DEUTSCHE
BUNDESBANK
EUROSYSTEM

Discussion Paper

Deutsche Bundesbank
No 29/2018

Interest rate rules under financial dominance

Vivien Lewis
Markus Roth

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

Internet http://www.bundesbank.de

ISBN 978–3–95729–486–9 (Printversion)
ISBN 978–3–95729–487–6 (Internetversion)

Non-technical summary

Research Question

What are the implications of bank capital requirements for the conduct of monetary policy?

Contribution

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. We derive a dynamic stochastic general equilibrium model with a banking sector and corporate borrowing. Entrepreneurs operate under limited liability and have to finance their projects by borrowing from banks. They are subject to default risk, such that external finance is costly. Since bank balance sheets are impaired by entrepreneurial defaults, there is a role for macroprudential policy to guard against bank defaults by imposing a minimum ratio of bank capital to assets. A capital requirement rule links the capital ratio to the amount of borrowing. We represent monetary policy as a simple interest rate feedback rule.

Results

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 and in the academic literature. The paper's main finding, a novel result in the literature, mirrors the fiscal dominance result according to which an active fiscal policy necessitates a passive monetary policy (and vice versa).

Nichttechnische Zusammenfassung

Fragestellung

Wie wirken sich Eigenkapitalanforderungen für Banken auf die Geldpolitik aus?

Beitrag

Diese Studie untersucht die Wechselwirkungen zwischen Geldpolitik und makroprudenzieller Politik im Rahmen eines dynamischen stochastischen Gleichgewichtsmodells, in dem Unternehmen Bankkredite benötigen um Investitionen zu tätigen. Diese Investitionen unterliegen stochastischen Schocks; wenn der Ertrag niedriger ausfällt als erwartet, meldet das Unternehmen Insolvenz an und Banken müssen einen Teil der Kredite abschreiben. Hohe Insolvenzraten bei Firmen führen somit zu erhöhten Bankenausfällen. Banken finanzieren Kredite mit Depositen und Eigenkapital. Sie sind verpflichtet, einen bestimmten Prozentsatz ihrer Kreditmenge als Eigenkapital vorzuhalten. Die Eigenkapitalquote wird mithilfe einer Politikregel gesteuert. Beim antizyklischen Kapitalpuffer wird die Eigenkapitalquote mit einem bestimmten Koeffizient erhöht, wenn das Kreditvolumen der Gesamtwirtschaft ansteigt. Die Geldpolitik wird als Zinsregel modelliert, wobei der Leitzins auf Änderungen in der Inflationsrate reagiert. Die zwei genannten Politikinstrumente werden eingesetzt, um sowohl Preis- als auch Finanzstabilität (niedrige Bankenausfallquote) zu sichern.

Ergebnisse

Wenn die makroprudenzielle Politik das Kreditwachstum nicht ausreichend stabilisiert und der Finanzsektor Verluste nicht absorbieren kann, ist die Geldpolitik „finanzieller Dominanz“ ausgesetzt. Die Zentralbank sieht sich in dem Fall gezwungen, Schulden im Privatsektor durch Inflation zu reduzieren um auf diese Weise die Finanzstabilität - und somit die Stabilität der gesamten Ökonomie - zu gewährleisten. Das Ziel der Preisstabilität wird dem Ziel der Finanzstabilität untergeordnet. Dieses Ergebnis ähnelt dem der „fiskalischen Dominanz“, wonach die Zentralbank bei übermäßigen Staatsschulden mehr Inflation zulässt als für die Wahrung der Preisstabilität erforderlich wäre.

Deutsche Bundesbank Discussion Paper No 29/2018

Interest Rate Rules under Financial Dominance*

Vivien Lewis† Deutsche Bundesbank

Markus Roth‡ Deutsche Bundesbank

Abstract

We study the equilibrium properties of a business cycle model with financial frictions and price adjustment costs. Capital-constrained entrepreneurs finance risky projects by borrowing from banks. Banks, in turn, make loans using equity and deposits. Because financial contracts are not contingent on aggregate risk, bank balance sheets are hit when entrepreneurial defaults are higher than expected. 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 stabilizing debt and monetary policy is subject to 'financial dominance'. A too aggressive response of the interest rate to inflation can lead to debt disinflation dynamics that destabilize the financial sector.

Keywords: bank capital, financial dominance, interest rate rule, macroprudential policy, Taylor Principle

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

*Thanks to Klaus Adam, Dirk Bursian, Fabio Canova, Miguel Casares, Ferre de Graeve, Maarten Dossche, Punnoose Jacob, Peter Karadi, Stéphane Moyen, Alexander Schulz, Chris Sims, Harald Uhlig, Stefania Villa and Todd Walker for useful discussions. We also benefited from comments made by seminar participants at Deutsche Bundesbank, the T2M Conference in Berlin 2015, the University of Rennes, the Workshop of the Eurosystem and Latin American Central Banks in Bogotá, the University of Exeter. The views expressed in this paper are solely the authors' and do not necessarily reflect the views of the Bundesbank or the Eurosystem. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement "Integrated Macro-Financial Modeling for Robust Policy Design" (MACFINROBODS, grant no. 612796). Research was partly carried out while Lewis was at KU Leuven.

†Corresponding author, Research Centre, Deutsche Bundesbank, Wilhelm-Epstein-Str. 14, 60431 Frankfurt am Main, Germany, vivien.lewis@bundesbank.de, Tel.: +49 69 9566 6254.

‡Financial Stability Department, Deutsche Bundesbank, Wilhelm-Epstein-Str. 14, 60431 Frankfurt am Main, Germany.

1 Introduction

Macroprudential policy has emerged as a new policy domain with the aim of safeguarding the stability of the financial system as a whole. Its transmission, effectiveness and interdependence with other policy areas are not yet fully understood. This paper sheds light on the implications of bank capital requirements for the conduct of monetary policy, and in turn, on the consequences of monetary policy for financial stability.

Most economists would agree that monetary and macroprudential policy are closely connected and cannot therefore be analyzed in isolation from each other.[1] The model presented here shows 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. In particular, 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 accommodating so as to reduce leverage 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, 2016; Leeper and Nason, 2015).

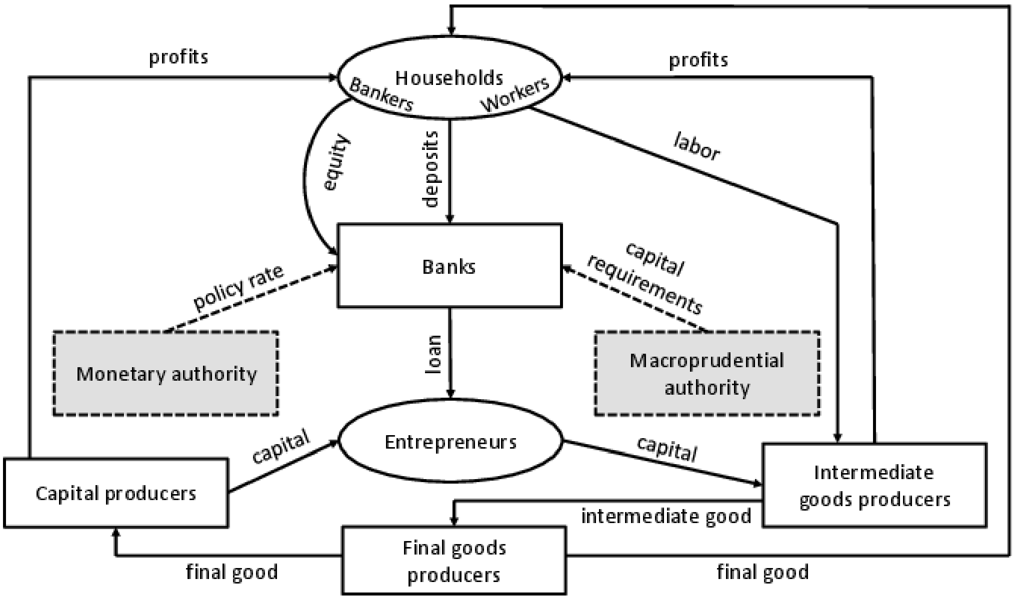
We derive a dynamic stochastic general equilibrium (DSGE) model with financial intermediation where both entrepreneurs and banks are subject to default risk. In this respect, we follow Clerc, Derviz, Mendicino, Moyen, Nikolov, Stracca, Suarez, and Vardoulakis (2015), but we abstract from mortgage lending.[2] As in Bernanke, Gertler, and Gilchrist (1999), insufficient net worth on the part of entrepreneurs leads to a demand for bank loans. Ex-post default leads to costly monitoring by banks. Differently from Bernanke et al. (1999), however, debt repayment is non-state-contingent and as a result, bank balance sheets are impaired in the case of higher-than-expected entrepreneur default rates. This model feature is similar to Zhang (2009), Benes and Kumhof (2015), and Clerc et al. (2015). Banks, too, face idiosyncratic shocks that force some of them into default. By symmetry with the corporate sector, declaring default results in monitoring activity by an agency we will call 'bank resolution authority'. This institution functions simultaneously as a deposit insurance agency. It collects the defaulting bank's remaining assets and pays out depositors in full. The shortfall is financed through lump-sum taxes on households. Since banks are no longer perfectly insured against adverse shocks, there is a role for macroprudential policy to dampen the financial cycle by imposing bank capital requirements. Figure 1 provides an overview of the model. Our model allows us to reassess monetary policy as a stabilization tool in the presence of financial frictions and macroprudential instruments. In particular, the macroprudential authority imposes a capital requirement on banks in the form of a minimum ratio of equity capital to 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 a fall in the return on deposits, which boosts bank profits and therefore the return on equity and bankers' net worth. In addition, the

[1] For a survey paper, Smets (2014).

[2] The model in Clerc et al. (2015) was extended and calibrated to Euro area data in Mendicino, Nikolov, Suarez, and Supera (forthcoming).

Figure 1: Model Illustration



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 and entrepreneurs).

ensuing rise in inflation acts to reduce the real value of bank deposits on the liability side of the bank's balance sheet, which amounts to a transfer from savers to banks and lowers the probability of bank default. Inflation thereby helps to maintain financial stability.

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. The monetary authority stabilizes inflation by following the Taylor Principle.

In our framework, the Taylor Principle can instead be destabilizing if it gives rise to a debt-disinflation spiral as in Fisher (1933). Tight monetary policy increases banks' debt, i.e. their deposit liabilities expressed in real terms, which makes them more vulnerable to adverse shocks such as unexpectedly high defaults on loans. Banks reduce new lending to firms, which in turn raises borrowing costs to entrepreneurs and their probability of default, with negative consequences for bank balance sheets.

Under both price setting frictions and financial frictions, it is therefore no longer clear if monetary policy should move interest rates more or 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 the bank is not required to raise sufficient new equity in response to a rise in credit demand (e.g. the capital ratio is held constant), the task of stabilizing borrowing falls onto monetary policy. To prevent the bank from granting too much credit to entrepreneurs, the central bank is forced to be more accommodating than is warranted to stabilize inflation. 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). If fiscal policy is ineffective in stabilizing public debt, monetary policy must do the job. We obtain a similar result for the case of 'financial dominance', i.e. when the macroprudential policy is ineffective in stabilizing private debt. 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 stabilize government debt when the appropriate fiscal instruments are absent. Brunnermeier and Sannikov (2016) show that price stability, fiscal sustainability and financial stability are intimately intertwined. Kumhof, Nunes, and Yakadina (2010) abstract from financial frictions and analyze 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 analyze the link between financial stability and price stability, focussing on financial dominance.

