Essays on the Financial Crisis and Macroprudential Regulation

D I S S E R T A T I O N
of the University of St. Gallen
School of Management,
Economics, Law, Social Sciences
and International Affairs
to obtain the title of
Doctor of Philosophy in Economics and Finance

submitted by
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from
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Dissertation no. 5034

Difo-Druck, Untersiemau 2020

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St. Gallen, June 15, 2020

The President:

Prof. Dr. Bernhard Ehrenzeller

Acknowledgments

Despite a popular image of researchers isolated in ivory towers, writing a dissertation is not a lonely endeavour and not only the achievement of one person alone. I would not have been able to complete this dissertation without the help and support several people have granted during the years. Therefore, I would like to take this opportunity to express my gratitude.

First of all, I would like to thank my supervisor, Christian Keuschnigg, for giving me the opportunity to write my dissertation and for his support. He encouraged me to participate in a new, challenging and highly interesting project and I have benefited a lot from his experience, broad knowledge and the many discussions we had. In addition, I am very grateful to Jesus Crespo Cuaresma, Guido Cozzi, and Reto Föllmi for their valuable feedback on my dissertation as part of the thesis committee.

I cannot express sufficient gratitude to my colleagues at the FGN for making the work at the institute so enjoyable. I am particularly grateful to my co-authors Michael Kogler and Hannah Winterberg for their constant support, encouragements and the many discussions of Matlab codes relating to Global1 to infinity. Special thanks to Lisa Essbaumer and Nicolas Eschenbaum for the continued moral support, helpful advice, and many pleasant breaks and dinners. You have helped my take my mind off work in case of frustration and have encouraged me at exactly the right moments. I also highly appreciate the indispensable support by Mirela Keuschnigg regarding employment and administrative matters.

Special thanks also to my fellow PhD students at the University of St. Gallen, particularly to Irene Fensore: Your tireless support has stretched over all types of subjects, from research, to workouts, to lunch preparations for a new mother, to babysitting. I would also like to thank my friends in Germany, particularly my sister Anne, for always being there for me.

Above all, I am most indebted to my parents, Sabine Berg-Kirschner and Martin Kirschner, for supporting me emotionally and financially throughout my academic career: No matter where I wanted to go or which subjects I wanted to study, you always had my back with unconditional love, support and advice. I am forever grateful for that. Last but not least, my heartfelt thanks goes to my partner, Patric Schmaus, for being a rockstar of love and patience and to our son, Emil, for bringing so much sunshine into our world. You have given me so much strength through this entire journey and I could not have done this without you.

St. Gallen, August 2020 Linda Kirschner

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Summary

The financial crisis was, at its core, a banking crisis, which affected the real economy through a rapid reduction in credit supply. This dissertation combines three essays on policy changes after the financial crisis. The first two chapters focus on regulatory rules proposed to avoid future credit crunches and the resulting contractionary effects on the real economy. In the first chapter, I introduce two different proposals for countercyclical capital buffers and compare their effectiveness in reducing macroeconomic fluctuations. The Basel III capital buffer is attuned to early warning signals of systemic risk, while dynamic loan loss provisions are set aside to cover expected losses. I show that the systemic risk buffer is more effective in reducing macroeconomic volatility in times of excessive lending booms and crunches. The second paper examines the effectiveness of the Basel III buffer more closely by considering different shocks to the economy and the banking sector. At the heart of the recent banking crisis were bank's difficulties to receive both equity and debt funding. I show that the macroeconomic implications of financial shocks are particularly serious if banks have only restricted access to deposits. These disturbances on the supply side of credit have more distressing consequences than comparable shocks to the credit demand side. Interestingly, I find that the Basel III buffer is most effective in dealing with these supply side shocks. The third chapter analyses the Eurozone crisis as a triple crisis of fiscal solvency, banking sector instability, and stagnant growth. Given negative feedback loops, and starting from bad initial conditions, Italy remains vulnerable to adverse economic shocks originating at home and abroad. Furthermore, we contrast the two cases of continued membership or exit from the Eurozone and find exiting will severely delay Italy's economic recovery at least in the long run.

Zusammenfassung

Im Kern war die Finanzkrise eine Bankenkrise, die die Realwirtschaft durch eine rasche Reduzierung des Kreditangebots traf. Diese Dissertation kombiniert drei Essays über politische Veränderungen nach der Finanzkrise. Die ersten beiden Kapitel konzentrieren sich auf regulatorische Vorschriften, die zur Vermeidung künftiger Kreditklemmen und den damit verbundenen negativen Auswirkungen auf die Realwirtschaft vorgeschlagen werden. Im ersten Kapitel stelle ich zwei verschiedene Vorschläge für antizyklische Kapitalpuffer vor und vergleiche ihre Wirksamkeit zur Reduzierung makroökonomischer Schwankungen. Der Eigenkapitalpuffer nach Basel III ist auf Frühwarnsignale für systemische Risiken abgestimmt, während dynamische Verlustrückstellungen zur Abdeckung erwarteter Verluste gebildet werden. Der systemische Risikopuffer scheint effektiver, um die makroökonomische Volatilität in Zeiten übermäßiger Kreditvergabe und -klemmen zu reduzieren. Das zweite Papier untersucht die Wirksamkeit des Basel III-Puffers genauer, indem es verschiedene Schocks für die Wirtschaft und den Bankensektor berücksichtigt. Im Mittelpunkt der jüngsten Bankenkrise standen die Schwierigkeiten der Bank, sowohl Eigen- als auch Fremdkapital zu erhalten. Ich zeige, dass die makroökonomischen Auswirkungen von finanziellen Schocks besonders ernst sind, wenn die Banken nur eingeschränkten Zugang zu Einlagen haben. Diese Störungen auf der Kreditangebotsseite haben schwerwiegendere Folgen als vergleichbare Schocks auf der Kreditnachfrageseite. Die Ergebnisse zeigen, dass der Basel-III-Puffer bei der Bewältigung dieser angebotsseitigen Schocks effektiv ist. Das dritte Kapitel analysiert die Krise in der Eurozone als eine dreifache Krise der Staatssolvenz, der Instabilität des Bankensektors und des stagnierenden Wachstums. Angesichts negativer Rückkopplungseffekte und ausgehend von schlechten Startbedingungen bleibt Italien anfällig für nachteilige wirtschaftliche Schocks, die ihren Ursprung im In- und Ausland haben. Darüber hinaus stellen wir die beiden Fälle einer fortgesetzten Mitgliedschaft oder eines Austritts aus der Eurozone gegenüber und stellen fest, dass ein Austritt Italiens Erholung mindestens in der langen Frist erheblich behindern wird.

Introduction

The financial crisis starting in the year 2007 has proven to exhibit long-lasting consequences. At its core, the crisis was a banking crisis, which affected the real economy mainly through the ability of the private sector to receive credit for investment and consumption decisions. Sudden dry-ups in bank liquidity revealed the vulnerability of the financial sector towards systemic risk. While insolvency risk of individual institutions might have been small, increasing uncertainty in the banking sector led to rising illiquidity and hence forced banks into default or required public bailouts. One crucial source of liquidity has been the interbank market, where banks were able to receive short-term interbank funding with relatively low credit risk. As uncertainty regarding bank defaults increased, risk premia for counterparty risk increased significantly, leading to sudden jumps in interbank loan spreads. It became increasingly difficult for banks to acquire debt funding and to quickly roll over short-term debt. This funding crisis had vast spillover effects to the economy as a whole when funding constrained banks reduced their credit supply. The result was a harsh credit crunch, a rising number of business failures, private defaults and a prolonged recession.

The Euro area was hit particularly hard as large imbalances had accumulated within the currency area prior to the crisis. Countries in the periphery of the Eurozone like Italy had acquired large public debt levels in comparison to their GDP. A substantial portion of this debt had been held by domestic banks creating strong links between sovereign debt and the banking sector. Just like the sovereign, banks were also highly leveraged in Italy and hence vulnerable to loan losses. Sluggish growth led to rising non-performing loan rates in Italy when small businesses started to default such that the highly levered banking sector was unable to absorb the sudden losses in the private sector. Several regional banks were deemed too important to fail, requiring the government to provide a public bailout. As a consequence, public debt increased substantially raising uncertainty in capital markets regarding potential government defaults. This, in turn, led to an increase in bank's portfolio risk and hence introduced a doom loop of ever increasing uncertainty regarding bank and sovereign defaults with spillovers to the real economy that reinforced the recession.

Due to the dire consequences of the financial crisis and the contagious effects to the overall economy, the reform of the banking sector has been pivotal in political discussion. The crisis has demonstrated that bank regulation focusing on preserving the financial stability of individual financial institutions was insufficient to prevent a systemic crisis. Strict capital requirements had actually enhanced the procyclicality of credit and contributed to the severe credit crunch. Researchers and policymakers thus agreed on the realignment of regulation towards a so-called 'macroprudential approach', regulation that focuses on the stability of the banking sector as a whole and the limitation of systemic risk. The central regulatory framework henceforth introduced to improve the stability of the banking sector has been called Basel III, as it supplements the preceeding Basel II rules. Among enhanced capital and liquidity requirements, it includes rules for a countercyclical buffer that is supposed to limit the procyclicality of lending and the accumulation of systemic risk. Besides this countercyclical buffer, alternative rules have been discussed to reduce procyclicality. Spain had introduced dynamic loan loss provisions prior to the crisis in order to cover expected losses over the business cycle. As the crisis in Spain unfolded with non-performing loan rates increasing by 6 percentage points above the expected average, a lending crisis could not be avoided, however.

This dissertation is a collection of research essays covering different policy changes after the financial crisis. The first chapter (*Preventing crises using countercyclical capital buffers*) addresses two specific proposals to avoid the repetition of such a serious credit crunch by improving financial stability through countercyclical capital regulation. The countercyclical capital buffer proposed in Basel III and the dynamic loan loss provisions introduced in Spain are both intended to limit bank's incentive to lend excessively during boom periods and to provide relief in a bust. While dynamic provisions are specifically required to cover expected loan losses over the credit cycle, the purpose of the Basel III buffer is more broadly defined in limiting systemic risk. As credit losses increased well beyond expected levels during the crisis, a countercyclical buffer according to the Basel rule would have been more effective in limiting macroeconomic fluctuations, particularly with respect to the credit crunch that paralysed the economy. In order to fully avoid the recession, a massive buffer would have been required, however.
The second chapter (*Deposit funding problems and stabilising effects of countercyclical capital regulation*) examines the effectiveness of the Basel III capital buffer more closely. In addition to trouble replacing loss absorbing equity, banks faced increasing difficulty to receive debt funding as the financial crisis unfolded, which amounted to constraints on the credit-supply side. One of the main drivers of the recession was the credit crunch on the interbank market. Increasing uncertainty about bank's solvency led to increases in counterparty risk premia and rapid dry-

up of liquidity in short-term lending. Banks with limited access to alternative debt funding sources like deposits were more affected than others. Numerical simulation of different financial shocks show that disturbances to the credit-supply side have more severe consequences for the economy as a whole than shocks to the credit-demand side. The Basel countercyclical buffer is able to effectively reduce macroeconomic volatility subsequent to these credit-supply side shocks and hence provides a valuable tool in avoiding future credit crunches. It lacks, however, the potential to substantially reduce fluctuations after shocks to non-financial disturbances and can even increase volatility in case of shocks to the credit-demand side. A countercyclical capital buffer is thus a necessary tool to enhance the stability of the financial sector, but it is not sufficient.

