{\omega}^E}{\sigma^E}\hat{\sigma}^E_t - \frac{1}{2}\sigma^E \hat{\sigma}^E_t\right)$
(25)	$\overline{\omega}^E \sigma^E F^{E\prime}(\hat{\omega}^E_t + \hat{\sigma}^E_t + \hat{F}^{E\prime}_t) = \widetilde{\Phi}''(\cdot)\left(\frac{1}{\sigma^E}\hat{\omega}^E_t - \frac{\ln \overline{\omega}^E}{\sigma^E}\hat{\sigma}^E_t + \frac{1}{2}\sigma^E \hat{\sigma}^E_t\right)$
(26)	$\Gamma^{E\prime}\hat{\Gamma}^{E\prime}_t = G^{E\prime}\hat{G}^{E\prime}_t - F^E \hat{F}^E_t - \overline{\omega}^E F^{E\prime}(\hat{\omega}^E_t - \hat{F}^{E\prime}_t)$
(27)	$\hat{\Gamma}^F_t = -\frac{\phi}{1-\phi}\hat{\phi}_{t-1} + \hat{R}^D_t - \hat{R}^F_t$

The system consists of 27 endogenous variables, $\hat{l}_t$, $\hat{K}_t$, $\hat{I}_t$, $\hat{c}_t$, $\hat{Y}_t$, $\hat{n}^E_t$, $\hat{b}_t$, $\hat{n}^B_t$, $\hat{d}_t$, $\hat{x}^E_t$, $\hat{\xi}^E_t$, $\hat{w}_t$, $\hat{r}^K_t$, $\hat{q}_t$, $\hat{\Pi}_t$, $\hat{s}_t$, $\hat{R}^E_t$, $\hat{R}^F_t$, $\hat{R}^B_t$, $\hat{\omega}^E_t$, $\hat{G}^E_t$, $\hat{F}^E_t$, $\hat{\Gamma}^E_t$, $\hat{G}^{E\prime}_t$, $\hat{F}^{E\prime}_t$, $\hat{\Gamma}^{E\prime}_t$, $\hat{\Gamma}^F_t$, two policy variables, $\hat{R}_t$, $\hat{\phi}_t$, and two exogenous processes, $\hat{A}_t$, $\hat{\varsigma}_t$. As can be seen from the table, $\hat{K}_t$, $\hat{q}_t$, $\hat{n}^B_t$, $\hat{b}_t$, $\hat{\phi}_t$ and $\hat{x}^E_t$ are endogenous state variables.