Other studies on the interdependence of monetary and macroprudential policy exist. Collard, Dellas, Diba, and Loisel (2017) describe how capital requirements should be set optimally in a setup with limited liability and deposit insurance, as in our model. Differently from our setup, however, the goal of macroprudential policy in their model is to deter socially excessive risk taking by banks in terms of their type of lending. De Paoli and Paustian (2017) analyze optimal coordination versus non-coordination between the two policies, under discretion as well as commitment. Their model differs from ours; for instance, in their model macroprudential policy takes the form of a tax on firm borrowing. Gelain and Ilbas (2017) estimate a medium-sized model in which the macroprudential instrument is a tax on bank capital. They study the gains from coordination under different assumptions on policy makers' preferences. In Christensen, Meh, and Moran (2011), the macroprudential instrument is a bank leverage constraint, as in our framework. However, in that paper risk taking as well as monitoring by banks is an endogenous choice, and a bank risk externality motivates countercyclical macroprudential policy. In Angeloni and Faia (2013), risk originates on the funding side of the bank and reflects the possibility of bank runs. Finally, the model of Benes and Kumhof (2015) is most similar to ours, but allows for banks to deviate from regulatory capital ratio targets, subject to a pecuniary penalty. Thus, aside from differences in modelling, none of the aforementioned papers focuses on equilibrium determinacy.

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

In the following, we outline the model, starting with entrepreneurs and their demand for loans, followed by a description of the financial contract. We then describe the behavior of banks and their equity holders ('bankers'). The remainder of the model is a standard New Keynesian setup with monopolistically competitive intermediate goods producers, price adjustment costs, competitive final goods producers and capital producers. Finally, we discuss the sources of uncertainty and define the decentralized equilibrium for given monetary and macroprudential policy rules.

2.1 Entrepreneurs

There exists a continuum of entrepreneurs on the unit interval indexed by $j \in (0,1)$. Entrepreneur j chooses a level of capital K^j_{t+1} 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 $\omega^{Ej}_{t+1} R^E_{t+1}$, where R^E_{t+1} is the aggregate nominal return on capital and ω^{Ej}_{t+1} is an idiosyncratic disturbance, *iid* log-normally distributed with mean $\mathbb{E}\{\omega^{Ej}_{t+1}\} = 1$. The nominal gross return to entrepreneurs of holding a unit of capital from t to $t+1$ is the sum of the rent on capital and the capital gain net of depreciation, divided by the currency price of capital, in period t,

$$R^E_{t+1} = \frac{P_{t+1}[r^K_{t+1} + (1-\delta)\, q_{t+1}]}{P_t q_t}. \tag{1}$$

The variable r^K_t denotes the real rental rate on capital, P_t is the price index at time t, and $\delta \in (0,1)$ measures the rate of depreciation. The entrepreneur has net worth n^{Ej}_t and spends an amount $q_t K^j_t$ on capital goods, both measured in units of the final consumption good. He borrows the remainder,

$$b^j_t = q_t K^j_t - n^{Ej}_t. \tag{2}$$

The entrepreneur's real wealth in period $t+1$ is given by the value of his capital stock bought in the previous period, $q_t K^j_t$, multiplied by the ex-post nominal rate of return on capital R^E_{t+1}, multiplied by the fraction of returns left to the entrepreneur $1 - \Gamma^E_{t+1}$, discounted by the gross rate of inflation defined as $\Pi_{t+1} \equiv P_{t+1}/P_t$,

$$\mathcal{W}^{Ej}_{t+1} = \left(1 - \Gamma^E_{t+1}\right) \frac{R^E_{t+1} q_t K^j_t}{\Pi_{t+1}}. \tag{3}$$

The discussion of the contracting problem between entrepreneurs and banks below contains a derivation of Γ^E_{t+1}. Each period, an entrepreneur faces the constant probability χ^E of exiting the market, in which case he consumes his residual wealth. Aggregate consumption by entrepreneurs is $c^E_{t+1} = \chi^E \mathcal{W}^E_{t+1}$. Those entrepreneurs surviving to the next period start off with net worth given by $n^{Ej}_{t+1} = (1-\chi^E)\mathcal{W}^{Ej}_{t+1}$.

2.2 Financial Contract

Once banks have signed a financial contract with entrepreneurs, depending on the realization of the idiosyncratic productivity shock, some entrepreneurs declare default while others continue operating. A productivity threshold $\overline{\omega}^{Ej}_{t+1}$ is defined such that for realizations of ω^{Ej}_{t+1} smaller than the threshold, the entrepreneur is unable to repay his loan in full, i.e. she declares default, while for values greater than the threshold, the entrepreneur honors his contractual obligation by paying the bank $Z^j_t b^j_t$, i.e.

$$\overline{\omega}^{Ej}_{t+1} R^E_{t+1} q_t K^j_t = Z^j_t b^j_t, \tag{4}$$

where Z^j_t is the contractual repayment rate. We rewrite the above condition as follows,

$$\overline{\omega}^{Ej}_{t+1} = \frac{x^j_t}{R^E_{t+1}}, \tag{5}$$

where we define the entrepreneur's loan-to-value ratio as $x^j_t \equiv Z^j_t b^j_t/(q_t K^j_t)$. The probability of an entrepreneur's default is defined by the respective cumulative distribution function evaluated at the threshold $\overline{\omega}^{Ej}_{t+1}$,

$$F^E_{t+1} = F^E(\overline{\omega}^{Ej}_{t+1}) \equiv \int_0^{\overline{\omega}^{Ej}_{t+1}} f^E(\omega^{Ej}_{t+1}) \mathrm{d}\omega^{Ej}_{t+1}, \tag{6}$$

where $f^E(.)$ is the respective probability density function. Following the notation in Bernanke et al. (1999), we define the share of returns subject to firm default as follows,

$$G^E_{t+1} = G^E(\overline{\omega}^{Ej}_{t+1}) \equiv \int_0^{\overline{\omega}^{Ej}_{t+1}} \omega^{Ej}_{t+1} f^E(\omega^{Ej}_{t+1}) \mathrm{d}\omega^{Ej}_{t+1}. \tag{7}$$

In the default case, the entrepreneur must pay the whole return $\omega^{Ej}_{t+1} R^E_{t+1} q_t K^j_t$ to the bank. The lender incurs a monitoring cost in order to observe the entrepreneur's realized return on capital. This cost is a proportion μ^E of the realized gross payoff of the project, i.e. $\mu^E \omega^{Ej}_{t+1} R^E_{t+1} q_t K^j_t$. In the non-default case, the bank receives the contractually agreed nominal payment $Z^j_t b^j_t$, which is independent of the realization of the idiosyncratic shock ω^{Ej}_{t+1} and depends solely on the threshold value $\overline{\omega}^{Ej}_{t+1}$, to which we turn below. The remainder, $(\omega^{Ej}_{t+1} - \overline{\omega}^{Ej}_{t+1}) R^E_{t+1} q_t K^j_t$, is left for the residual claimant, the entrepreneur.

The entrepreneur is risk-neutral and cares only about the mean return on his wealth. Limited liability implies that, in currency terms, the expected project return, net of loan repayments, realized if the entrepreneur does not default, is given by

$$\mathbb{E}_t \left\{ \int_{\overline{\omega}^{Ej}_{t+1}}^{\infty} \omega^{Ej}_{t+1} R^E_{t+1} q_t K^j_t f^E(\omega^{Ej}_{t+1}) \mathrm{d}\omega^{Ej}_{t+1} - [1 - F^E(\overline{\omega}^{Ej}_{t+1})] Z^j_t b^j_t \right\}, \tag{8}$$

where the expectation is taken with respect to the random variable R^E_{t+1}. The terms of the loan contract determine the amount of capital K^j_{t+1} and the loan-to-value ratio x^j_t, which in turn pins down the repayment rate Z^j_t. Expression (8) is not contingent on the realization of the aggregate state R^E_{t+1} as in Bernanke et al. (1999), but on its expected value. The realization of R^E_{t+1} then determines the cutoff $\overline{\omega}^{Ej}_{t+1}$ through (5). Therefore, higher-than-expected firm defaults impinge on bank balance sheets, such that the bank bears some of the losses stemming from aggregate risk, as in Zhang (2009), Benes and Kumhof (2015) and Clerc et al. (2015). If instead the cutoff productivity level and the repayment rate are contingent on the aggregate state as in Bernanke et al. (1999), entrepreneurs bear all the aggregate risk, and the banking sector is perfectly insulated from any losses stemming from firm defaults. Substituting out $Z^j_t b^j_t$ using the cutoff (4), and using our assumption that $\mathbb{E}_t\{\omega^{Ej}_{t+1}\} = 1$, allows us to rewrite the expected return (8) as

$$\left(1 - \Gamma^E_{t+1}\right) R^E_{t+1} q_t K^j_t, \tag{9}$$

where we define the share of the project return accruing to the bank, gross of monitoring costs, as

$$\Gamma^E_{t+1} = \Gamma^E(\overline{\omega}^{Ej}_{t+1}) \equiv G^E(\overline{\omega}^{Ej}_{t+1}) + [1 - F^E(\overline{\omega}^{Ej}_{t+1})]\overline{\omega}^{Ej}_{t+1}. \tag{10}$$

Hence, the share of the project return to the bank, *net* of monitoring costs, is $\Gamma^E_{t+1} - \mu^E G^E_{t+1}$. In order for the bank to agree to 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, n^B_t, in the interbank market (right hand side),

$$\mathbb{E}_t\{(1 - \Gamma^F_{t+1})[(1 - F^E_{t+1})\overline{\omega}^{Ej}_{t+1} + (1 - \mu^E)G^E_{t+1}]R^E_{t+1} q_t K^j_t\} \geq \mathbb{E}_t\{R^B_{t+1} n^B_t\}, \tag{11}$$

where Γ^F_{t+1} is the share of the project return accruing to the bank after paying depositors, as we discuss in detail below, and R^B_{t+1} denotes the nominal return on equity. Using the above results we now derive the financial contract. The entrepreneur's problem is to choose a loan-to-value ratio x^j_t and capital K^j_{t+1} to maximize his expected profits (9), subject to the bank's participation constraint (11). The optimality conditions of the contracting problem are:

$$\mathbb{E}_t\{-\Gamma^{E\prime}_{t+1} + \xi^j_t \left(1 - \Gamma^F_{t+1}\right) \left(\Gamma^{E\prime}_{t+1} - \mu^E G^{E\prime}_{t+1}\right)\} = 0, \tag{12}$$

$$\mathbb{E}_t\{\left(1 - \Gamma^E_{t+1}\right) R^E_{t+1} + \xi^j_t \left[\left(1 - \Gamma^F_{t+1}\right) \left(\Gamma^E_{t+1} - \mu^E G^E_{t+1}\right) R^E_{t+1} - R^B_{t+1} n^B_t / b_t\right]\} = 0, \tag{13}$$

where ξ^j_t is the Lagrange multiplier on the bank participation constraint. Consider a representative bank with a diversified portfolio of loans to all entrepreneurs. The bank's realized return on loans to entrepreneurs, denoted R^F_{t+1}, is given by the payoff to the bank in $t + 1$, net of monitoring costs, divided by the volume of loans. That is,

$$R^F_{t+1} = \frac{(\Gamma^E_{t+1} - \mu^E G^E_{t+1}) R^E_{t+1} q_t K_t}{b_t}. \tag{14}$$