The third and last chapter (*Italy and the Eurozone Trilemma*) examines the situation in the periphery of the Eurozone as a triple crisis of (i) a sovereign debt crisis, (ii) a banking crisis, and (iii) a growth and competitiveness crisis. Taking Italy as an example, we analyse how high leverage and debt overhang in both banking sector and government introduced vicious cycles that interacted and reinforced each other after substantial credit losses and public bank bailouts. Larger public deficits, in turn, weakened economic growth perspectives and higher private defaults, introducing their own doom loops between public debt and growth as well as rising non-performing loan rates and banks. While being part of a currency union, Italy's ability to address these problems remains limited. If Italy reintroduced the Lira, it could regain competitiveness by currency devaluation and could taylor monetary policy to its specific needs. Such an exit of the Euro area would come at the risk of massive capital flight, however. We model the accumulation of imbalances in the Euro area in one comprehensive, open-economy dynamic stochastic general equilibrium model and illustrate the main drivers of the vicious cycles in the Italian crisis. Furthermore, we contrast the two cases of continued membership or exit from the Eurozone. We find that Italy's problems do not disappear by exit.We find that exiting might dampen the short run effects of a recession at the expense of prolonged recovery. Capital market reactions, however, are likely to lead to an escalation in the exit scenario that eliminates even the short term advantages and lead into a severe, long term recession.

Chapter 1

Preventing crises using countercyclical capital buffers

Linda Kirschner[1]

In the wake of the recent financial crisis, regulation has shown to enforce credit cycle fluctuations in an undesired way. As a consequence, it has been suggested that macroprudential regulation should be designed to act countercyclically. I study the potential of two different countercyclical regulatory regimes to mitigate the procyclicality of lending and hence promote macroeconomic stability. In a dynamic stochastic general equilibrium model, I analyse time-varying capital requirements and dynamic provisioning. While both instruments serve to reduce cyclicality, their purpose and workings differ such that their calibration is not necessarily straight forward for regulators. I demonstrate the conditions that render the two instruments equivalent. Subsequently, I calibrate the instruments in line with current European regulatory proposals. The simulations show that a countercyclical buffer as suggested by Basel III is more effective in reducing macroeconomic volatility than the dynamic loan loss provisions introduced by the Bank of Spain. The Spanish proposal is vulnerable if latent risk over the business cycle is underestimated, while the Basel III buffer is more effective in times of excessive lending booms and crunches. In order to mitigate the serious macroeconomic consequences of a credit crisis similar to the recent one, however, the Basel III capital buffer would have to be substantial.
JEL Classification: E320, G180

[1] I thank Christian Keuschnigg, Erwan Morellec, seminar participants at University of St.Gallen and the participants of the SFI Doctoral Workshop in Lausanne for helpful discussion and comments.

1.1 Introduction

Banking crises are a recurring phenomenon, particularly in the aftermath of boom periods with extensive credit growth.[2] Figure 1 gives an indication of credit and GDP growth in Europe in recent years indicating that credit cycles typically lag business cycles by approximately one year. The reason for this delayed reaction of credit to GDP lies partly in bank regulation. As bank equity serves to cover unexpected loan losses, regulation aims to impose capital requirements that are sufficiently high to stabilise banks during downturns, i.e., in times of increased loan losses.[3] However, if the macroeconomy was going into recession and bank's profits were hit by a negative shock, the capital position of the bank would be reduced. In order to satisfy its capital requirements, the bank could be inclined to avoid high leverage by reducing credit supply exactly at a time when lending would be required to stimulate the economy and thus worsening the situation for borrowers in the real economy through a credit crunch. Capital requirements thus have the potential to introduce additional procyclicality into credit markets.[4]

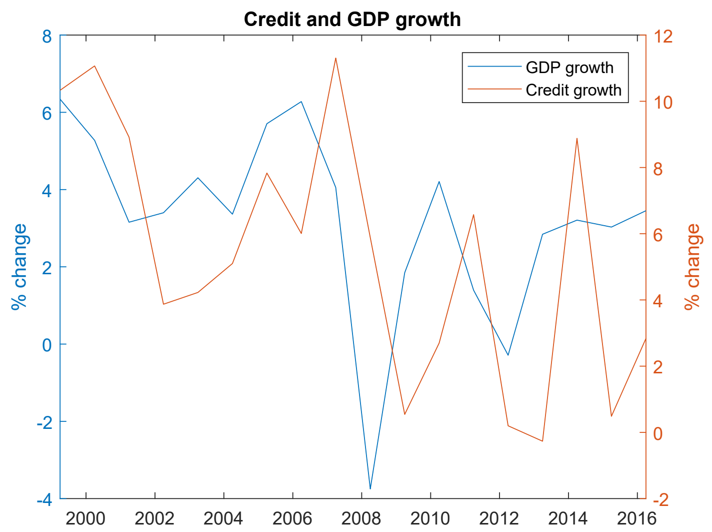

Figure 1: Credit and Gdp growth in Europe 2000-2016

This procyclicality sparked a vivid discussion among researchers and policymakers about the design and implementation of macroprudential instruments that would serve to mitigate the

[2]See Demirgüç-Kunt and Detragiache (19); Agénor and Montiel (2)

[3]In this paper, I do not assess the optimality of regulation in general. Regulation is assumed to exist a priori. This assumption seems justified as a report by the Basel Committee estimates that an increase in banking sector's committed equity ratio from 7% to 8% reduces the risk of a banking crisis by 1 percentage point which produces an expected annual GDP higher by 0.2%-0.6% (Hannoun (27)). In addition, there is theoretical rationale for the adoption of (risk-weighted) capital requirement approach: (i) Reduction of risk taking incentive for bank managers (Rochet (41)), (ii) insufficient monitoring (Dewatripont and Tirole (20)), and (iii) reduction of externalities from bank failure (Kashyap and Stein (36)).

[4]Angelini et al. (5)

procyclicality of credit supply while keeping the bank stable at the same time. In this paper, I compare the effectiveness of two countercyclical regulatory instruments in stabilising business and credit cycle fluctuation. One regulatory instrument that has received a lot of attention during the discussions is a countercyclical capital requirement rule. It requires banks to hold a higher fraction of equity in proportion to their assets during good times while offering some relief during bad times by requiring a smaller fraction of equity. The aim is to limit excessive credit growth in boom periods while avoiding the risk of a credit crunch in times of distress.
Another instrument that has received serious consideration as a countercyclical regulatory rule is a dynamic loan loss provision. Usually, the intention behind loan-loss provisions is to cover expected losses.[5] *Dynamic* (i.e., countercyclical) provisions aim to build up loan loss reserves during good times when loan origination is generally high and loan losses are negligible. This buffer of loan loss reserves is built up according to long-run expected loan losses, i.e., loan losses over the business cycle. This way, dynamic provisioning aims to limit the probability of bank failure due to capital deficiency and hence avoid a credit crunch. Additionally, it provides an incentive for banks to be more careful when extending loans during boom times due to provisioning costs.

The necessity for countercyclical regulation has been well established in the aftermath of the recent financial crisis and new regulation has been put in place to mitigate the cyclicality of lending. However, the effectiveness of this regulation is still unclear since the new rules either have not been put to a serious reality test yet as in the case of Basel III or have indicated to be insufficient during the crisis. The introduction of dynamic provisioning in Spain in the year 2000 has shown that particularly the calibration of the regulatory rules is not trivial: making countercyclicality not strict enough might not reduce excessive lending sufficiently during the boom, leaving the banking sector still vulnerable to credit losses. To determine the effectiveness of the two instruments and to make them comparable, it is pivotal to understand the differences in their underlying intentions and designs.
Dynamic loan loss provisions are supposed to cover expected loan losses. They provide a forward-looking provisioning system that assesses credit risk exposure over the whole business cycle. In this paper, banks charge a loan interest rate depending on expected loan losses over the business cycle. Therefore, the size of the loan loss provision buffer crucially depends upon

[5] It has been a matter of some discussion, however, at which point in time a loss can actually be expected. Under recent accounting rules (IAS 39), specific loan loss provisions require banks to set aside provisions for *incurred* losses. This requires an expense (hence a lowering of profits) at the time the loan loss has already occurred (usually 90 days after the payment should have been made). Therefore, loan loss provisions have been an additional source of procyclicality. Following criticism of this incurred loss approach in the aftermath of the financial crisis, the International Accounting Standards Board (IASB) has been redesigning loan loss provisions to serve an expected loss approach instead. The amended version of IFRS 9 *Financial Instruments* (IASB (32)) has become effective in 2018. In this paper, I will focus on such an expected loss approach.

the expectation of *long-run credit risk*. If credit risk is underestimated, the buffer can turn out to be insufficient to cover the losses.
In contrast, countercyclical capital requirements are used to increase a bank's equity position for an unexpected loan loss. They are intended as a backward-looking instrument based on early warning signals for increasing *systemic risk*. The calibration of this buffer hence depends less on the expectation of the latent credit risk and instead on the estimation of systemic risk. The loan rate depends on the deviation in these early warning signals. In both cases, loan rates depend on the chosen regulatory setting, thus the Modigliani Miller theorem does not hold and the choice of regulation matters for real decisions.

I introduce both instruments into a stylised DSGE model with a banking sector. To evaluate the responses of the stylised model economy to business cycle fluctuations, I introduce a one standard deviation TFP shock that covers a significant portion of typical business cycle fluctuation. I use the volatility of output as a measure for macroeconomic stability and also provide results for the volatility of other macroeconomic variables like consumption and lending. First, I introduce the countercyclical capital buffer in accordance with Basel III and simulate the impulse responses to a similar TFP shock. The results suggest that the Basel III buffer reduces economic volatility by up to 14% and volatility of lending by 36% during such an economic contraction. Second, I introduce dynamic loan loss provisioning according to the Spanish regulatory framework, which only reduces output volatility marginally. This supports empirical findings documenting that the Spanish rule was insufficient to limit the credit boom prior to the crisis and subsequent credit crunch.[6] The results suggest that Basel buffer attuned to increases of systemic risk is more effective in limiting excessive lending booms and crunches. This implies that regulators who are concerned about limiting macroeconomic volatility should require capital buffers that accumulate more capital than suggested by the expected losses over the typical business cycle.
Additionally, I analyse the consequences of a sequence of loan losses similar to the losses Europe's banking system suffered during the recent crisis. The results show that even a Basel III buffer would have been insufficient to fully mitigate the resulting recession, suggesting that the buffer actually required would have to be substantially larger than the one proposed in the Basel III regulation.

[6] See Jiménez et al. (34)

1.2 Literature

Even before the financial crisis, some authors (e.g. Kashyap and Stein (36)) suggested that capital charges for banks should depend on the business cycle. After the financial crisis hit, this idea gained popularity. Repullo and Suarez (40) show that while banks hold voluntary capital buffers during boom periods, these buffers are insufficient to avoid a credit crunch in case of a recession. They conclude that cyclical capital requirements would serve to mitigate the credit contraction. The literature shows that a key issue for the implementation of time-varying capital requirements is the base for the time deviation. When demanding that capital requirements should be higher during good times, it is crucial how 'good times' are defined. Angelini et al. (5, 6) explore countercyclical capital requirements based on changes in the output gap within the Gerali et al. (24) framework using Bayesian estimation techniques. They find that a countercyclical capital requirement works well in mitigating credit supply's procyclicality if the capital is required to vary with respect to the business cycle, particularly with respect to output. Benes and Kumhof (10) argue that a capital requirement based on the deviation of the credit gap serves best to smooth business cycle fluctuations when compared to deviations from the credit-to-GDP gap or the output gap. They find that an instrument determined by the loan gap as well as loan-to-GDP gap directly stears bank balance sheets in the desired direction while the output gap could be influenced by parameters independent of the state of bank's balance sheet. The Basel III document proposes a cyclical requirement that varies with excessive lending. The rationale is that deviations in the credit-gap and the credit-to-GDP ratio serve as good indications for changes in systemic risk.[7] Repullo and Suarez (40) criticise parts of this approach. According to their research (and as also indicated by Figure 1) business cycles and credit cycles do not necessarily overlap, making the use of a strict rule depending only on the credit-to-GDP ratio problematic. They find that particularly in downturns when credit usually lags the business cycle, the credit-to-GDP ratio takes time to significantly deviate from its trend. In the worst case, capital requirements could be reduced when the economy is in a good state again and hence even add to the procyclicality.[8]

While the introduction and implementation of time-varying capital requirements has been subject to academic discussion for quite some time, there exist fewer theoretical discussions regarding dynamic loan loss provisions. One study by Wezel et al. (44) uses counterfactual simulations on the basis of historical data come to the conclusion that dynamic provisioning can help to mitigate loan losses in downturns. Bouvatier and Lepetit (12) provide an analytical contribu-

[7] Basel Committee on Banking Supervision (8)

[8] See Repullo and Suarez (40)

tion to the topic by implementing loan loss provisions in a partial equilibrium framework. They find that forward-looking provisions serve to address procyclicality without providing quantitative results. Agénor and Zilberman (3) integrate the Bouvatier & Lepetit model into a New Keynesian framework. Their research suggests that dynamic provisioning in combination with a credit-gap augmented Taylor rule is an effective way to address financial volatility. However, their model does not distinguish between debt and equity funding. Given that bank's capital regulation is a pivotal source of procyclicality, their results might overestimate the capability to mitigate amplification through the banking sector.
While there are only these few theoretical studies on the subject, a lot of empirical research has been done regarding the requirement by the Bank of Spain for dynamic provisions. Most prominently, Saurina (42) and Jiménez et al. (34) conduct empirical studies to assess the performance of the Spanish system. The studies agree on the effectiveness of loan loss provisioning in mitigating the downturn of credit supply during the crisis. Jiménez et al. conclude that the provisioning scheme worked effectively in allowing banks that were affected by the regulation (i.e. having one percentage point higher provisioning funds at the beginning of the crisis) to cut committed credit less (by 9 percentage points) during the financial crisis than banks without the additional capital buffer. In contrast, when analysing the preceding boom period, they do not find a significant effect of the regulation on credit supply, particularly with respect to the Spanish real estate sector. Saurina (42) notes that while the provisioning scheme was calibrated to include the worst recessions of the past decades, it was still too small to account for the losses accumulated in the recent crisis and it was not cut out to prevent the excessive credit boom in real estate. This underestimation illustrates a gap between theoretical research and macroprudential practice. While the necessity for macroprudential regulation becomes clearer, the question about the optimal design and calibration of such regulation is still not conclusively answered.

The lack of theoretical models on loan loss provisions is closely linked to a lack of DSGE models including default. While there are a number of papers addressing macroprudential regulation in a DSGE context, most of these models rule out default in equilibrium.[9] However, since macroprudential policy is mostly called for as a tool to mitigate systemic risk, default should not be neglected.[10] Furthermore, an introduction of dynamic loan loss provisions into the theoretical model requires the possibility of borrowers to default on their obligation towards banks. The contribution of the paper to the existing literature is hence twofold: First, it integrates

[9] See Iacoviello (29), Iacoviello and Neri (31) on credit market frictions in form of collateral constraints and (24), (21), Iacoviello (30) for stylized DSGE models incorporating banking sectors as well as Angelini et al. (5) on macroprudential regulation in DSGE models with stylized banking sector

[10] For the importance of default in macroeconomic models see Goodhart and Tsomocos (26) & Iacoviello (30)

a dynamic provisioning scheme into a DSGE framework where banks need to satisfy capital requirements and entrepreneurs can default on their obligations to banks. Second, it offers a basis to evaluate the performance of different countercyclical instruments in smoothing lending and output fluctuations.

1.3 Model

I develop a simple DSGE model which incorporates a banking sector and illustrates its interaction with the real economy. The model is sufficiently simple to allow for the identification of causes for the main effects but detailed enough to implement macroprudential instruments.
The model economy is similar to Iacoviello (30). It comprises a discrete time, closed economy with patient households, borrowing constrained entrepreneurs and a stylized banking sector with credit frictions. However, I deviate from Iacoviello in the description of the banking sector. Bankers do not optimise their own consumption but act on behalf of their owners, the private households. Therefore, I do not need to assume that banks and their owners face different stochastic discount factors and an evaluation of welfare gains can focus on households. The set up of the banking sector is similar to the wholesale branch in Gerali et al. (24). The banks operate under perfect competition by combining their net worth and deposits in order to issue loans. Bank's lending capacity is limited by a regulatory rule on capital adequacy and banks adjust their leverage position accordingly. In contrast to Gerali et al., however, banks do not enjoy monopolistic market power such that they can adjust interest rates. In this model, banks take interest rates as given in their optimisation.[11] In contrast to many other models, there is a positive probability that firms do not repay their obligations to banks in full and there exist a fraction of non-performing loans in equilibrium. The discount factor of the households (β_P) is assumed to be higher than entrepreneur's ($\beta_P > \beta_E$). This gives rise to positive financial flows in equilibrium as households deposit savings with the banks and entrepreneurs borrow from banks since they cannot directly borrow from households. Firms face a borrowing constraint tied to the value of their collateral holdings. The entrepreneurs produce consumption goods using capital and household's labour. Banks receive deposits and equity and use both to provide loans to firms. Scarce bank capital is owned by households and used to cover unexpected credit losses. As equity suffers losses, the bank is forced to adjust its leverage position by borrowing less from households and lending less to entrepreneurs. The bank's capital position hence affects the supply of credit and demand for deposits. Therefore, two main frictions coexist and

[11] The model lends itself easily to an examination of the influence of bank's market power in the effectiveness of regulation. This study would require an extension of the banking sector by the 'retail branch' described by Gerali et al.

interact in the model's equilibrium. Entrepreneurs are credit constrained by the value of their collateral while banks cannot borrow unlimited amounts from depositors, but must satisfy a regulatory capital constraint.

1.3.1 Households

Similar to Iacoviello (2015), households choose between leisure, consumption, and placing deposits into banks. The representative household maximises expected discounted utility

$$\max_{C_t^P, N_t, D_t} E_t \sum_{t=0}^{\infty} \beta_P^t \left[\log(C_t^P) + \tau \log(1 - N_t)\right]$$

where C_t^P denotes the consumption of each household. Households earn wage W_t per hour worked, N_t, and place one-period deposits D_t with the banks earning gross interest of R_t^D. The households thus face the following flow of funds constraint:

$$C_t^P + D_t + K_t^B = W_t N_t + R_{t-1}^D D_{t-1} + R_{t-1}^{KB} K_{t-1}^B + \Pi_t \tag{1}$$

where K_t^B denotes bank's equity paying a gross return rate of R_t^{KB} and Π_t a lump-sum profit from banks. Households use the repayment of last period's deposits including interest as well as their labour income and return on equity to consume, and place new deposits and capital with banks. They are the only owners of banks and they cannot actively invest or deinvest in banks to account for the scarcity of bank equity.[12] It is assumed that bank equity pays a strictly higher return than deposits to make up for the potential risk of bank equity.[13] This risk premium is denoted by $\xi > 1$:

$$R_t^{KB} = \xi R_t^D \tag{2}$$

Denoting the marginal utility of consumption with $u_{CP,t} = 1/C_t^P$ yields the standard first-order condition for consumption/ deposits:[14]

$$u_{CP,t} = \beta_P E_t[R_t^D u_{CP,t+1}], \tag{3}$$

the Euler equation, stating that the household is indifferent in the equilibrium between consumption today and saving to consume tomorrow. There is no risk in deposits repayments.[15]

[12] This assumption has been commonly used in the literature, see for example Gerali et al. (24)

[13] There exist strong empirical evidence for the existence of a spread between equity and debt funding. See Campbell et al. (13); Covas and Den Haan (17)

[14] Details on agents' optimisation problem can be found in Appendix 1.A.2.

[15] It is implicitly assumed that there is some government guarantee hence the riskiness of bank's decisions doesn't affect lending behaviour of households.

Labour supply is increasing in wage according to:

$$W_t = \frac{\tau}{1 - N_t} \frac{1}{u_{CP,t}} \tag{4}$$

1.3.2 Entrepreneurs

The firms produce output using identical Cobb-Douglas production functions with capital and labour input. Labour is mobile across firms and the labour market is perfectly competitive. There is hence one representative firm. The firm is owned by the representative entrepreneurs and there are no frictions between firm and owner. However, the firm is still subject to financial constraints. The entrepreneur solves the problem[16]

$$\max_{C_t^E, K_t^E, L_t, H_t} E_t \sum_{t=0}^{\infty} \beta_E^t \left[\log(C_t^E)\right]$$

subject to the budget constraint:

$$C_t^E + K_t^E + (1 - J_t) R_{t-1}^E L_{t-1} + J_t m_E K_{t-1}^E + W_t H_t = Y_t + (1 - \delta_K) K_{t-1}^E + L_t \tag{5}$$

and the production function

$$Y_t = A_t (K_{t-1}^E)^{\alpha} (H_t)^{1-\alpha} \tag{6}$$

as well as a borrowing constraint. According to Equation (5), entrepreneurs consume C_t^E, borrow L_t from banks at gross interest rate R_t^E, pay wages to households for H_t hours worked, replace depreciated capital and produce output Y_t. Output is subject to exogenous shocks with respect to factor productivity. As technology shocks have been identified as the one of the main drivers of cyclical fluctuations,[17] they serve to illustrate agents' behaviour during business cycle fluctuations. The stochastic process for TFP, A_t, follows

$$A_t = (1 - \rho_A)\bar{A} + \rho_A A_{t-1} + \epsilon_{t,A} \tag{7}$$

Firms repay their obligations to banks at a rate of $(1 - J_t)$.[18] J_t thus denotes the probability of a

[16] The entrepreneur is not risk neutral, see Carlstrom and Fuest (14) for discussion. Net worth would respond too sharply to output shocks.