2.3 Banks

There exists a continuum of banks on the unit interval, indexed by $i \in (0, 1)$. Bank i's balance sheet reads $n^B_t + d^i_t = b^i_t$. It obtains a return on the loans it provides to entrepreneurs, b^i_t, and pays out a return on deposits d^i_t. Bank i's loan return is given by

$\omega^{Fi}_{t+1} R^F_{t+1} b^i_t$, where ω^{Fi}_{t+1} is an idiosyncratic disturbance, *iid* log-normally distributed with mean $\mathbb{E}\{\omega^{Fi}_{t+1}\} = 1$. The nominal return on deposits, equal to the policy rate, is denoted R^D_{t+1}. The bank fails if its return on loans does not cover payments to depositors. Similar to the entrepreneurial sector, there exists a threshold productivity level $\overline{\omega}^{Fi}_{t+1}$ below which bank i fails,

$$\overline{\omega}^{Fi}_{t+1} R^F_{t+1} b^i_t = R^D_{t+1} d^i_t. \tag{15}$$

In the default case, the bank must pay the whole return $\omega^{Fi}_{t+1} R^F_{t+1} b^i_t$ to the bank resolution authority. That agency incurs a monitoring cost equal to a proportion μ^F of the return on loans to the failed bank, i.e. $\mu^F \omega^{Fi}_{t+1} R^F_{t+1} b^i_t$. In the non-default case, depositors receive the nominal return $R^D_{t+1} d^i_t$, which by (15) equals $\overline{\omega}^{Fi}_{t+1} R^F_{t+1} b^i_t$. The remainder, $(\omega^{Fi}_{t+1} - \overline{\omega}^{Fi}_{t+1}) R^F_{t+1} b^i_t$, is left for the residual claimant, the bank equity holder. Using similar notation as above, we denote the bank default rate as follows,

$$F^F_{t+1} = F^F(\overline{\omega}^{Fi}_{t+1}) \equiv \int_0^{\overline{\omega}^{Fi}_{t+1}} f^F(\omega^{Fi}_{t+1}) \mathrm{d}\omega^{Fi}_{t+1}, \tag{16}$$

where $f^F(.)$ is the respective probability density function. The share of the return on loans subject to bank defaults is defined accordingly,

$$G^F_{t+1} = G^F(\overline{\omega}^{Fi}_{t+1}) \equiv \int_0^{\overline{\omega}^{Fi}_{t+1}} \omega^{Fi}_{t+1} f^F(\omega^{Fi}_{t+1}) \mathrm{d}\omega^{Fi}_{t+1}. \tag{17}$$

In currency terms, the realized return to the banker, net of deposit payments, in the case of non-default, is given by

$$\int_{\overline{\omega}^{Fi}_{t+1}}^{\infty} \omega^{Fi}_{t+1} R^F_{t+1} b^i_t f^F(\omega^{Fi}_{t+1}) \mathrm{d}\omega^{Fi}_{t+1} - [1 - F^F(\overline{\omega}^{Fi}_{t+1})] R^D_{t+1} d^i_t. \tag{18}$$

Substituting out $R^D_{t+1} d^i_t$ using (15) allows us to rewrite the equity return (18) as

$$(1 - \Gamma^F_{t+1}) R^F_{t+1} b^i_t, \tag{19}$$

where $1 - \Gamma^F_{t+1}$ is the share of the loan return, net of interest payments to depositors, accruing to the banker. The remainder, Γ^F_{t+1}, is the share of the loan return going to the bank resolution authority, gross of monitoring costs,

$$\Gamma^F_{t+1} = \Gamma^F(\overline{\omega}^{Fi}_{t+1}) \equiv G^F(\overline{\omega}^{Fi}_{t+1}) + [1 - F^F(\overline{\omega}^{Fi}_{t+1})] \overline{\omega}^{Fi}_{t+1}. \tag{20}$$

Then, the share of the project return to the bank resolution authority, *net* of monitoring costs, is $\Gamma^F_{t+1} - \mu^F G^F_{t+1}$. Consider a representative bank equity holder with a diversified portfolio of shares in all banks. The realized gross rate of return on a banker's portfolio, R^B_{t+1}, is given by the ratio of bank profits to banker net worth,

$$R^B_{t+1} = \frac{(1 - \Gamma^F_{t+1}) R^F_{t+1} b_t}{n^B_t}. \tag{21}$$

As in Gertler and Karadi (2011), a household consists of a large number of members, a fraction $1 - \mathcal{F}$ of which are workers and the rest are bankers. The only investment opportunity for the banker is to provide equity to the bank. A banker's real wealth in period $t + 1$ is given by his equity return: net worth multiplied by the ex-post nominal rate of return on equity R_{t+1}^B, discounted by the gross rate of inflation,

$$\mathcal{W}_{t+1}^B = \frac{R_{t+1}^B n_t^B}{\Pi_{t+1}}. \tag{22}$$

Each period, a bank equity holder faces a constant probability χ^B of ceasing to be a banker and rejoining his household, to which he turns over his residual wealth, $\chi^B \mathcal{W}_{t+1}^B$. Households use a fraction ι/χ^B of that transfer as startup funding to new bankers that are chosen at random among the household members at the start of each period, such that the proportions of workers and bankers remain constant at all times. Those bankers that remain in that occupation carry their wealth over to the next period. Thus, aggregate net worth of bankers is given by $n_{t+1}^B = (1 - \chi^B + \iota)\mathcal{W}_{t+1}^B$.

2.4 Households

Households are infinitely lived and maximize lifetime utility as follows,

$$\max_{c_t, l_t, d_t} \mathbb{E}_t \sum_{s=0}^{\infty} \beta^{t+s} \left(\ln c_{t+s} - \varphi \frac{l_{t+s}^{1+\eta}}{1+\eta} \right), \tag{23}$$

where $\beta \in (0, 1)$ is the subjective discount factor, c_t is consumption, l_t is labor, φ is the weight on labor disutility and $\eta \geq 0$ is the inverse Frisch elasticity of labor supply. The household chooses paths for c_t, l_t and bank deposits d_t to maximize utility (23), subject to the sequence of budget constraints,

$$c_t + d_t + t_t \leq w_t l_t + \frac{R_t^D d_{t-1}}{\Pi_t} + \chi^B \mathcal{W}_t^B + \Xi_t^K + \Xi_t^P, \tag{24}$$

where t_t are lump-sum taxes (in terms of the final consumption good), w_t is the real wage, Ξ_t^K are capital producers' profits and Ξ_t^P are intermediate goods producers' profits, both of which are redistributed to households in a lump-sum fashion. The household's first order optimality conditions can be simplified to a labor supply equation, $w_t = \varphi_t l_t^\eta / \Lambda_t$, and a consumption Euler equation, $1 = \mathbb{E}_t\{\beta_{t,t+1} R_{t+1}^D / \Pi_{t+1}\}$, where $\beta_{t,t+s} = \beta^{t+s}\Lambda_{t+s}/\Lambda_t$ is the household's stochastic discount factor between t and $t + s$ and the Lagrange multiplier on the budget constraint (24), $\Lambda_t = 1/c_t$, captures the shadow value of household wealth in real terms.

2.5 Production

Within the production sector, we distinguish between 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 and to capital goods producers. Intermediate goods producers use capital and labor to produce the goods used as inputs by the final goods producers. They set prices subject to quadratic adjustment costs, which introduces a New Keynesian Phillips curve in our model. Finally, capital goods producers buy the final consumption good and convert it to capital, which they sell to the entrepreneurs.

A final goods firm bundles the differentiated intermediate 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 optimization problem of the final goods firm is to choose the amount of inputs Y_{it} that maximize profits $\{P_tY_t - \int_0^1 Y_{it}P_{it}\mathrm{d}i\}$, subject to the production function, $Y_t = (\int_0^1 Y_{it}^{(\varepsilon-1)/\varepsilon}\mathrm{d}i)^{\varepsilon/(\varepsilon-1)}$, where $\varepsilon > 1$ is the elasticity of substitution between goods varieties. From the first order condition we derive the demand for intermediate goods, $Y_{it}^d = (P_{it}/P_t)^{-\varepsilon}Y_t$. Substituting Y_{it} in the production function yields the price of final output, which we interpret as an aggregate price index, $P_t = (\int_0^1 P_{it}^{1-\varepsilon}\mathrm{d}i)^{1/(1-\varepsilon)}$.

There is a continuum of intermediate goods producers indexed by $i \in (0,1)$. Each of them produces a differentiated good using $Y_{it} = A_tK_{it}^{\alpha}l_{it}^{1-\alpha}$, where $\alpha \in (0,1)$ is the capital share in production, A_t is aggregate technology, K_{it} are capital services and l_{it} is labor input. Intermediate goods firm i maximizes profits,

$$\Xi_{it}^P = \frac{P_{it}Y_{it}}{P_t} - \frac{\kappa_p}{2}\left(\frac{P_{it}}{P_{it-1}} - 1\right)^2 Y_{it} - r_t^K K_{it} - w_tl_{it}, \tag{25}$$

subject to the technological constraint and the demand constraint. Price adjustment costs are a function of the firm's price change P_{it}/P_{it-1}, where $\kappa_p > 0$ measures the degree of price rigidity. Perfectly flexible prices are given by $\kappa_p \to 0$. The demands for capital and labor are given by $w_t = (1-\alpha)s_tY_{it}/l_{it}$ and $r_t^K = \alpha s_tY_{it}/K_{it}$, respectively, where the Lagrange multiplier on the demand constraint, s_t, represents real marginal costs. Substituting the capital-labor ratio in the labor demand function yields $s_t = w_t^{1-\alpha}(r_t^K)^{\alpha}/[\alpha^{\alpha}(1-\alpha)^{1-\alpha}A_t]$. Firm i's price setting problem is

$$\max_{P_{it}} \mathbb{E}_t \sum_{s=0}^{\infty} \beta_{t,t+s}\left\{\tfrac{P_{it+s}Y_{it+s}^d}{P_{t+s}} - \tfrac{\kappa_p}{2}\left(\tfrac{P_{it+s}}{P_{it+s-1}} - 1\right)^2 Y_{it+s}^d + s_{t+s}(Y_{it+s} - Y_{it+s}^d)\right\}, \tag{26}$$

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

$$\kappa_p\Pi_t(\Pi_t - 1) = s_t\varepsilon - (\varepsilon - 1) + \kappa_p\mathbb{E}_t\{\beta_{t,t+1}\Pi_{t+1}(\Pi_{t+1} - 1)\tfrac{Y_{t+1}}{Y_t}\}. \tag{27}$$

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. Investment is subject to quadratic adjustment costs as in Christiano, Eichenbaum, and Evans (2005), which yields a variable price of capital. The representative capital-producing firm chooses a path for investment I_t to maximize profits given by $\mathbb{E}_t\sum_{s=0}^{\infty}\beta_{t,t+s}[q_{t+s}\Delta x_{t+s} - I_{t+s}]$.
Net capital accumulation is $\Delta x_t = K_t - (1-\delta)K_{t-1} = [1 - \frac{\kappa_I}{2}(\frac{I_t}{I_{t-1}} - 1)^2]I_t$. The optimality

condition for investment is

$$1 = q_t \left[1 - \frac{\kappa_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \kappa_I \left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}}\right] + \mathbb{E}_t\{q_{t+1}\beta_{t,t+1}\kappa_I \left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\}. \tag{28}$$

Capital producers' profits, in real terms, are $\Xi_t^K = q_t[K_t - (1-\delta)K_{t-1}] - I_t$.

2.6 Sources of Uncertainty

We consider two sources of uncertainty, shocks to technology A_t and to firm risk ω_t^E. The logarithm of technology follows a stationary first-order autoregressive process,

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_t^A, \tag{29}$$

where $\rho_A \in (0,1)$ and ε_t^A is an *iid* normal shock with mean zero and standard deviation σ_A. Firm productivity ω_t^E is a random variable following a log-normal distribution with mean one and standard deviation $\sigma_t^E = \sigma^E \varsigma_t$. We introduce time variability of firm risk via an autoregressive process,

$$\ln \varsigma_t = \rho_\varsigma \ln \varsigma_{t-1} + \varepsilon_t^\varsigma, \tag{30}$$

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

2.7 Market Clearing and Equilibrium

Final goods produced must equal goods demanded by households and entrepreneurs; goods used for investment (net of adjustment costs), resources lost when adjusting prices, and resources lost in the recovery of funds associated with entrepreneur and bank defaults,

$$Y_t = c_t + \chi^E \mathcal{W}_t^E + I_t + \frac{\kappa_p}{2}(\Pi_t - 1)^2 Y_t + \mu^E G_t^E \frac{R_t^E q_{t-1} K_t}{\Pi_t} + \mu^F G_t^F \frac{R_t^F b_{t-1}}{\Pi_t}. \tag{31}$$

Firms' labor demand must equal households' labor supply, $(1-\alpha)\, s_t Y_t / l_t = \varphi_t l_t^\eta / \Lambda_t$. 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. Because of full deposit insurance, the policy rate is identical to the risk-free deposit rate, $R_t = R_t^D$. We are now ready to provide a formal definition of equilibrium in our economy.

Definition: *An equilibrium is a set of allocations* $\{l_t,\, K_t,\, I_t,\, c_t,\, Y_t,\, n_t^E,\, b_t,\, n_t^B,\, d_t,\, x_t\}_{t=0}^\infty$*, prices* $\{w_t,\, r_t^K,\, q_t,\, \Pi_t,\, s_t\}_{t=0}^\infty$ *and rates of return* $\{R_t^E,\, R_t^F,\, R_t^B\}_{t=0}^\infty$ *which, given 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 summarized in Table 1.* The derivation of the model's steady state and its calibration are described next.

2.8 Model Calibration and Steady State

We derive the deterministic steady state with trend inflation. To this end, we solve numerically for the entrepreneur and bank productivity cutoffs, $\overline{\omega}^E$ and $\overline{\omega}^F$, the proportion

Table 1: **Summary of Model Equations**

1	$w_t = \varphi l_t^{\eta} c_t$
2	$1 = \beta E_t\{\frac{c_t}{c_{t+1}}\frac{R_t^D}{\Pi_{t+1}}\}$
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	$\kappa_p \Pi_t(\Pi_t - 1) = s_t\varepsilon - (\varepsilon - 1)[1 - \frac{\kappa_p}{2}(\Pi_t - 1)^2] + \kappa_p \beta E_t\{\frac{c_t}{c_{t+1}}\Pi_{t+1}(\Pi_{t+1}-1)\frac{Y_{t+1}}{Y_t}\}$
7	$1 = q_t[1 - \frac{\kappa_I}{2}(\frac{I_t}{I_{t-1}}-1)^2 - \kappa_I(\frac{I_t}{I_{t-1}}-1)\frac{I_t}{I_{t-1}}] + E_t\{q_{t+1}\beta_{t,t+1}\kappa_I(\frac{I_{t+1}}{I_t}-1)(\frac{I_{t+1}}{I_t})^2\}$
8	$K_t = [1 - \frac{\kappa_I}{2}(\frac{I_t}{I_{t-1}} - 1)^2]I_t + (1-\delta)K_{t-1}$
9	$n_t^E = (1-\chi^E)(1-\Gamma_t^E)\frac{R_t^E q_{t-1}K_{t-1}}{\Pi_t}$
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	$Y_t = c_t + \chi^E W_t^E + I_t + \frac{\kappa_p}{2}(\Pi_t - 1)^2 Y_t + \mu^E G_t^E\frac{R_t^E q_{t-1}K_t}{\Pi_t} + \mu^F G_t^F\frac{R_t^F b_{t-1}}{\Pi_t}$
15	$E_t\{(1-\Gamma_{t+1}^E)R_{t+1}^E + \xi_t[(1-\Gamma_t^F)(\Gamma_{t+1}^E - \mu^E G_{t+1}^E)R_{t+1}^E - \phi_t R_{t+1}^B]\} = 0$
16	$\xi_t = \frac{\Gamma_{t+1}^{E\prime}}{(\Gamma_{t+1}^{E\prime} - \mu^E G_{t+1}^{E\prime})(1-\Gamma_t^F)}$
17	$R_t^E = \frac{r_t^K + (1-\delta)q_t}{q_{t-1}}\Pi_t$
18	$R_t^F = (\Gamma_t^E - \mu^E G_t^E)\frac{R_t^E q_{t-1}K_{t-1}}{b_{t-1}}$
19	$R_t^B = (1-\Gamma_t^F)\frac{R_t^F}{\phi_{t-1}}$
20	$\overline{\omega}_t^E = \frac{x_{t-1}^E}{R_t^E}$
21	$\overline{\omega}_t^F = \frac{d_t R_t^D}{b_t R_t^F}$
Auxiliary Variables	
22-24	$F_t^E = \Phi(\frac{\ln\overline{\omega}_t^E + \frac{1}{2}(\sigma_t^E)^2}{\sigma_t^E})$, $G_t^E = \Phi(\frac{\ln\overline{\omega}_t^E - \frac{1}{2}(\sigma_t^E)^2}{\sigma_t^E})$, $\Gamma_t^E = G_t^E + \overline{\omega}_t^E(1-F_t^E)$
25-27	$G_t^{E\prime} = \frac{1}{\overline{\omega}_t^E\sigma_t^E}\Phi'(\frac{\ln\overline{\omega}_t^E - \frac{1}{2}(\sigma_t^E)^2}{\sigma_t^E})$, $F_t^{E\prime} = \frac{1}{\overline{\omega}_t^E\sigma_t^E}\Phi'(\frac{\ln\overline{\omega}_t^E + \frac{1}{2}(\sigma_t^E)^2}{\sigma_t^E})$, $\Gamma_t^{E\prime} = G_t^{E\prime} + (1-F_t^E) - \overline{\omega}_t^E F_t^{E\prime}$
28-30	$F_t^F = \Phi(\frac{\ln\overline{\omega}_t^F + \frac{1}{2}(\sigma_t^F)^2}{\sigma_t^F})$, $G_t^F = \Phi(\frac{\ln\overline{\omega}_t^F - \frac{1}{2}(\sigma_t^F)^2}{\sigma_t^F})$, $\Gamma_t^F = G_t^F + \overline{\omega}_t^F(1-F_t^F)$

The system consists of 30 endogenous variables, l_t, K_t, I_t, c_t, Y_t, n_t^E, b_t, n_t^B, d_t, x_t, w_t, r_t^K, q_t, Π_t, s_t, ξ_t, R_t^E, R_t^F, R_t^B, $\overline{\omega}_t^E$, $\overline{\omega}_t^F$, G_t^E, F_t^E, Γ_t^E, $G_t^{E\prime}$, $F_t^{E\prime}$, $\Gamma_t^{E\prime}$, G_t^F, F_t^F, Γ_t^F, two policy variables, R_t, ϕ_t, and two exogenous processes, A_t and ς_t. The functions $\Phi(\cdot)$ and $\Phi'(\cdot)$ denote, respectively, the cumulative distribution function and the probability density function of the standard normal distribution.

of the project return lost in monitoring, μ^E, the entrepreneur exit rate χ^E, and the standard deviations of the idiosyncratic shocks hitting firms and banks, σ^E and σ^F. Setting initial values for those six parameters allows us to solve for the remaining steady state variables recursively as shown in Table 3.

We calibrate the model to a quarterly frequency. We normalize technology and risk shocks in steady state by setting $A = \varsigma = 1$. We also set the weight on labor disutility φ so as to normalize labor to unity in steady state, $l = 1$. Table 2 summarized the calibration of our model parameters.We set $\Pi = 1.005$ to yield an annualized inflation rate of 2 percent as observed in US data over the period 1984-2016. The subjective discount factor β is set to 0.99, implying a quarterly risk-free (gross) nominal interest rate of $R = 1.005/0.99 = 1.01$ or a real annual (net) interest rate of roughly 2%, given an annual inflation rate of 2%. The inverse of the Frisch elasticity of labor supply is set to $\eta = 1$, as in Christiano et al. (2014). This value lies in between the micro estimates of the Frisch elasticity, which are typically below 1, and the calibrated values used in macro studies, which tend to be above 1. As is standard in the literature (see Bernanke et al., 1999, and Carlstrom, Fuerst, and Paustian, 2016, among many others), the capital share in production is set to $\alpha = 0.35$, while the depreciation rate is $\delta = 0.025$, such that 10% of the capital stock is depleted each year. The substitution elasticity between goods varieties is $\varepsilon = 6$, implying a gross steady state markup of $\varepsilon/(\varepsilon - 1) = 1.2$ (Christensen and Dib, 2008). The Rotemberg price adjustment cost parameter is $\kappa_p = 30$, which corresponds to a price duration of around 3 quarters in the Calvo model of staggered price adjustment; that value is in line with the duration implied by the posterior estimate of the Calvo parameter in Smets and Wouters (2007).[3] The investment adjustment cost parameter is set to $\kappa_I = 2.43$, the estimate of Carlstrom et al. (2014). The financial parameters and interest rates are displayed in Table 4.

We first discuss the financial parameters, before turning to the ranking of the various interest rates and spreads in steady state. Following Bernanke et al. (1999), we target (i) a ratio of capital to net worth, $\varrho \equiv qK/n^E$, of 2, (ii) a spread between the return on capital and the deposit rate, $\upsilon \equiv R^E/R^D$, of 200 basis points per year, and (iii) a quarterly entrepreneur default rate of $F^E = 0.0075$, which corresponds to an annual default rate of 3%. As far as the banking sector is concerned, we set the steady state capital requirement for banks, i.e. the ratio of equity to loans, of 8%, that is $\phi = 0.08$ as recommended by the Basel Accords. We set the probability of bank default F^Fequal to the ratio of bank failures to the number of commercial banks, which is 0.9% per annum for the period 1984-2015 according to the Federal Deposit Insurance Corporation.[4] On the one hand, if we count bank *closings* rather than failures, we find a rate of 2.7% per annum in US data.[5] On the other hand, de Walque, Pierrard, and Rouabah (2010) report

[3]For the algebraic relationship between the Rotemberg and Calvo parameters see Cantore, Levine, and Melina (2014).

[4]The annual number of banks and bank failures in the US, starting in 1936, can be downloaded from www.fdic.gov.

[5]Bank closings are downloaded from the Bureau of Labor Statistics Business Dynamics database, http://data.bls.gov/cgi-bin/dsrv?db. The industry considered is 'Credit intermediation and related activities'.