[17] See Schmitt-Grohé and Uribe (43) who estimate that 30% of the variance in output growth stems from unanticipated shocks to TFP.

[18] Note that default modelled here assumes that bank's wealth is not destroyed but redistributed to the borrowers. There are large legal and social costs involved if corporations default, which are not taken into account in this simple model set-up. An extension of the framework could capture this by modelling pecuniary and non-pecuniary costs associated with default and include an optimal default decision of firms in line with De Walque et al. (18).

loan default often referred to as the non-performing loan ratio. If firms default, their collateral $J_t m_E K^E_{t-1}$ is lost.[19] Instead of assuming the probability of default to be exogenously given, I account for the cyclicality of default. The empirical literature suggests that the fraction of non-performing loans is negatively affected by changes in output.[20] Dimitrios et al. (22) find that one percentage point increase in the output gap leads to a 0.19 percentage point decrease in the non-performing loan rate. Beck et al. (9) find that GDP growth typically affects non-performing loan rates with a time lag of at least one quarter. I thus define the fraction of non-performing loans as

$$J_t = (1-\rho_J)\bar{J} - \omega\left(\frac{Y_{t-1}-\bar{Y}}{\bar{Y}}\right) + \rho_J J_{t-1} \tag{8}$$

to account for this link. $\bar{J}$ is the average non-performing loan rate over the business cycle and ρ_J denotes the persistence of a deviation from that trend. The term $\frac{Y_{t-1}-\bar{Y}}{\bar{Y}}$ denotes the cyclical component of output and $\omega > 0$ the sensitivity of non-performing loans to the output gap. If output is larger than in the steady state, i.e., during economic expansion, the fraction of non-performing loans falls below the steady state level, and vice versa in an economic downturn. I assume that the relationship between non-performing loans and the output gap is linear and symmetrical in both economic expansion and downturn which is a common assumption in the literature (see Beck et al. (9) and Dimitrios et al. (22)). However, Glen and Mondragón-Vélez (25) find empirical evidence to the contrary. They estimate that the relation between nonperforming loans and growth becomes highly non-linear in case of severe macroeconomic distress. Therefore, Equation (8) might require further adjustment if we considered declines in GDP growth by more than 6 percentage points. As long as we investigate normal business cycle fluctuations, the linear relationship seems appropriate.[21]

Default on loan obligations leads to a loss of collateral determined by the borrowing constraint:

$$L_t \leq m_E \frac{K^E_t}{R^E_t} \tag{9}$$

[19] It is assumed that capital can be sold partially at face value.

[20] See Bikker and Metzemakers (11); Nkusu (39); Louzis et al. (38). The reason I focus on corporate loans instead of mortgages lies in the responsiveness to macroeconomic conditions. Louzis et al. (38) analyse the Greek lending sector and find that the NPL ratio on mortgages act least responsive to economic conditions, suggesting that growth affects corporate loans more than private loans.

[21] For further research, it would be interesting to investigate asymmetries regarding the reaction of non-performing loan rates to changes in output in a downturn vs a boom period. Research by Nkusu (2011) indicates that the non-performing loan rate reacts more strongly to downturns than to economic expansions. It would be interesting to investigate how this asymmetric relationship affects bank's ability to accumulate an appropriate buffer during an economic expansion if it is reduced more quickly during times of distress. For this paper, I will focus on the effects during a downturn and hence estimate the related parameters considering an economic contraction.

Entrepreneurs cannot borrow more than a fraction m_E of the chosen value of capital such that m_E can be interpreted as the loan-to-value (LTV) ratio for corporate loans.[22] Intuitively, it is possible to interpret the case of $m_E = 0$ as the extreme case when firm capital is not accepted as collateral at all and firms are thus unable to borrow.

In analogy to Iacoviello (2015), I define λ_t^E as the multiplier of the borrowing constraint, which is normalized by the marginal utility of consumption. This yields the first-order conditions for optimal consumption as the Euler equation[23]

$$(1 - \lambda_t^E)u_{CE,t} = \beta_E E_t[((1 - J_{t+1})R_t^E)u_{CE,t+1}]. \tag{10}$$

The entrepreneur can increase consumption today by borrowing from the bank, raising loans by one unit. By doing so, the borrowing constraint tightens one-for-one reducing the utility of the extra loan unit by λ_t^E. Overall, today's payoff from loans is $1 - \lambda_t^E$. This must equal the discounted marginal costs in the next period. The cost of a loan unit are determined by the interest rate settled in period t and the expected default rate in the next period. Capital demand is given by

$$(1 - \lambda_t^E \frac{m_E}{R_t^E})u_{CE,t} = \beta_E E_t[(1 - \delta + R_{t+1}^K - J_{t+1}m_E)u_{CE,t+1}]. \tag{11}$$

The entrepreneur can invest in one more unit of capital which relaxes the borrowing constraint by $\lambda_t^E \frac{m_E}{R_t^E}$. One more unit of capital yields the marginal return illustrated by the right-hand-side of Equation (11).

In addition, the first-order conditions yield labour demand

$$W_t H_t = (1 - \alpha)Y_t \tag{12}$$

and the user cost of capital

$$R_t^K = \frac{\alpha Y_t}{K_{t-1}^E}. \tag{13}$$

Both the Euler equation (10) and the capital demand equation (11) differ from the usual, unconstrained formulation due to the Lagrange multiplier on the borrowing constraint. λ^E denotes the increase in lifetime utility from borrowing one unit, consuming (Equation (10)) or investing (Equation (11)) it and reducing consumption accordingly in the future. In the absence of uncertainty, the assumption of $\beta_E < \beta_P$ ensures that entrepreneurs are constrained

[22]In analogy to Iacoviello (29), the assumption placed on the discount factor is such that, absent uncertainty, entrepreneurs' borrowing constraint binds in the neighbourhood of the steady state.

[23]Details on agents' optimisation problem can be found in Appendix 1.A.2.

in the neighbourhood of the steady state. However, in the presence of uncertainty, the concave objective function might provide an incentive in some states for entrepreneurs to "self-insure". That way, they borrow less than their credit limit allows in order to smooth consumption. A precautionary savings motive would hence dominate the agent's impatience. This would lead to an asymmetry around the steady state leaving agents constrained during economic downturns and unconstrained during booms. A linear approximation of an asymmetric model around the steady state could lead to inaccurate results. Therefore, I assume that the degree of impatience outweighs uncertainty such that agents are always constrained.[24]

1.3.3 Banks

In analogy to the wholesale banking sector in Gerali et al. (24), the banks act as intermediaries for all financial transactions in the model as the other agents are unable to lend directly to each other. Banks are competitive and hence adjust their supply of loans and demand of deposits in response to shocks or cyclical conditions in the economy.[25] There are two pivotal constraints to the banking sector in this model. The first implies that each bank must obey the balance sheet identity

$$L_t = D_t + K_t^B \tag{14}$$

stating that the bank can finance the loans to firms, L_t, with deposits, D_t, and bank capital, K_t^B. As far as the balance sheet is concerned, the funding sources are perfect substitutes.

Bank's funding choice is limited by the second constraint determining the amount that the bank is able to borrow. The bank's capital-to-asset ratio must be at least equal to an endogenously determined fraction γ_t such that

$$\frac{TK_t^B}{L_t} \geq \gamma_t.^{26} \tag{15}$$

where TK_t^B denotes bank's capital position after the potential expense for loan loss provisions LLP_t such that $TK_t^B = K_t^B - LLP_t$. From (15), it follows that bank capital is defined as

$$K_t^B \geq \gamma_t L_t + LLP_t \tag{16}$$

[24]This assumption is common in the literature. For formal proof, refer to Iacoviello (29).

[25]An extension of this towards a setting with imperfect competition in the banking sector similar to Gerali et al. (24) would be possible to study banks adjustment of interest rates and mark-ups following shocks to the system.

[26]Bank's capital requirement ratio is kept very simple in this paper. However, it can easily be extended towards a Basel II setting with risk-weighted assets and cyclical risk weights. This extension adds procyclicality to the credit supply and leaves the results of the countercyclical instruments hence slightly less pronounced. Since it does affect the different instruments discussed here in the same way and does hence not change how they compare to each other, I have neglected the introduction of risk weights to the denominator in this paper for the sake of simplicity.

In contrast to Gerali et al. (24) and Kollmann (2013), I assume that banks cannot engage in costly 'creative accounting' to deviate from the regulatory requirement. Rather, banks need to adjust their balance sheet and reduce their asset position in order to satisfy the requirement similar to the setting described by Iacoviello (2015). Since banks are maximising cashflows and debt funding is always cheaper than equity funding, banks hold the lowest amount of capital required.[27] The constraint on capital (16) thus binds in the neighbourhood of the steady state. In absence of the constraint, it would be optimal for banks to hold no equity. Given the constraint, they hold as little as possible. Bank capital hence takes on a central role for the credit supply.

γ_t denotes a capital requirement ratio that could be either constant in vein of Basel II or potentially time-varying in the spirit of Basel III. The latter regulatory setting requires a countercyclical capital ratio that increases during good times and decreases during recessions. The intention of the Basel Committee is to provide a tool that can react if systemic risk in the banking sector increases. They have found that excess growth in credit to the private sector provides a good indication of systemic risk.[28] The jurisdiction thus assesses whether credit growth is excessive and puts in place a buffer capital requirement from 0 to 2.5% on top of the capital requirement rate of 8%. In order to give banks sufficient time to adjust capital, the decision is pre-announced by 12 months.[29] In analogy to Basel III, I model capital requirements as adjustments in response to deviations in credit from its trend:

$$\gamma_t = (1-\rho_\gamma)\bar{\gamma} + \chi\Big(\frac{L_{t-1}-\bar{L}}{\bar{L}}\Big) + \rho_\gamma\gamma_{t-1} \tag{17}$$

where $\bar{L}$ denotes the trend in credit, ρ_γ gives an indication about the speed of the regulatory authority's reaction as well as the persistence of their response, and χ indicates the sensitivity of the instrument to changes in the credit gap. If $\chi = 0$, the capital requirement rate is time-

[27] This strict requirement could be relaxed by introducing a cost for deviating from the required capital structure as in Gerali et al. (24); Kollmann (37), thereby allowing banks to hold voluntary capital buffers above the minimum threshold. I have not modelled a voluntary capital buffer here as I want to focus on the effects of a change in regulation. It might be interesting for further research to analyse the consequences on voluntary capital buffers if regulation is introduced. Previous research suggested that the introduction of regulation changed the reason for banks to hold voluntary buffers (see Agénor et al. (1) where capital buffers have signalling effects that translate into changes in market borrowing costs). To avoid a potential Lucas' critique, I focus only on the effects of changes in regulatory capital.

[28] For a detailed discussion please refer to Drehmann et al. (23); Repullo and Suarez (40); Basel Committee on Banking Supervision (8) as well as Jokivuolle et al. (35) for empirical evidence across Europe. The majority of researchers studying the effectiveness of countercyclical buffers have therefore focussed capital rules depending on the loan gap (Clerc et al. (16)) or the loan-to-GDP gap (Angelini et al. (6)). This approach is supported by Benes and Kumhof (10) who found that these capital rules develop larger welfare gains compared to a policy rule determined by the output gap.

[29] Basel Committee on Banking Supervision (8)

invariant similar to the Basel II regulation prior to the crisis.

Furthermore, the amount of bank capital in Equation (16) depends on dynamic loan loss provisions LLP_t.[30] To serve as a countercyclical instrument, dynamic loan loss provisions must be related to the latent risk over the whole business cycle instead of a specific incurred loss. The average of non-performing loans over the business cycle ($\bar{J}$) serves as an indication for the long-run estimation of latent credit risk. During economic expansion, credit losses are lower than this long-run estimation. This is the time to build up a buffer of loan loss reserves. In contrast, the fraction of non-performing loans during a downturn is higher than in the steady state such that banks should be able to use this buffer to cover some of the losses. In vein of Bouvatier and Lepetit (12) , I model dynamic loan loss provisions as

$$LLP_t = \lambda(\bar{J} - J_t)L_t \tag{18}$$

The difference in short-term risk, J_t, from the long-term latent risk perception, $\bar{J}$, builds the cyclical component in the dynamic loan loss provision. During economic expansion, the fraction of non-performing loans is lower than in the steady state, which yields a positive value in Equation (18). In contrast, dynamic loan loss provisions will be negative in an economic downturn when the short-term risk value is higher than the long-run estimation and loan loss provisions become smaller than zero. The smoothing parameter λ indicates to which degree the bank has to set up the provisions. If $\lambda = 1$, the bank has to set aside profits to an amount equal to the expected losses. If $\lambda < 1$, the provisions can be lower than the expected losses and in the case that $\lambda = 0$, no loan loss provisions are required to be set aside.

Therefore, the model set up describes different scenarios depending on the calibration of the two parameters, χ and λ:

$$\text{Regulation} \begin{cases} \chi = 0, \lambda = 0 & \text{Basel II} \\ \chi > 0, \lambda = 0 & \text{Countercyclical capital requirement, Basel III} \\ \chi = 0, \lambda > 0 & \text{Dynamic loan loss provisions, Bank of Spain} \end{cases}$$

By changing the parameter values, we can compare the performance of the different instruments.

[30] To illustrate the workings of dynamic provisioning clearly, I only model the dynamic (forward-looking) component of loan loss provisions and neglect specific provisions on incurred losses. This yields simpler equations for dynamic LLPs and the same steady state as the other settings. Inclusion of specific provisions would add to the procyclicality of loan loss provisions thus reduce the smoothing effect. For a study of the procyclicality of specific provisions for incurred losses and the interaction with a dynamic compenent, refer to Agénor and Zilberman (3).

Banking sector's budget can be set up as follows

$$\begin{aligned}\Pi_t =& R^D_{t-1}D_{t-1} + L_t + R^{KB}_{t-1}K^B_{t-1} - (1-J_t)R^E_{t-1}L_{t-1} - J_t\kappa R^E_{t-1}L_{t-1} \\ &- D_t - K^B_t\end{aligned} \tag{19}$$

In period t, the bank receives the repayment of loans from firms which might fall short to repay the entire obligation including interest by fraction J_t. If firms default on their loans, the bank receives the collateral. However, since asset repossession is not costless, banks receive only a fraction κ of the collateral $m_E K^E_{t-1} = R^E_{t-1}L_{t-1}$ as liquidation value. Carlstrom and Fuest (14) find that bankruptcy costs commonly amount to 20-36% of the asset value. In addition, the bank receives deposits from households. Simultaneously, the bank repays deposits including interest received in the previous period and lends to the productive sector.

In the absence of unexpected shocks, banks make zero profits. If the non-performing loan rate is lower than expected, i.e. if the loan repayment rate is higher, banks make a positive profit that increases retained earnings and hence allows banks to extend more credit. In case of a negative shock with higher non-performing loan rates, banks make a loss that must be absorbed by their equity. Bank profits turn negative, acting as a capital injection from households. Due to the fact that equity is more expensive than debt funding, banks adjust their loan portfolio to reduce the amount of equity required.

The bank's optimisation problem consists of choosing loans and deposits so as to maximise the discounted sum of cashflows[31] subject to the capital requirement constraint (16) and taking the interest rates R^D_t and R^E_t as well as the capital requirement rate γ_t and entrepreneur's default rate J_t as given. This yields the following first-order conditions[32]

$$1 = \beta_P R^D_t \tag{20}$$

$$1 - \gamma_t - \lambda(\bar{J} - J_t) = \beta_P E_t[((1 - J_{t+1}(1-\kappa))R^E_t - R^{KB}_t(\gamma_t + \lambda(\bar{J} - J_t)))] \tag{21}$$

[31] Since households are the only bank owners, future profits are valued at their discount factor. For the sake of simplicity, I have assumed that it is constant and independent of the cost of equity. This assumption is common in the literature, see for example Bouvatier and Lepetit (12).

[32] Details on agents' optimisation problem can be found in Appendix 1.A.2.

Assuming no countercyclical regulation, i.e. $\chi = 0$ **and** $\lambda = 0$, yields Equation (21) as

$$1 - \bar{\gamma} = \beta_P E_t[((1 - J_{t+1}(1 - \kappa))R_t^E - R_t^{KB}\bar{\gamma})] \tag{22}$$

The first-order conditions indicate the reason why loans and deposits pay different interest rates in equilibrium. There are essentially two ways for the bank to increase current cash flows: Equation (20) demonstrates the first option. The banker is able to increase cash flow today by borrowing one more unit of deposits at the cost of a reduction of cash flow at $t + 1$. In the optimum, the bank must be indifferent between the marginal profit and the discounted expected costs for the additional deposit in the future. The alternative is shown by Equation (22). Instead of restructuring funds on the liability side of the balance sheet, the bank could focus on its assets. The banker can increase current cash flows by lending less to firms. One fewer unit of loans tightens the borrowing constraint since fewer loans implies that the bank possesses fewer assets that can be used as collateral. Therefore, the marginal profit from lowering assets by one unit is equal to $(1-\bar{\gamma})$. The higher the capital requirement $\bar{\gamma}$, the lower the usefulness of loans as collateral and thereby, the lower the gain from loan reduction. Bank's effective (gross) rate of return on loans is $((1 - J_{t+1}(1 - \kappa))R_t^E - R_t^{KB}\bar{\gamma})$. In the optimum, the bank must again be indifferent between the marginal profit today and the expected future costs of lower revenues.

For the bank to be indifferent between borrowing and lending, the returns on loans must compensate. From Equations (20) - (22), returns on loans are given by

$$\begin{aligned} R_t^E &= E_t\left[\frac{1}{1 - J_{t+1}(1-\kappa)}\left[(1-\bar{\gamma})R_t^D + \bar{\gamma}R_t^{KB}\right]\right] \\ &= E_t\left[\frac{1}{1 - J_{t+1}(1-\kappa)}R_t^F\right] \end{aligned} \tag{23}$$

where R_t^F denote the funding costs as the weighted cost of capital. This lending rate equation is the key channel through which macroprudential regulation is going to affect the financial sector in the simulation. In this benchmark setting, there are two main channels that determine the loan rate. The first is the *risk premium channel.* Banks charge a risk premium due to the possibility of loan default. The expected marginal return on loans in period $t+1$ is only $E_t[(1 - J_{t+1}(1 - \kappa))R_t^E]$. The smaller κ, the higher the loss given default. The bank hence takes the fraction of non-performing loans and the value of repossessed collateral into account and consequently charges higher interest rates according to the expectation of the return after entrepreneur's default. In addition, the loan rate is determined by bank's funding costs, the *funding cost channel.* The higher the capital requirement $\bar{\gamma}$, the larger the fraction of equity required to fund the loan. The larger the capital requirement rate, the more equity funding is required for the banks. As equity is more expensive than debt funding by the factor ξ, the spread between the corporate loan rate and the deposit rate is higher the larger the capital requirement rate.

In this scenario, bank capital is defined as

$$K_t^B = \bar{\gamma} L_t \tag{24}$$

The capital requirement rate is exogenously fixed by the regulator and banks lend exactly as much as they can given their capital. In contrast to Gerali et al. (2010) and Kollmann (2011), banks are acting in an environment of perfect competition. Therefore, they cannot increase equity capital mainly by earning retentions. If banks suffer unexpected credit losses, negative profits allow for an increase in equity by banks' owners, the households. However, since equity is expensive for banks, they will react mainly by adjusting their loan portfolio and hence reduce lending to entrepreneurs.

To use this framework in order to examine different regulatory instruments, I introduce a countercyclical capital requirement rate and a dynamic loan loss provision. Both instruments are equivalent in their purpose of building a buffer stock of equity during good times that can be drawn upon during bad times. The workings and thus the calibration of the instruments might differ, however. A countercyclical capital requirement is at the core of the Basel III proposal whereas dynamic loan loss provisions have been introduced by the bank of Spain. In order to evaluate the different policy proposals regarding their effectiveness to reduce macroeconomic fluctuations, I will illustrate the conditions under which they are equivalent first. That way, the quantitative results are easier to interpret and evaluate.

Assuming a countercyclical capital buffer in accordance with Basel III, i.e. $\chi > 0$ **and** $\lambda = 0$ yields bank capital as

$$K_t^B = \gamma_t L_t \tag{25}$$

and the lending rate as

$$
\begin{aligned}
R_t^E &= E_t\left[\frac{1}{1-J_{t+1}(1-\kappa)}\Big[(1-\gamma_t)R_t^D + \gamma_t R_t^{KB}\Big]\right] \\
R_t^E &= E_t\left[\frac{1}{1-J_{t+1}(1-\kappa)}\left[\Big(1-(1-\rho_\gamma)\bar{\gamma} + \chi\Big(\frac{L_{t-1}-\bar{L}}{\bar{L}}\Big) + \rho_\gamma\gamma_{t-1}\Big)R_t^D\right.\right. \\
&\quad \left.\left. + \Big((1-\rho_\gamma)\bar{\gamma} + \chi\Big(\frac{L_{t-1}-\bar{L}}{\bar{L}}\Big) + \rho_\gamma\gamma_{t-1}\Big)R_t^{KB}\right]\right] \\
&= E_t\left[\frac{1}{1-J_{t+1}(1-\kappa)}R_t^{FB}\right]
\end{aligned}
\tag{26}
$$

where R_t^{FB} denote the funding costs with a countercyclical capital buffer in place. These costs deviate from the funding costs R_t^F in boom periods as well as in downturns.

$$
R_t^F \begin{cases} < R_t^{FB} & \text{during economic expansion when } \bar{L} < L_t \\ > R_t^{FB} & \text{during economic distress when } \bar{L} > L_t \end{cases}
$$

During economic expansions as the credit gap turns positive, banks are required to hold more expensive equity capital and thus funding costs are higher compared to the steady state or the case without countercyclical regulation. To compensate for the additional costs, the bank increases the interest rate accordingly. During bad times, the countercyclical buffer provides relief allowing banks to hold less equity, resulting in lower funding costs and thus reducing the incentive for banks to shrink their balance sheet by decreasing lending. The instrument can thus be used to prevent a credit crunch which is one of the pivotal characteristics of macroprudential policy.[33]

While funding costs R^F are determined by a fixed capital ratio $\bar{\gamma}$, the capital requirement rate varies in the countercyclical case and hence changes the lending rate accordingly. During times with a positive credit gap, banks need to keep a higher portion of equity. Since equity is more expensive than debt funding, bank's funding costs increase and banks charge higher loan rates. During downturns, the loan rate is decreasing with lower funding costs.