Table 2: **Benchmark Calibration**

Parameter Value	Description	Target/Reference
Structural Parameters		
$\beta = 0.99$	Household discount factor	Bernanke et al. (1999)
$\eta = 1$	Inverse Frisch labor elasticity	Christiano, Motto, and Rostagno (2014)
$\varphi = 0.7461$	Weight on labor disutility	Labor = 1 in steady state
$\alpha = 0.35$	Capital share in production	Bernanke et al. (1999)
$\delta = 0.025$	Capital depreciation rate	Bernanke et al. (1999)
$\varepsilon = 6$	Substitutability between goods	Christensen and Dib (2008)
$\kappa_p = 30$	Price adjustment cost	Smets and Wouters (2007)
$\kappa_I = 2.43$	Investment adjustment cost	Carlstrom, Fuerst, Ortiz, and Paustian (2014)
Shock Parameters[(1)]		
$\sigma^A = 0.0385$	Size technology shock	US data
$\rho^A = 0.9753$	Persistence technology shock	US data
$\sigma^\varsigma = 0.0247$	Size firm risk shock	US data
$\rho^\varsigma = 0.6960$	Persistence firm risk shock	US data
Inflation Target		
$\Pi = 1.005$	Steady state inflation	US data[(2)]

Note: [(1)]See Section 2.8 on calibration strategy to determine the shock parameters. [(2)]Value corresponds to growth of US GDP deflator over the period 1984-2016.

Table 3: **Computation of Steady State**

1-2	$R^D = \frac{\Pi}{\beta}$, $R^E = R^D \upsilon$
3-4	$q = 1$, $r^K = [\frac{R^E}{\Pi} - (1-\delta)]q$
5	$s = \frac{\varepsilon-1}{\varepsilon} + \frac{\kappa_p}{\varepsilon}(1-\beta)(\Pi-1)\Pi$
6-8	$K = [\frac{1}{A}(\frac{1}{\alpha}\frac{r^K}{s}) l^{\alpha-1}]^{\frac{1}{\alpha-1}}$, $I = \delta K$, $Y = (\frac{1}{\alpha}\frac{r^K}{s})K$
9-12	$n^E = \frac{qK}{\varrho}$, $b = qK - n^E$, $n^B = \phi b$, $d = b - n^B$
13-14	$G^E = \Phi(\frac{\ln\varpi^E - \frac{1}{2}(\sigma^E)^2}{\sigma^E})$, $\Gamma^E = G^E + \varpi^E(1-F^E)$
15-16	$F^{E\prime} = \frac{1}{\varpi^E\sigma^E}\Phi'(\frac{\ln\varpi^E + \frac{1}{2}(\sigma^E)^2}{\sigma^E})$, $G^{E\prime} = \frac{1}{\varpi^E\sigma^E}\Phi'(\frac{\ln\varpi^E - \frac{1}{2}(\sigma^E)^2}{\sigma^E})$
17	$\Gamma^{E\prime} = G^{E\prime} + (1-F^E) - \varpi^E F^{E\prime}$
18-19	$G^F = \Phi(\frac{\ln\varpi^F - \frac{1}{2}(\sigma^F)^2}{\sigma^F})$, $\Gamma^F = (1-F^F)\varpi^F + G^F$
20	$\xi = \frac{\Gamma^{E\prime}}{(1-\Gamma^F)(\Gamma^{E\prime} - \mu^E G^{E\prime})}$
21	$R^F = (\Gamma^E - \mu^E G^E)\frac{R^E qK}{b}$
22	$R^B = (1-\Gamma^F)\frac{R^F}{\phi}$
23	$\chi^B = \iota + 1 - \frac{\Pi}{R^B}$
24	$c = Y - \chi^E(1-\Gamma^E)\frac{R^E qK}{\Pi} - I - \frac{\kappa_p}{2}(\Pi-1)^2 Y - \mu^E G^E \frac{R^E qK}{\Pi} - \mu^F G^F \frac{R^F b}{\Pi}$
25	$w = (1-\alpha)s\frac{Y}{l}$
26	$\varphi = \frac{w}{c l^\eta}$
27	$x = \varpi^E R^E$

28	$0 = -1 + \frac{1}{\beta}(1-\chi^E)\left(1-\Gamma^E\right)\upsilon\varrho$
29	$0 = (1-\Gamma^E)R^E + \xi[(1-\Gamma^F)(\Gamma^E - \mu^E G^E)R^E - \phi R^B]$
30	$0 = -F^E + \Phi(\frac{\ln(\varpi^E) + \frac{1}{2}(\sigma^E)^2}{\sigma^E})$
31	$0 = -n^E + (1-\chi^E)(1-\Gamma^E)\frac{R^E qK}{\Pi}$
32	$0 = -F^F + \Phi(\frac{\ln(\varpi^F) + \frac{1}{2}(\sigma^F)^2}{\sigma^F})$
33	$0 = -\varpi^F + (1-\phi)\frac{R^D}{R^F}$

Given initial values for ϖ^E, μ^E, σ^E, χ^E, ϖ^F, σ^F, we can compute the 27 parameters R^D, R^E, q, r^K, s, K, I, Y, G^E, Γ^E, $G^{E\prime}$, $F^{E\prime}$, $\Gamma^{E\prime}$, ξ, n^E, b, n^B, χ^B, R^F, R^B, G^F, Γ^F, c, w, φ, d, x, using equations 1 to 27. We then solve the six equations 28-33 numerically for ϖ^E, μ^E, σ^E, χ^E, σ^F, ϖ^F, given the calibrated parameters in Tables 2 and 4 below, together with the values of the 27 steady state variables found above.

Table 4: **Financial Parameters and Interest Rates**

Value/Target	Description	Target/Reference
Calibrated Financial Parameters		
$\varrho \equiv \frac{qK}{n^E} = 2$	Entrepreneur leverage ratio	Bernanke et al. (1999)
$\upsilon \equiv \frac{R^E}{R^D} = 1.005$	Capital return spread	Bernanke et al. (1999)
$400F^E = 3$	Entrepreneur default rate per annum, in %	Bernanke et al. (1999)
$400F^F = 0.9$	Bank default rate per annum, in %	US data(1)
$\phi = 0.08$	Bank capital requirement	Basel Accords
$\mu^F = 0.3$	Bank monitoring cost	Clerc et al. (2015)
$\iota = 0.002$	Transfer to entering bankers	Gertler and Karadi (2011)
Implied Financial Parameters		
$\overline{\omega}^E = 0.499$	Entrepreneur productivity cutoff	–
$\chi^E = 0.018$	Entrepreneur exit rate	–
$\mu^E = 0.100$	Entrepreneur monitoring cost	–
$\sigma^E = 0.271$	Entrepreneur risk volatility	–
$\overline{\omega}^F = 0.919$	Bank productivity cutoff	–
$\sigma^F = 0.029$	Bank risk volatility	–
$\chi^B = 0.022$	Banker exit rate	–
Implied Steady State Rates of Return		
$R = 1.0152$	Policy rate	–
$R^D = 1.0152$	Return on deposits	–
$R^F = 1.0159$	Return on loans	–
$R^E = 1.0202$	Return on capital	–
$R^B = 1.0252$	Return on equity	–

Note: All interest rates and rates of return are gross rates. (1)See Section 2.8 on the calibration of the US bank default rate.

a value of 0.4% per annum based on the Z-score method to compute the probability that banks' own funds are not sufficient to absorb losses. Our value therefore lies within this range of estimates. Finally, bank monitoring costs are calibrated to $\mu^F = 0.3$ as in Clerc et al. (2015).[6] Laeven and Valencia (2010) report a median fraction of bank assets lost due to bank failures - in the US between 1986 and 2008 - of around 20%. As in Gertler and Karadi (2011), the proportional transfer to new bankers is set to $\iota = 0.002$.

In the following, we report and discuss the implied financial parameters. In the corporate sector, we obtain a productivity cutoff of roughly one half, $\overline{\omega}^E = 0.498$, a monitoring cost equal to $\mu^E = 0.09$, a standard deviation of the idiosyncratic shock to the project return of $\sigma^E = 0.271$, and an entrepreneur exit rate of $\chi^E = 0.018$. In the banking sector, we find a productivity cutoff of $\overline{\omega}^F = 0.92$, a standard deviation of bank risk equal to $\sigma^F = 0.014$, a bank failure rate of 1.36% per annum. The banker exit rate is found to be $\chi^B = 0.025$.

In our model, bank resolution costs are substantially higher than firm monitoring costs ($\mu^F > \mu^E$). This may reflect the greater opaqueness of bank balance sheets, which makes monitoring more difficult (Morgan, 2002). Moreover, the role of banks in financial intermediation suggests that the costs and externalities associated with bank failures are particularly high. E.g. Kupiec and Ramirez (2013) find that bank failures cause non-bank commercial failures and have long-lasting negative effects on economic growth. Our implied banker turnover rate χ^B is in the ballpark of the numbers found in the literature, e.g. Gertler and Kiyotaki (2010) and Angeloni and Faia (2013) impose a value of 0.028 and 0.03, respectively. The implied equity return premium, R^B/R^D, is roughly 400 basis points per annum, which is somewhat lower than equity return spread in US data found to equal 578 basis points per year, which is computed as the difference between the return on average equity for all U.S. banks and the 10-year treasury constant maturity rate over the period 1984Q1-2016Q3.[7]

Interest rates in the model follow a hierarchical ordering. The risk-free rate corresponds to the deposit rate R^D and to the policy rate R in steady state. The realized return on bank loans is R^F. This return contains a discount which is related to the monitoring cost that the bank must incur when an entrepreneur declares default. The next higher rate of return is the return on capital, R^E. The return on capital is higher than the realized loan return R^F, because it needs to compensate the entrepreneur for running the risk of default while it is not reduced by any monitoring cost. Finally, the return on equity earned by bankers R^B exceeds the realized 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; the higher is the capital requirement, the more equity banks will hold, and hence the lower is the implied return on equity, R^B.

We assume autoregressive processes for the (log) technology shock, $\ln A_t$, and the (log) firm risk shock, $\ln \varsigma_t$. Similarly to Benes and Kumhof (2015) and Batini, Melina, and Villa (2016), we set the standard deviations and the persistence of the shock processes via

[6] Differently from the monitoring cost related to the entrepreneurial sector, bank monitoring costs μ^F do not affect the computation of the steady state financial variables (see Table 3). They only appear in the aggregate resource constraint.

[7] More specifically, we consider the spread between return on equity of all US banks (series 'USROE' in FRED Database, https://fred.stlouisfed.org/) and the 10-year Treasury constant maturity rate (series 'GS10' in FRED), the latter being the risk-free rate generally considered in the literature.

moment-matching of the empirical standard deviations and the persistences of real output and real lending.[8] As in Lewis and Villa (2016), we construct a quadratic loss function $\sum_{j=1}^{4}(x_j^m - x_j^d)^2$, where x_j^m is the j-th moment in the model and x_j^m is its analogue in the data, and we numerically search for those parameters that minimize this loss function. This procedure leads to estimates of persistent TFP and risk shocks, with $\rho_A = 0.975$ and $\rho_\varsigma = 0.696$, and standard deviations equal to $\sigma^A = 0.0385$ and $\sigma^\varsigma = 0.0247$, respectively.

3 Macroprudential and Monetary Policy

We now analyze the interaction of monetary and macroprudential policy in the form of simple rules. We follow the approach in Kumhof et al. (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.[9] 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. First, we analyze the determinacy properties of the model, i.e. the conditions under which a unique stable equilibrium solution to the model exists. Second, we perform a welfare analysis which provides information about preferred values of policy coefficients for our simple rules.

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:

$$\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{\tau_\Pi}\left(\frac{b_t}{b}\right)^{\tau_b}. \tag{32}$$

[8] Data on the US are taken from the Alfred database of the St. Louis Fed and the Flow of Funds for the period 1952Q1-2016Q1. The time series are detrended using the HP filter.