Lastly, **assuming dynamic loan loss provisioning, i.e.** $\chi = 0$ **and** $\lambda > 0$ yields bank capital as

$$K_t^B = \bar{\gamma}L_t + LLP_t \tag{27}$$

[33] See Hanson et al. (28)

In case of an economic crisis, the bank can draw from its buffer of loan loss reserves and may use them as additional capital.

The lending rate is given as

$$\begin{aligned} R_t^E &= E_t\left[\frac{1}{1-J_{t+1}(1-\kappa)}\left[(1-\bar{\gamma}-(\bar{J}-J_t))R_t^D+(\bar{\gamma}+(\bar{J}-J_t))R_t^{KB}\right]\right] \\ &= E_t\left[\frac{1}{1-J_{t+1}(1-\kappa)}R_t^{FS}\right] \end{aligned} \tag{28}$$

with R_t^{FS} denoting the funding costs in the dynamic provisioning case.

$$R_t^F \begin{cases} < R_t^{FS} & \text{during economic expansion when } \bar{J} > J_t \\ > R_t^{FS} & \text{during economic distress when } \bar{J} < J_t \end{cases}$$

An increase of loans by one unit leads to an increase in provisions by

$$\frac{\delta LLP_t}{\delta L_t} = \lambda(\bar{J} - J_t) \tag{29}$$

which is costly for bankers during good times when $J_t < \bar{J}$ since it requires more equity funding. To compensate for the additional costs, the bank increases the interest rate accordingly. However, during bad times (i.e., times in which the non-performing loan rate exceeds its steady state) the costs for loan loss provisions are negative and provide relief to the bank mitigating the increase in interest rate.

1.3.4 Market clearing and equilibrium

In this paper, all agents are representative. Market clearing can be illustrated by aggregating all budget constraints of the model.[34] Substituting bank's profits (19) into household sector's budget constraint (1) and substituting entrepreneur's budget constraint (5) yields

$$W_t(N_t - H_t) + (C_t^P + C_t^E + K_t^E - (1-\delta)K_{t-1}^E + (1-\kappa)J_t m_E K_{t-1}^E - Y_t) = 0 \tag{30}$$

The market clearing condition for the goods market is

$$Y_t = C_t + I_t + (1-\kappa)J_t m_E K_{t-1}^E \tag{31}$$

[34] For details, refer to Appendix 1.A.5.

where aggregate consumption is defined as

$$C_t = C_t^P + C_t^E \tag{32}$$

Investment is defined as the change of physical capital

$$I_t = K_t^E - (1-\delta)K_{t-1}^E \tag{33}$$

and $(1-\kappa)J_t m_E K_{t-1}^E$ denotes the deadweight loss due to the liquidation of firm capital after default.

Labour market clears if labour supply equals labour demand

$$N_t = H_t \tag{34}$$

Walras' Law states that we can solve for either the goods or the labour market clearing.

For a solution of the model dynamics, I solve a linearized version of the model in equilibrium while assuming that the constraints given by Equations (9) and (16) are always binding. Furthermore, I ensure that the shock size is such that the Lagrange multipliers are strictly positive in the simulation.

1.3.5 Equivalence of the two instruments

In this section, I aim to illustrate the circumstances that make the two instruments equivalent. The regulatory setting influences the amount of bank's equity including the capital buffer. Bank capital in the countercyclical buffer scenario is defined as

$$K_t^B = \gamma_t L_t = \Big[(1-\rho_\gamma)\bar{\gamma} + \chi\Big(\frac{L_{t-1}-\bar{L}}{\bar{L}}\Big) + \rho_\gamma \gamma_{t-1}\Big] L_t$$

and in the dynamic provisioning setting as

$$K_t^B = \bar{\gamma} L_t + LLP_t = \Big[\bar{\gamma} + \lambda\Big(\bar{J} - \Big((1-\rho_J)\bar{J} - \omega\Big(\frac{Y_{t-1}-\bar{Y}}{\bar{Y}}\Big) + \rho_J J_{t-1}\Big)\Big)\Big] L_t$$

The two instruments are equivalent if

$$(1-\rho_\gamma)\bar{\gamma} + \chi\Big(\frac{L_{t-1}-\bar{L}}{\bar{L}}\Big) + \rho_\gamma \gamma_{t-1} = \bar{\gamma} + \lambda\Big(\bar{J} - \Big((1-\rho_J)\bar{J} - \omega\Big(\frac{Y_{t-1}-\bar{Y}}{\bar{Y}}\Big) + \rho_J J_{t-1}\Big)\Big)$$

When responding to a shock, the two instruments are equivalent if:

$$(1-\rho_\gamma)\bar{\gamma} + \chi\Big(\frac{L_{t-1}-\bar{L}}{\bar{L}}\Big) + \rho_\gamma\bar{\gamma} = \bar{\gamma} + \lambda\Big(\bar{J} - \Big((1-\rho_J)\bar{J} - \omega\Big(\frac{Y_{t-1}-\bar{Y}}{\bar{Y}}\Big) + \rho_J\bar{J}\Big)\Big)$$
$$\chi = \lambda\omega\Big(\frac{Y_{t-1}-\bar{Y}}{\bar{Y}}\Big)/\Big(\frac{L_{t-1}-\bar{L}}{\bar{L}}\Big)$$

For the two instruments to be equivalent, the regulator must choose the sensitivity of the countercyclical capital requirement in accordance with the sensitivity of the non-performing loans to the output gap. Intuitively, this is simple to understand. The buffer of loan loss provisions must be set up such that it covers the expected loan losses over the business cycle. Loan losses depend on the output gap with a sensitivity ω. Therefore, the buffer of loan loss provisions is determined by the value of $\lambda\omega$. If the regulator chooses that loan loss provisions must be set aside for the exact amount of expected loan losses, λ is equal to 1. The parameter ω can be estimated from the causal relation between non-performing loan rates and the output gap. For the countercyclical buffer to be equivalent in size, its sensitivity must hence correspond to $\lambda\omega$ as well.

1.3.6 Steady state properties

Evaluating Equation (3) at the non-stochastic steady state gives the interest rate for deposits as inverse of household's discount factor

$$R^D = \frac{1}{\beta_P} \tag{35}$$

As $\gamma_t = \bar{\gamma}$ and $J_t = \bar{J}$ in the non-stochastic steady state, the bank's gross interest rate spread evaluated at its steady state is given by:

$$\begin{aligned} R^E &= \frac{1}{1-\bar{J}(1-\kappa)}[(1-\bar{\gamma})R^D + \bar{\gamma}\xi R^D] \\ &= \frac{1}{1-\bar{J}(1-\kappa)}[1+(\xi-1)\bar{\gamma}]R^D \end{aligned} \tag{36}$$

Even if $\bar{J}$ was equal to zero, the spread between bank lending and borrowing would still be positive since the risk premium $\xi > 1$. This indicates that there always exists a spread between the gross interest rate on loans and on deposits. This spread ensures that bank's capital constraint is always tight.

For the entrepreneur to be credit constrained in the steady state, the multiplier on her borrowing constraint must be positive ($\lambda^E > 0$). Given $\lambda^E = 1-\beta_E(1-\bar{J})R^E$, this requires $\beta_E(1-\bar{J})R^E <$

1. If $\kappa = 0$:

$$\begin{aligned}
\lambda^E &= 1 - \beta_E(1-\bar{J})\frac{1}{1-\bar{J}(1-\kappa)}[1+(\xi-1)\bar{\gamma}]R^D \\
&= 1 - \beta_E(1-\bar{J})\frac{1}{1-\bar{J}}[1+(\xi-1)\bar{\gamma}]R^D \\
&= 1 - \beta_E/\beta_P[1+(\xi-1)\bar{\gamma}]
\end{aligned} \tag{37}$$

Therefore, a necessary condition for the entrepreneur to be credit constrained is that she must be more impatient than the household (i.e. $\beta_P > \beta_E$). I verify that entrepreneur's discount factor is chosen such that the Lagrange multiplier is always positive throughout the simulation. Thereby, I ensure that the entrepreneur is always credit constrained.

The borrowing constraints on bankers as well as firms lead to decreases in the steady state output when compared to a completely frictionless economy. Banker's borrowing constraint limits the amount of debt they can use to invest in corporate loans while entrepreneurs are also constrained in their ability to invest for production. Additionally, the possibility of loan default leads to lower steady state output when compared to a frictionless economy.

1.4 Quantitative Analysis

Simulation is used to find to which extent the use of the countercyclical instruments could reduce macroeconomic volatility.[35] I calibrate the two instruments in accordance with recent policy suggestions and compare their ability to respond to business cycle fluctuations.

1.4.1 Calibration

In this section, I show how the parameters in the simulation are chosen. Some standard parameters are calibrated in accordance with the literature. The time periods are set as quarters of a year and discount factors are defined such that $\beta_P > \beta_E$. I set household's discount factor at 0.9925 in order to obtain a steady state interest rate on deposits around 3.1% p.a. The entrepreneur's discount factor is set to 0.94 which is in line with suggestions by Iacoviello and Neri (31). τ, the preference parameter on free time, is set to 2 indicating that the agent spends half his time working.

[35] The paper uses the software Dynare to obtain solutions for the equilibrium for the respective regulatory instrument by solving a second order approximation to the model.

Corporate loan-to-value (LTV) ratios are controversial in the literature since there is a high range depending on the regulations in different sectors and countries. I use Eurostat time series data on corporate loans and the value of shares and equity in the non-financial sectors within the European Union. I calculate the ratio between loans and equity value for the time period prior to the financial crisis. The loan-to-value ratio received is equal to 0.29.[36] This is slightly below the ratios used in Christensen et al. (15) who find a value of 32% for Canada and Gerali et al. (24) who use 35% for the Euro area. The share of capital in the production function is set at 0.35 and the depreciation rate of capital is set at 0.025 which are standard settings in the literature.

The banking sector depends crucially on the capital requirement ratio. According to the Basel agreement, the minimum capital ratio cannot be lower than 8%. However, most banks adopt a slightly higher effective ratio to avoid penalties, as suggested by the empirical study by Demirgüç-Kunt and Detragiache (19). They find that banks in advanced economies hold approximately 12% of capital on average. I set the capital requirement ratio accordingly.[37] Using this calibration, the steady state ratio of corporate credit to output is approximately 1.3. This is slightly above the range calculated by Nkusu (39) of an average credit-to-GDP ratio for developed countries of 1.25. The fraction of non-performing loans in equilibrium is determined as the average non-performing loan rate of the Euro area prior to 2007 yielding 2.5% p.a. or 0.64% per quarter.[38] This is exactly in line with the long-term latent risk estimation for developed countries in Nkusu of approximately 2.5% calculated from a variety of sources. Data on the bank lending to deposit spread for the European Union suggests that banks charge on average 4% spread for lending over deposit borrowing. This implies a corporate loan interest rate of 7.1% in the steady state. The spread between lending and deposits depends on two main factors in this model. Firstly, bank's funding costs: since banks need to satisfy the capital requirement ratio, 12% of the loan needs to be funded by equity. The excess return on equity prior to the crisis in the Euro area was approximately 9.2% p.a. over the risk free rate which implies an equity premium ξ of 1.02. Bank's refinancing costs are thus approximately 4.1% p.a. Secondly, the spread is determined by the potential credit loss, thus accounting for the expected non-performing loan rate and the expected value of asset recovery. To account for the large credit spread between deposit and loan rates, the recovery rate κ which determines the bankruptcy value of firm's capital for the bank, must be small. Therefore, I set it 0.2, which is at the lower end of Carlstrom and Fuerst's (1997) determined range.

[36] Details on the data used in the calibration can be found in Appendix 1.A.6

[37] Using 10% capital requirement ratio instead of 12% provides similar results.

[38] Due to large increases in NPLs during the crisis, the value would have been 4% if periods after 2007 would have been included.

Nkusu determines that non-performing loans depend significantly on the output gap which is consistent with the estimation by Bikker and Metzemakers (11) for OECD countries and Bouvatier and Lepetit (12) for the European area. In order to confirm these estimates and to receive a parameter for ω (the sensitivity of the non-performing loan rate to the output gap), I use linear regression for time series data on the non-performing loan rate as well as GDP for the Euro area for the period between 1998-2014. Table 6 yields the results. The scaling of the observations is crucial to allow for the regression result to be used in the simulation. The model uses a quarterly frequency and thus the variables must be scaled quarterly. Unfortunately, NPL rates have not been reported quarterly for the EU before 2014. Data is received annually for the time period between 1998-2014 for GDP and NPL rates. I divide the annual time series by four to express them in quarterly terms in order to render them comparable to the model specification of J_t. Figure 10 plots the time series for the output gap ratio and the NPL rate, indicating a strong trend in the data. Simply regressing the output gap ratio on the NPL rate would yield spurious regression results due to the strong trend in GDP. Therefore, I use first differences regressing

$$\begin{aligned}\Delta J_t = J_t - J_{t-1} &= -\omega\frac{Y_{t-1}-\bar{Y}}{\bar{Y}} + \omega\frac{Y_{t-2}-\bar{Y}}{\bar{Y}} + \rho_J J_{t-1} - \rho_J J_{t-2} \\ &= -\omega(\frac{\Delta Y_{t-1}}{\bar{Y}}) + \rho_J \Delta J_{t-1}\end{aligned} \tag{38}$$

Plotting the time series' indicates that an increase in the first differences of the output gap ratio leads to a decrease in first differences of the non-performing loan rate (see Figure 10).[39]

Variable	
FD Output gap ratio	0.0473***
	(0.0114)
FD NPL gap	0.4021***
	(0.1625)
cons	0.00018
	(0.0003)
N	14
R^2	0.66

$^{***}p < 0.01$

Table 1: DEPENDENT VARIABLE: NON-PERFORMING LOANS ΔJ

[39]HP-filtering the data leads to similar results.

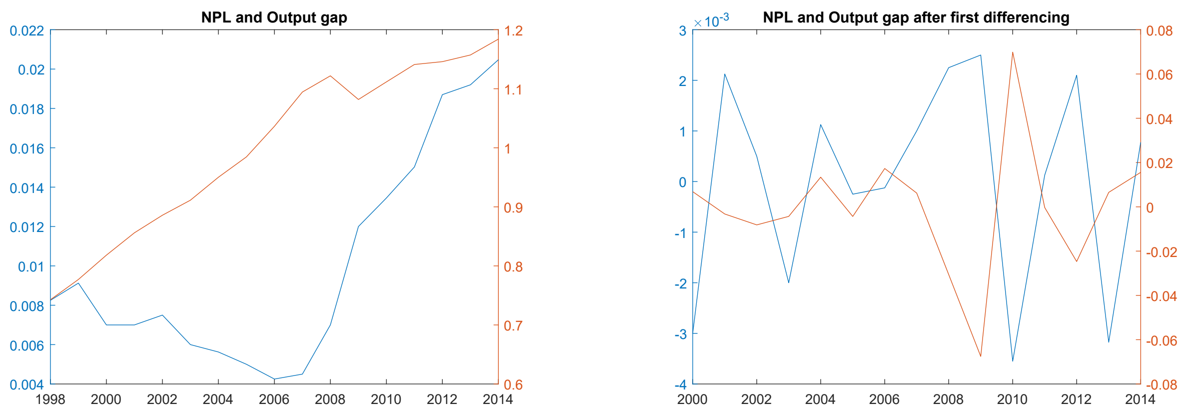

Figure 2: NPL rates and output gap ratio: Time series with trend and after first differencing

This yields a significant $\omega = 0.0473$ and ρ_J equal to 0.4. If the output gap ratio falls by one percentage point, the non-performing loan rate increases by approximately 0.05 percentage points per quarter or 0.16 percentage points per annum.[40]

The countercyclical instruments are thus calibrated using these estimations for the expected loan losses. Dynamic loan loss provisions by the Bank of Spain require Spanish banks to hold loan loss provisions for the full amount of expected losses over the business cycle, therefore $\lambda = 1$. In accordance with the literature on the Basel III policy, I set the persistence parameter in the captal requirement rule at 0.92 (Angelini et al. (5)), indicating high persistence. χ indicates the sensitivity to the business cycle. Equivalnece of the two instruments in calibration would require that in the steady state $\chi = 1 \times 0.04$. However, Basel regulators have announced that the countercyclical capital buffer should be in the range of 0 to 2.5%.[41] Therefore, I calibrate χ such that the time-varying capital requirement fluctuates up to 2.5 percentage points around the steady state subsequent to large shocks.

The calibration of the TFP shock in Equation (7) follows the estimation by Gerali et al. (24) for the Euro area. All parameters are summarized in Table 2.

1.4.2 TFP shock

The effects of an adverse one standard deviation technology shock to key macroeconomic variables are illustrated in Figure 3. The first visible effect is the immediate decrease in output through the production function. Output drops by 1.3% in the basic setting which drives down

[40] Dimitrios et al. (22) use GMM estimation for Euro area data and find a similar effect.
[41] Basel Committee on Banking Supervision (8)

Description	Value	Evidence in literature
Discount factor Savers β_P	0.9925	Iacoviello and Neri (31)
Discount factor Entrepreneurs β_E	0.94	Iacoviello and Neri (31)
Share of capital in production function α	0.35	Jermann and Quadrini (33)
Depreciation of capital δ	0.025	Jermann and Quadrini (33)
Weight on leisure in utility function τ	2	Iacoviello and Neri (31)
Equity premium ξ	1.023	Data
Corporate LTV ratio m_E	0.29	Gerali et al. (24)
Collateral value after bankrupty κ	0.2	Carlstrom and Fuest (14)
Capital Requirement for Bank Loans γ	0.12	Demirgüç-Kunt and Detragiache (19)
Steady state of NPL $\bar{J}$	0.0064	Data and Nkusu (39)
Sensitivity of NPL w.r.t. output gap ω	0.0473	Data and Dimitrios et al. (22)
Smoothing parameter LLP λ	1	Bank of Spain
Sensitivity of countercyc. cap. req. χ	0.1837	Data
Persistence of technology shock ρ_A	0.939	Gerali et al. (24)
Persistence of NPL shock ρ_J	0.4	Data
Persistence of CCR rule ρ_γ	0.92	Angelini et al. (5)

Table 2: Parameter values

investment by 8% and firm capital by 1.2% since these variables are positively linked to TFP. The drop in capital decreases the demand for labour and leads to a reduction in wages. Households receive lower labour income and thus consumption is lowered by 1%.

When considering the banking sector, bank loans (as well as deposits) and bank capital decrease during the economic contraction. While output decreases, the non-performing loan rate increases and hence firms repay a smaller fraction of loans. Figure 4 shows the increase of the non-performing loan rate from 2.55% p.a. to 2.95% p.a., an increase that is rather small when considering the financial crisis where non-performing loan rates reached a maximum of more than 8% p.a. over the entire Euro area. In peripheral regions such as Italy and Greece, the non-performing loan rate even rose to 16% and 21%, respectively. If the repayment is lower than the prior expectation, banks make losses which need to be covered by equity. Since equity is scarce, banks reduce the lending to the real economy in order to continue to satisfy the capital requirement constraint. In addition, higher expected non-performing loan rates lead to a 0.5 percentage point increase in loan interest rates. Together with firm's lower marginal product of capital due to the lower TFP, the higher interest rates discourage credit demand. Lending drops by 1% as banks deleverage.