[9] Brunnermeier and Sannikov (2016) define financial dominance more generally as the 'inability or unwillingness of the financial sector to absorb losses'.

The response of the interest rate to lending, the second term in the monetary policy rule (32), has been called 'Leaning Against The Wind' (LATW) in the literature.[10] Similar specifications can be found in many papers, for instance in Benes and Kumhof (2015) or in Lambertini, Mendicino, and Teresa Punzi (2013). The idea behind a positive coefficient on borrowing, $\tau_b > 0$, is that monetary policy may want to curtail excessive borrowing and dampen financial cycles by varying the interest rate, even if inflation is subdued.

Banks are subject to the following minimum capital requirement,

$$n_t^B \geq \phi_t b_t, \tag{33}$$

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. In equilibrium, constraint (33) holds with equality, i.e. $n_t^B = \phi_t b_t$. The bank has no incentive to hold more equity capital than necessary. Similar to entrepreneurs, bankers are protected by limited liability; they can walk away in the case of default. Since deposit funding is cheaper than equity funding, banks maximize profits by increasing leverage up to the capital constraint. On the one hand, deposit funding is cheap thanks to full deposit insurance, which shifts the default risk away from depositors and onto taxpayers, who fund the bank resolution authority. The depositors have no reason to monitor the banks' activities, such that the deposit rate coincides with the policy interest rate. On the other hand, bank capital is expensive because of limited asset market participation: recall that only 'bankers' are allowed to hold equity, and therefore the amount of available equity funding is restricted to the accumulated wealth of bankers. As a result, an equity return premium emerges.

Macroprudential policy is given by a rule that sets the bank capital requirement in response to changes in lending,

$$\frac{\phi_t}{\phi} = \left(\frac{b_t}{b}\right)^{\zeta_b}. \tag{34}$$

The capital requirement rule in (34) has been used in this form in other studies, e.g. in Benes and Kumhof (2015) and in Clerc et al. (2015). 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 characterize 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.

[10] LATW may also refer to an augmented monetary policy rule where the interest rate responds to asset prices, see e.g. Cecchetti, for Monetary, Studies, Genberg, Lipsky, and Wadhwani (2000) and Bernanke and Gertler (2001). We do not consider this type of rule here.

Countercyclical Capital Buffer

We analyze 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), where $\tau_\Pi \neq 0$, $\tau_b = 0$, and $\zeta_b \geq 0$. 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 15, while the vertical axis shows the coefficient on inflation in the interest rate rule (τ_Π), varying between -2 and 2. Even though we do not consider a negative inflation coefficient as economically meaningful, we 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 four regions, two of which correspond to parameter combinations with a unique stable solution (determinacy): the lower left and upper right regions. 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 simultaneously accommodating or aggressive. 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* region, 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-disinflation 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 stabilizing 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* region in Figure 2. In that case, the debt-disinflation effect, which jeopardizes 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* region, 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.

Figure 2: Determinacy Analysis: Countercyclical Capital Buffer

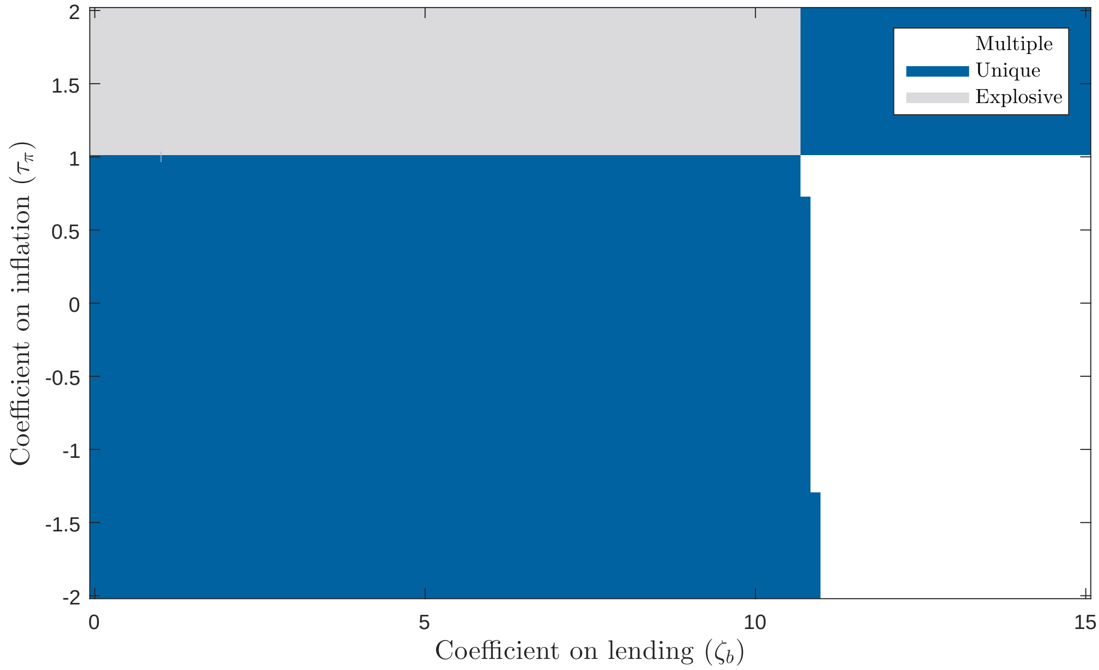
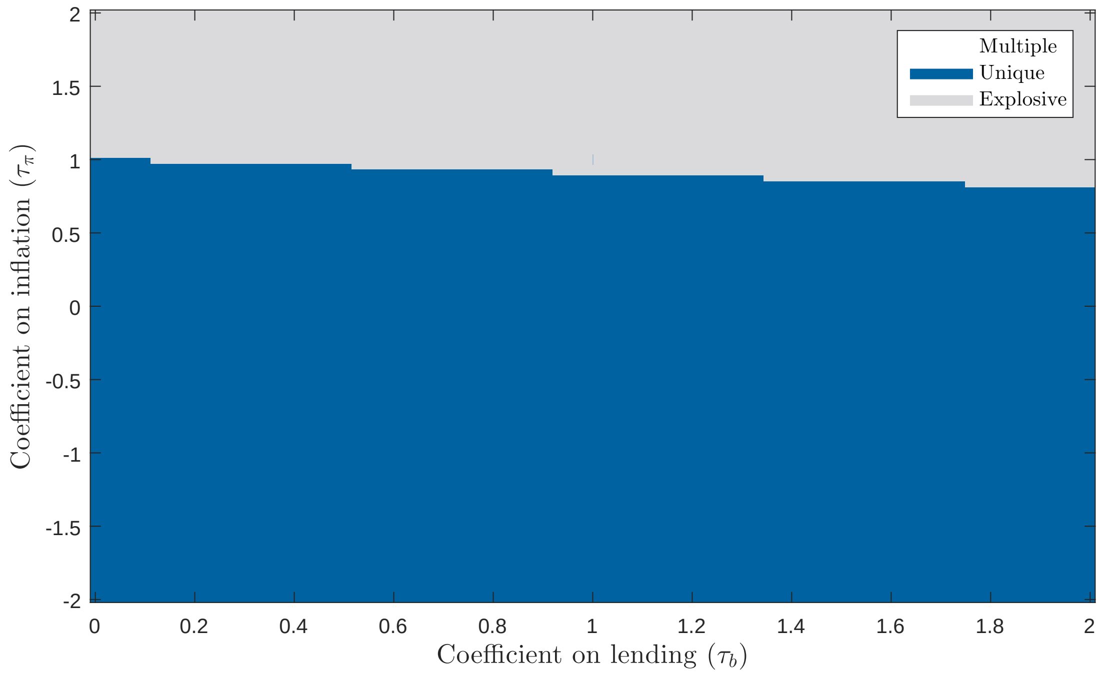


Figure 3: Determinacy Analysis: Leaning Against the Wind



Note: These figures show the model's determinacy properties as a function of the respective response coefficients on inflation and lending. 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.

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 region of Figure 2, the macroprudential rule (34) 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 boosts bankers' return per unit of equity. The rates of return on equity and on entrepreneurial capital are positively related, see (21). Thus, the return on risky investment rises and the entrepreneurs' expectation becomes a self-fulfilling prophecy.

One narrative suggests that the global financial crisis of 2007/8 was partly caused by 'monetary excesses' in the pre-crisis years, i.e. policy rates far below the rates implied by the Taylor rule benchmark, see Taylor (2009). One possible reason for this deviation, put forward by Hofmann and Bogdanova (2012), is an asymmetric policy response to the financial cycle: while financial downturns are met with a monetary loosening, financial market booms trigger a tightening of monetary policy only if price stability is threatened. Through the lens of our model, an accommodative monetary policy stance caused by financial stability concerns represents an incidence of financial dominance (lower left quadrant in Figure 2). Without an effective macroprudential policy in place, a normalization of monetary policy and higher policy rates would entail the risk of Fisherian debt disinflation, undermining the stability of the system (upper left region in Figure 2).

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 $\tau_\Pi \neq 0$, $\tau_b \geq 0$, and $\zeta_b = 0$. We proceed in the same way as above and analyze determinacy and the transmission mechanism in this variant of the model. We let the inflation coefficient τ_Π range from -2 to 2 as above, and we let the 'leaning against the wind' coefficent τ_b range from 0 to 2.

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 the 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 stable equilibrium. This result is due to the fact that there is no cyclical instrument other than inflation that can stabilize lending. Therefore, the Fisher debt-disinflation 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 stabilizing 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, consider the dynamic equation which is crucial for equilibrium determinacy: the banker's net worth equation:

$$n_{t+1}^B = (1 - \chi^B + \iota) \frac{R_{t+1}^B}{\Pi_{t+1}} n_t^B. \tag{35}$$

The stability of this process depends on the properties of the terms in front of n_t^B. First, it depends on the survival rate of the bankers, $1 - \chi^B$ and on ι, the proportion of the exiting banker's transfer used as startup funds for new bankers. Second, it depends on the real effective return on equity, R_{t+1}^B / Π_{t+1}. The latter is, firstly, a positive function of the capital requirement ϕ_t. When the bank is required to finance a larger fraction of loans using equity, this raises the return on equity per unit held, given that the amount of banker net worth is limited. Second, the effective real equity return is a negative function of inflation. Given nominal loan contracts, a high rate of inflation diminishes the entrepreneur's project return expressed in consumption units, which in turn lowers the bank's payoff on loans, and ultimately the return to equity holders. Thus, ceteris paribus, the real return on equity is expected to be increasing in the macroprudential policy coefficient ζ_b and decreasing in the inflation coefficient τ_Π. This explains the explosive region in the top left corner of Figure 2 and in the upper half of Figure 3.

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.

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 then to 0.25, and carrying out the same determinacy analysis as above. The result of this exercise is shown in Figure 4 and Figure 5. We can see from the figures 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. The intuition for this finding is that the equity return is positively related to both the bank capital requirement ϕ and the macroprudential coefficient ζ_b. To keep the 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 (see Basel Committee on Banking Supervision, 2010a and Basel Committee on Banking Supervision, 2010b) stipulates a (constant) capital ratio of 8%.[11] 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. Finally, Clerc et al. (2015) show - in a more elaborate model with mortgage lending and household defaults, and less than perfect deposit insurance - that the welfare-optimizing steady state capital ratio is

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

Figure 4: Determinacy Analysis: 10% Bank Capital Requirement

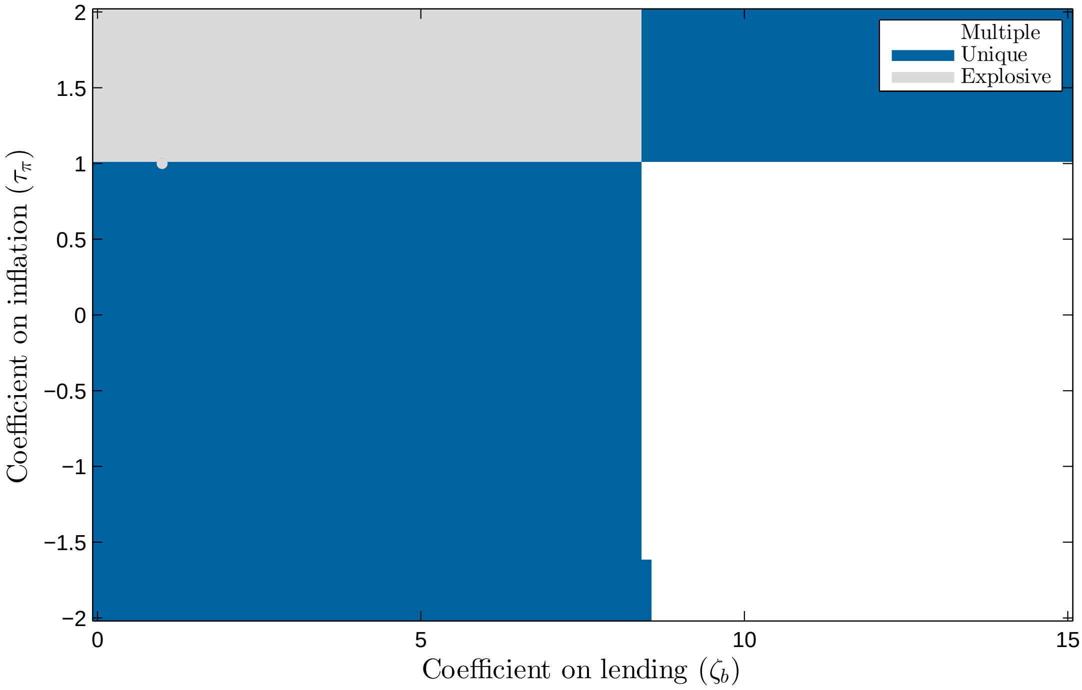
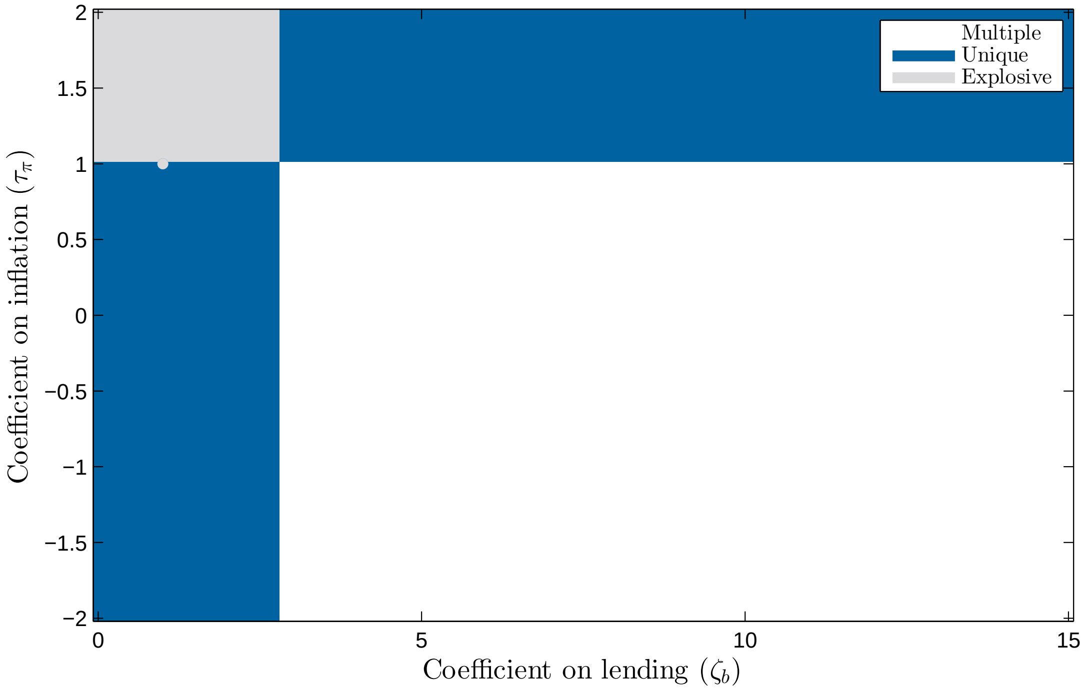


Figure 5: Determinacy Analysis: 25% Bank Capital Requirement



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 lending. The upper figure shows the results for the benchmark calibration where $\varphi = 0.10$. The lower figure shows the results for an even higher steady state capital requirement, $\varphi = 0.25$.

positive.

Second, we note that altering the steady state inflation rate, bank and firm default rates, the price adjustment cost, or firm leverage does not change the CCyB threshold value.

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 used 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,

$$V_0^r = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_t^r - \varphi \frac{(l_t^r)^{1+\eta}}{1+\eta} \right\}. \tag{36}$$

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, where in (36) we replace the superscript 'r' with an 'a'. In general, an alternative policy regime is not welfare-optimal. 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 $\lambda \in (0,1)$ such that

$$V_0^a = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln\left[(1-\lambda)\, c_t^r\right] - \varphi \frac{(l_t^r)^{1+\eta}}{1+\eta} \right\}. \tag{37}$$

We can rewrite the above expression in terms of the reference policy utility level, i.e. $V_0^a = \ln(1-\lambda)/(1-\beta) + V_0^r$. Solving this expression for λ, we obtain

$$\lambda = 1 - \exp\left[(1-\beta)(V_0^a - V_0^r)\right]. \tag{38}$$

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

As above, we consider two policy regimes, a 'countercyclical capital buffer' 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 characterize 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: *The optimal countercyclical capital buffer (CCyB) policy is characterized by $\tau_b = 0$ and a pair of policy coefficients τ_Π and ζ_b in the policy rules (32) and (34), which maximize welfare in the economy described by the equilibrium conditions summarized in Table 1.*

Figure 6 shows the welfare loss, relative to the optimized rule, associated with different pairs of policy coefficients τ_Π and ζ_b, where $\tau_\Pi \in [-2, 2]$ and $\zeta_b \in [0, 15]$. More precisely, we plot the welfare loss in percentage terms, i.e. $100{\cdot}\lambda$. The figure shows that a combination of an active macroprudential policy and a passive monetary policy rule is optimal. The corresponding policy coefficients are shown as the small blue area in the lower left region; the optimal macroprudential rule coefficient ζ_b is positive but rather low, while the optimal inflation coefficient in the interest rate rule, τ_Π, is highly negative. The latter result mirrors the finding in Kumhof et al. (2010) in a model with fiscal dominance. Notice, however, that the welfare gain from setting a negative Taylor coefficient, relative to e.g. $\tau_\Pi = 0$, is small. In addition, large parts of the lower left region in the figure, which is associated with low values of both τ_Π and ζ_b, result in the same welfare loss as do combinations of coefficients in the upper right quadrant. We cannot therefore argue that a passive monetary - active macroprudential policy stance is preferable in general.

Definition: *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 (32), which maximize welfare in the economy described by the equilibrium conditions summarized in Table 1.*

Figure 7 shows the percentage welfare loss relative to the optimized rule, $100{\cdot}\lambda$, associated with different pairs of policy coefficients τ_Π and τ_b, where $\tau_\Pi \in [-2, 2]$ and $\tau_b \in [0, 2]$. As the figure shows, for a given Taylor coefficient, 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. Here, too, we find that the optimal coefficient on inflation is negative, while the optimal coefficient on lending is zero. This finding clearly indicates that leaning against the wind, in the form of a positive coefficient on lending 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 take 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 (2014), who argues that leaning against the wind can have perverse effects

Figure 6: Welfare Analysis: Countercyclical Capital Buffer

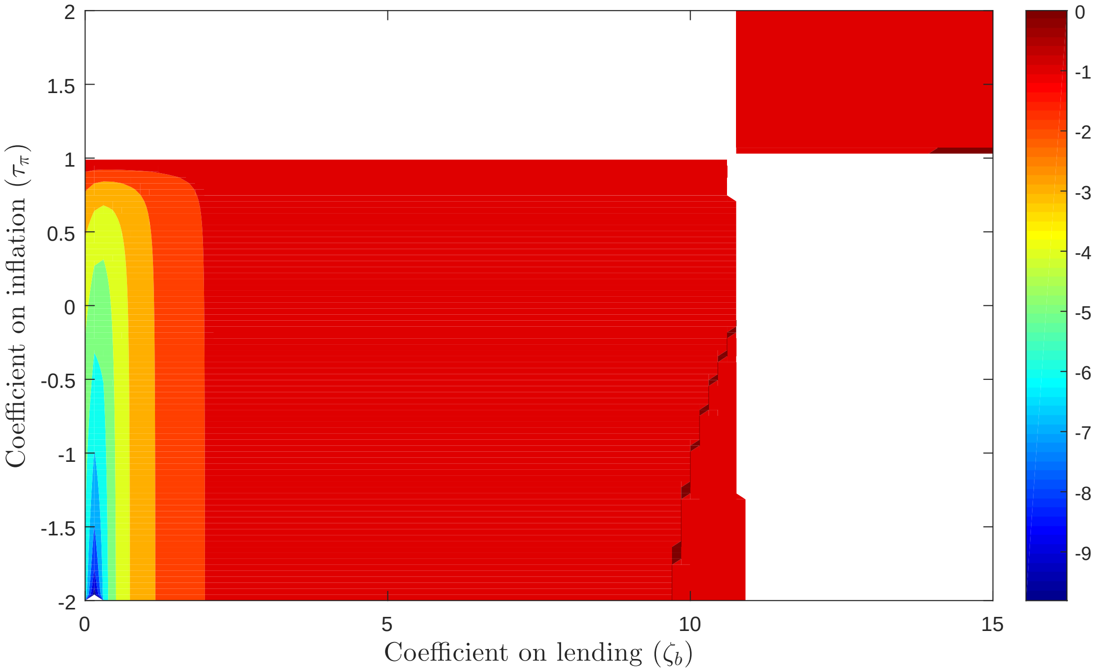
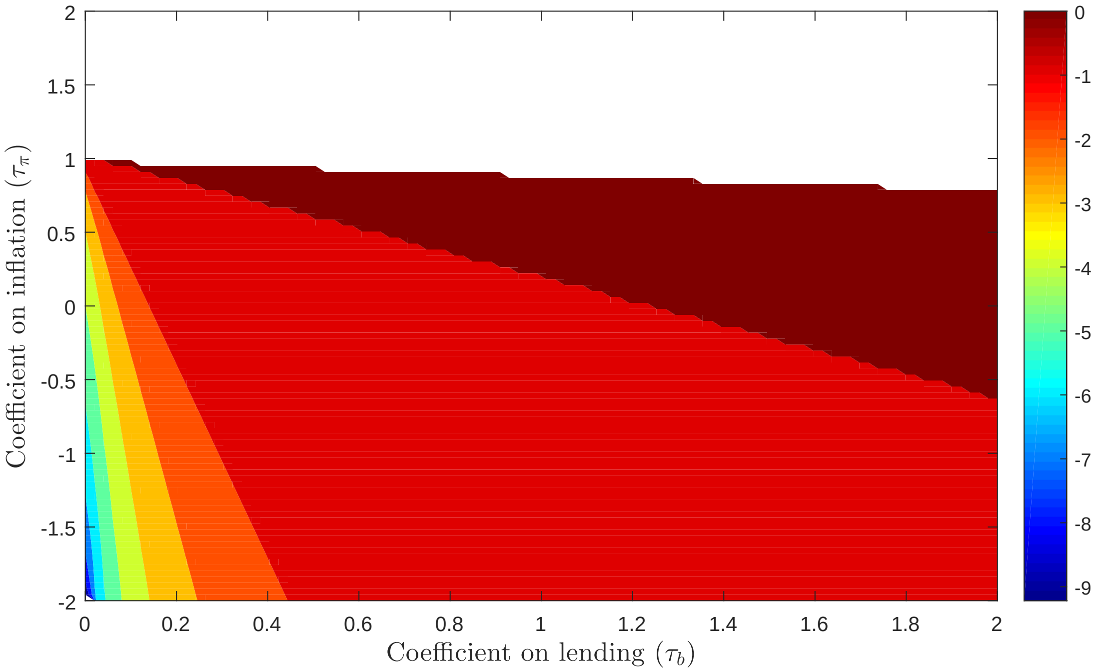


Figure 7: Welfare Analysis: Leaning against the Wind



Note: These figures show the welfare loss relative to the optimized policy rule, $100{\cdot}\lambda$, as a function of the respective response coefficients on inflation and lending. 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.

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.

The two policy regimes, CCyB and LATW, give rise to the same welfare level along the vertical axis where $\zeta_b = \tau_b = 0$. As mentioned above, setting τ_b to a positive value reduces welfare. Then, given that the optimal pair of coefficients in the CCyB model involves a non-zero value for ζ_b and therefore does not lie on the vertical axis, we can conclude that, overall, the CCyB model dominates the LATW model in welfare terms.

5 Conclusion

We consider a monetary business cycle model with elements of financial frictions as in Bernanke et al. (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 as well as aggregate risk, there exists a costly state verification problem whereby banks incur monitoring costs when an entrepreneur declares default. In Bernanke et al. (1999), the financial intermediary's balance sheet plays no role. This is because idiosyncratic risk is perfectly hedged and 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. In addition, banks are hit by idiosyncratic shocks, such that some of them default. A bank resolution authority monitors failed banks and provides full deposit insurance by levying lump-sum taxes on households. By regulation, banks are required to finance a minimum fraction of their assets in terms of equity capital.

Financial dominance prevails when macroprudential policy is ineffective in stabilizing 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.

One way to achieve determinacy 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 stabilizing effect and re-establishes the Taylor Principle, such that the central bank can focus on its primary objective, which is to safeguard price stability.

A second possibility is the combination of an active macroprudential and a passive monetary policy. 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 faces a tradeoff between financial stability and price stability, which it resolves by allowing inflation to rise in order to reduce the real value of private sector debt.

Our analysis shows that the parameter region characterized by financial dominance can be shrunk by increasing the steady state capital requirement. The optimal countercyclical capital buffer (CCyB) coefficient is positive but rather small. While the optimal Taylor coefficient is negative, only a limited welfare loss results from setting it to a positive value instead. For greater CCyB coefficients, the welfare levels under the two regimes, active monetary and passive macroprudential policy and vice versa, are comparable. We might therefore conclude that getting the steady state capital requirement right is rather more important than fine-tuning the CCyB coefficient for a given steady state policy.

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 suboptimal relative to an optimized monetary policy rule combined with a capital requirement rule that responds to cyclical fluctuations in lending. The latter result is consistent with the Tinbergen Principle according to which each individual policy target requires a separate instrument.

References

Angeloni, I. and E. Faia (2013). Capital regulation and monetary policy with fragile banks. *Journal of Monetary Economics 60*(3), 311–324.

Basel Committee on Banking Supervision (2010a). Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems (revised June 2011).

Basel Committee on Banking Supervision (2010b). Guidance for National Authorities Operating the Countercyclical Capital Buffer.

Batini, N., G. Melina, and S. Villa (2016, May). Fiscal Buffers, Private Debt, and Stagnation; The Good, the Bad and the Ugly. IMF Working Papers 16/104, International Monetary Fund.

Benes, J. and M. Kumhof (2015). Risky bank lending and countercyclical capital buffers. *Journal of Economic Dynamics and Control 58*(C), 58–80.

Bernanke, B. S. and M. Gertler (2001, May). Should Central Banks Respond to Movements in Asset Prices? *American Economic Review 91*(2), 253–257.

Bernanke, B. S., M. Gertler, and S. Gilchrist (1999). The financial accelerator in a quantitative business cycle framework. In J. B. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*, Volume 1 of *Handbook of Macroeconomics*, Chapter 21, pp. 1341–1393. Elsevier.

Brunnermeier, M. K. and Y. Sannikov (2016, August). The I Theory of Money. CEPR Discussion Papers 11444, C.E.P.R. Discussion Papers.

Cantore, C., P. Levine, and G. Melina (2014, July). A Fiscal Stimulus and Jobless Recovery. *Scandinavian Journal of Economics 116*(3), 669–701.

Carlstrom, C. T., T. S. Fuerst, A. Ortiz, and M. Paustian (2014). Estimating contract indexation in a Financial Accelerator Model. *Journal of Economic Dynamics and Control 46*(C), 130–149.

Carlstrom, C. T., T. S. Fuerst, and M. Paustian (2016, January). Optimal Contracts, Aggregate Risk, and the Financial Accelerator. *American Economic Journal: Macroeconomics 8*(1), 119–147.

Cecchetti, S., I. C. for Monetary, B. Studies, H. Genberg, J. Lipsky, and S. Wadhwani (2000). *Asset Prices and Central Bank Policy.* Geneva reports on the world economy. International Center for Monetary and Banking Studies.

Chari, V. V., L. J. Christiano, and P. J. Kehoe (1991, August). Optimal Fiscal and Monetary Policy: Some Recent Results. *Journal of Money, Credit and Banking 23*(3), 519–539.

Christensen, I. and A. Dib (2008, January). The Financial Accelerator in an Estimated New Keynesian Model. *Review of Economic Dynamics 11*(1), 155–178.

Christensen, I., C. Meh, and K. Moran (2011). Bank Leverage Regulation and Macroeconomic Dynamics. Staff Working Papers 11-32, Bank of Canada.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005, February). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy 113*(1), 1–45.

Christiano, L. J., R. Motto, and M. Rostagno (2014, January). Risk Shocks. *American Economic Review 104*(1), 27–65.

Clerc, L., A. Derviz, C. Mendicino, S. Moyen, K. Nikolov, L. Stracca, J. Suarez, and A. P. Vardoulakis (2015, June). Capital Regulation in a Macroeconomic Model with Three Layers of Default. *International Journal of Central Banking 11*(3), 9–63.

Collard, F., H. Dellas, B. Diba, and O. Loisel (2017, January). Optimal Monetary and Prudential Policies. *American Economic Journal: Macroeconomics 9*(1), 40–87.

De Paoli, B. and M. Paustian (2017). Coordinating monetary and macroprudential policies. *Journal of Money, Credit and Banking 49*(2-3), 319–349.

de Walque, G., O. Pierrard, and A. Rouabah (2010, December). Financial (In)Stability, Supervision and Liquidity Injections: A Dynamic General Equilibrium Approach. *Economic Journal 120*(549), 1234–1261.

Fisher, I. (1933). The debt-deflation theory of great depressions. *Econometrica 1*(4), 337–357.

Gelain, P. and P. Ilbas (2017). Monetary and macroprudential policies in an estimated model with financial intermediation. *Journal of Economic Dynamics and Control 78*(C), 164–189.

Gertler, M. and P. Karadi (2011, January). A model of unconventional monetary policy. *Journal of Monetary Economics 58*(1), 17–34.

Gertler, M. and N. Kiyotaki (2010). Financial Intermediation and Credit Policy in Business Cycle Analysis. In B. M. Friedman and M. Woodford (Eds.), *Handbook of Monetary Economics*, Volume 3 of *Handbook of Monetary Economics*, Chapter 11, pp. 547–599. Elsevier.

Hannoun, H. (2012, 2). Monetary Policy in the Crisis: Testing the Limits of Monetary Policy. Speech at the 47th SEACEN Governors' Conference, Seoul, Korea, 13-14 February 2012.

Hofmann, B. and B. Bogdanova (2012, September). Taylor rules and monetary policy: a global "Great Deviation"? *BIS Quarterly Review*.

Kumhof, M., R. Nunes, and I. Yakadina (2010, February). Simple Monetary Rules under Fiscal Dominance. *Journal of Money, Credit and Banking 42*(1), 63–92.

Kupiec, P. H. and C. D. Ramirez (2013). Bank failures and the cost of systemic risk: Evidence from 1900 to 1930. *Journal of Financial Intermediation 22*(3), 285–307.

Laeven, L. and F. Valencia (2010, June). Resolution of Banking Crises; The Good, the Bad, and the Ugly. IMF Working Papers 10/146, International Monetary Fund.

Lambertini, L., C. Mendicino, and M. Teresa Punzi (2013). Leaning against boom–bust cycles in credit and housing prices. *Journal of Economic Dynamics and Control 37*(8), 1500–1522.

Leeper, E. M. (1991, February). Equilibria under 'active' and 'passive' monetary and fiscal policies. *Journal of Monetary Economics 27*(1), 129–147.

Leeper, E. M. and J. M. Nason (2015, July). Bringing Financial Stability into Monetary Policy. Working Paper Series 305, Sveriges Riksbank (Central Bank of Sweden).

Lewis, V. and S. Villa (2016, October). The Interdependence of Monetary and Macroprudential Policy under the Zero Lower Bound. Working Paper Research 310, National Bank of Belgium.

Mendicino, C., K. Nikolov, J. Suarez, and D. Supera (forthcoming). Optimal Dynamic Capital Requirements. *Journal of Money Credit and Banking*.

Morgan, D. P. (2002, September). Rating Banks: Risk and Uncertainty in an Opaque Industry. *American Economic Review 92*(4), 874–888.

Schmitt-Grohé, S. and M. Uribe (2007, September). Optimal simple and implementable monetary and fiscal rules. *Journal of Monetary Economics 54*(6), 1702–1725.

Smets, F. (2014, June). Financial Stability and Monetary Policy: How Closely Interlinked? *International Journal of Central Banking 10*(2), 263–300.

Smets, F. and R. Wouters (2007, June). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *American Economic Review 97*(3), 586–606.

Svensson, L. E. (2014, June). Inflation Targeting and “Leaning against the Wind”. *International Journal of Central Banking 10*(2), 103–114.

Taylor, J. B. (1993, December). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy 39*(1), 195–214.

Taylor, J. B. (2009, January). The Financial Crisis and the Policy Responses: An Empirical Analysis of What Went Wrong. NBER Working Papers 14631, National Bureau of Economic Research, Inc.

Weidmann, J. (2013, 11). What can Monetary Policy do? Speech at the 2013 Süddeutsche Zeitung conference for business leaders, 21 November.2013.

Woodford, M. (2001, May). The Taylor Rule and Optimal Monetary Policy. *American Economic Review 91*(2), 232–237.

Zhang, L. (2009). Bank capital regulation, the lending channel and business cycles. Discussion Paper Series 1: Economic Studies 2009, Deutsche Bundesbank.