At this stage, I introduce the two instruments. Intuitively, countercyclical capital regulation should serve to mitigate the contractionary effects on lending during a bust phase and allow

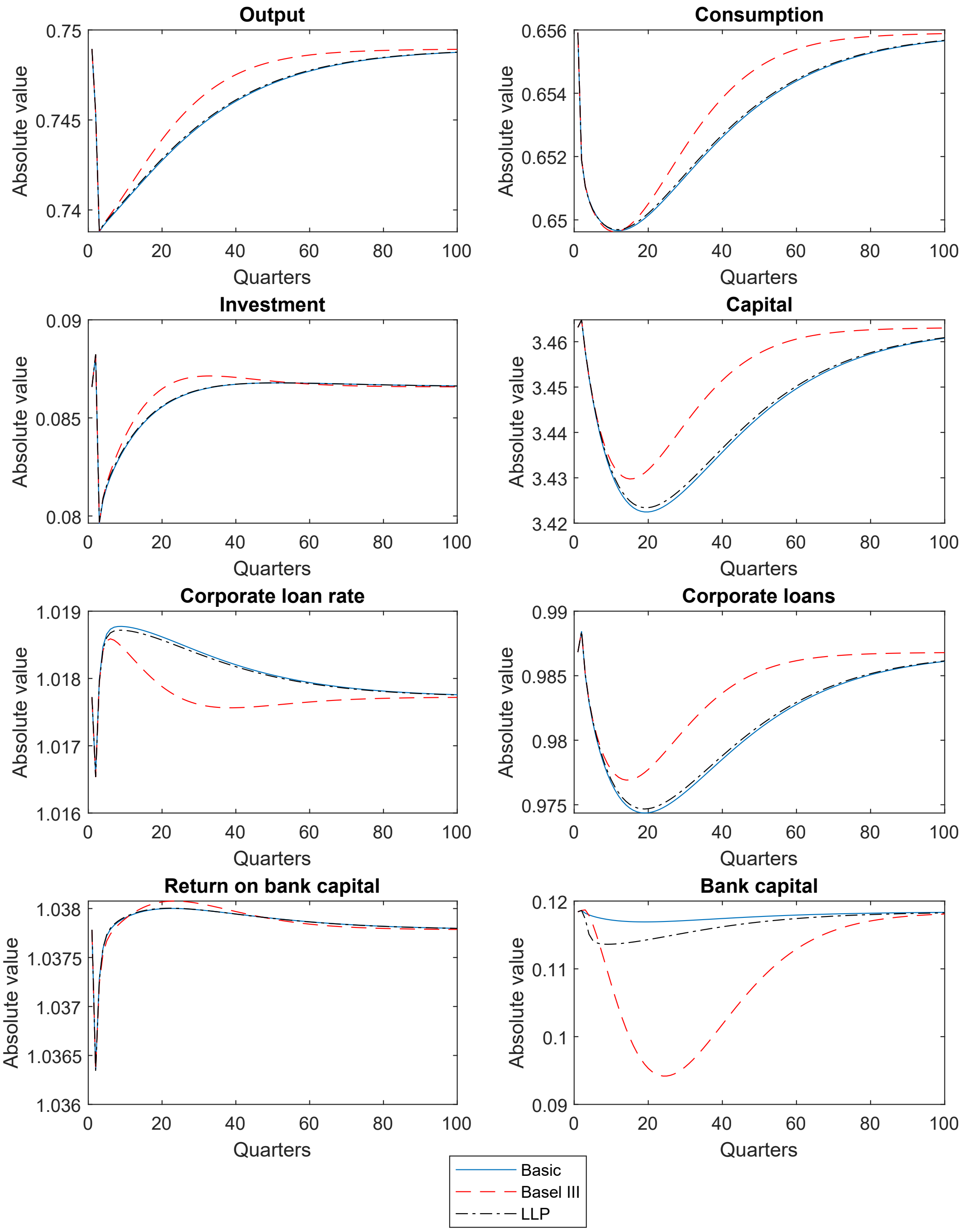

Figure 3: Impulse response functions after an adverse one standard deviation technology shock for the different scenarios

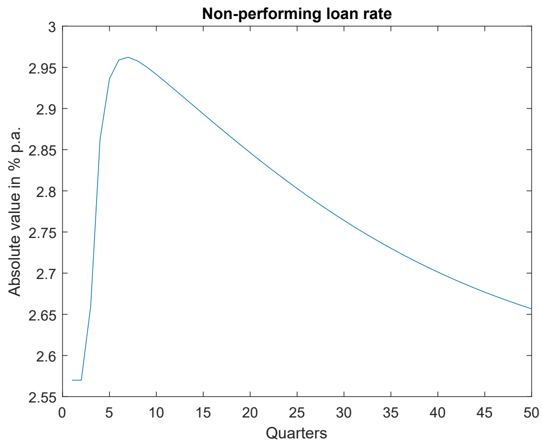

Figure 4: INCREASE IN THE NON-PERFORMING LOAN RATE FROM 2.55% P.A. TO 2.95% P.A.

banks to hold a smaller fraction of equity in order to provide relief to the economy. The results comply with this intuition. Beside the contractionary effect on lending via reduced credit demand and incentive for banks to deleverage as in the basic setting, the TFP shock affects credit supply via the borrowing constraint. γ_t changes as Y_t changes and thus the corporate loan rate directly adjusts to the TFP shock. Figure 3 shows that the increase in corporate loan rate is smaller for the Basel III buffer. The capital-to-asset ratio decreases with the productivity shock providing relief to credit conditions when compared to the basic case. The bank's capital decreases by 2.5 percentage points and the parameter value for χ allowing this decrease is equal to 2. As soon as the economy is no longer hit by the productivity shock, the ability of banks to reduce their equity position wears off. Bank capital increases as required capital-to-asset ratio increases. Compared to the basic setting, I find that loans do not decrease as much as in the basic setting since the loan rate does not increase as much.

Since $\bar{\gamma}$ remains the same in the dynamic provisioning setting as in the basic case, the TFP shock does not affect the bank's borrowing constraint similarly as in the cyclical requirements case. However, as output decreases, the requirement to build a buffer of loan loss reserves decreases as non-performing loan rates rise above the steady state level and the bank is allowed to use loan loss provisions. The results of the IRFs are smaller than the ones in the Basel III setting. The reason lies in the calibration of the instruments. They would have been equivalent if

$$\chi\left(\frac{L_{t-1}-\bar{L}}{\bar{L}}\right)=\lambda\omega\left(\frac{Y_{t-1}-\bar{Y}}{\bar{Y}}\right) \tag{39}$$

If the credit gap rises faster than the output gap, the Basel III buffer is larger even if χ were equal to $\lambda\omega$. This is exactly the case in times of excessive credit growth or a credit crunch.

Additionally, if we assume that the Basel buffer increases up to its maximum value of 2.5%, the value of χ to allow for this increase is equal to 2, which is approximately 40 times higher than the loan loss provisioning buffer calibration of $\lambda\omega = 1 \times 0.0473$, and hence the Basel buffer exceeds the loan loss provisoning buffer in size.

1.4.3 Economic fluctuations

In this section, I want to estimate the effect of the introduction of the macroprudential instruments on the variability of key macroeconomic variables. For this purpose, I study the unconditional standard deviation of these variables and compare them to the basic setting.[42] The impulse response functions have indicated that the basic countercyclical buffers established so far only provide little stabilization for the economy. Using unconditional standard deviation helps to quantify these effects. The results are depicted in Figure 5 showing the unconditional standard deviations of output (σ_Y), consumption (σ_C), and lending (σ_L).

I find that the introduction of macroprudential instruments is able to reduce the standard deviation of selected macroeconomic variables after a technology shock but only marginally. The reduction relative to the basic setting ranges from 1.1% in consumption to up to 2.9% in lending. The standard deviation of output is reduced by 1.3%. In contrast, the Basel III buffer reduces the volatility of output by 13.8%, consumption by 11.6% and lending fluctuations by 35.8%. This reduction in output volatility lies in the range determined by Angelini et al. (4) from 10% to 22% reduction.[43] If regulators want to focus on smoothing macroeconomic fluctuations, they have more freedom to calibrate such a systemic risk buffer. The Spanish provisioning system is strictly calibrated towards expected loan losses. The regulator does not have any opportunities to adjust this buffer if systemic risk in the banking sector is increasing and there is a substantial risk that losses might be underestimated. If this is the case, the buffer is insufficient to cover dramatic losses similar to the ones in the recent financial crisis. The medium risk bucket implies an expected long term risk of 2.5% p.a. which was adequate prior to the financial crisis but not in its aftermath. In order to examine the performance of the two buffers in light of the recent financial crisis, I use this model to analyse a sequence of unexpected credit losses next.

[42] This measure is only an approximation of macroeconomic fluctuations. I use first-order approximations of this model which might affect the results. A more thorough analysis would require higher order approximations. However, this approximate approach has been commonly used in the literature to provide indications regarding macroeconomic fluctuations. For details on the approach, please refer to Angelini et al. (4)

[43] Angelini et al. study the reduction of output volatility for a variety of macroeconomic models that introduce a countercyclical capital requirement.

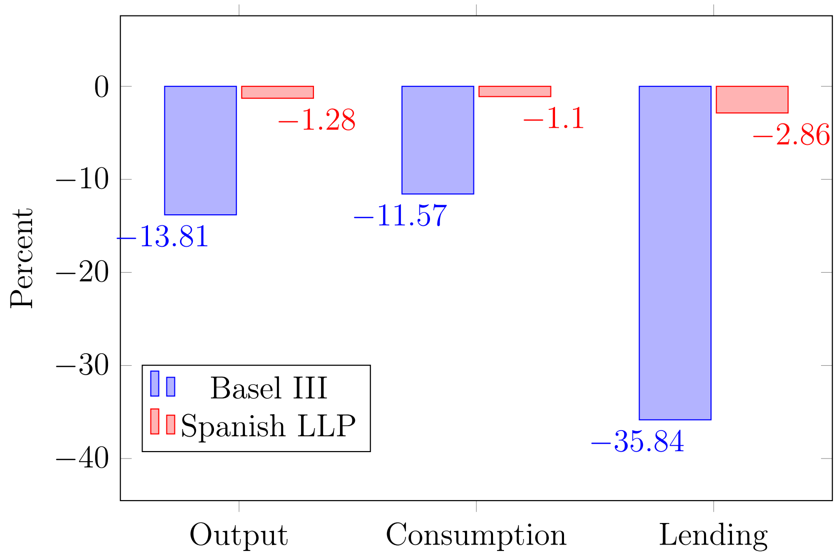

Figure 5: Change in unconditional standard deviation after TFP shock

1.5 Extension: Capital buffer during financial crisis

In addition, I aim to examine whether the two instruments would have been sufficient to mitigate the credit crunch and resulting recession that hit the Euro area as a consequence of the financial crisis. Particularly at the periphery of the Euro area, an increase in non-performing loan rates led to massive credit losses which could not be absorbed by highly leveraged banking sectors. In this section, I introduce such a large shock to non-performing loan rates to determine how much banks need to deleverage in response to such a shock in this model and whether this could be mitigated by the buffers discussed. Non-performing loan rates are thus assumed to follow the process

$$J_t = (1 - \rho_J)\bar{J} - \omega\left(\frac{Y_{t-1} - \bar{Y}}{\bar{Y}}\right) + \rho_J J_{t+1} + \epsilon_t^J \tag{40}$$

I extend Equation (8) by ϵ_t^J, representing a potential financial shock to the non-performing loan rate that is not directly corresponding to change in the output gap. I introduce a sequence of unexpected shocks to ϵ_t^J, each quarter equal to 0.25 percentage points which lasts 24 quarters and increases the non-performing loan rate to 8.2% after 6 years before the non-performing loan rate gradually returns to its steady state. Figure 6 shows that these non-performing loan rates closely mimic the development in Europe during recent years. Note that an unexpected increase in non-performing loans implies a redistribution of wealth from banks towards the borrowers as entrepreneurs do not repay their loan obligation in full but loose only part of their collateral. As an unexpectedly low fraction of loans are repaid, bank equity is required to cover for the unexpected loss. However, banks remain capital constrained even during a financial crisis. To satisfy the capital requirements, the bank reduces assets by providing fewer loans,

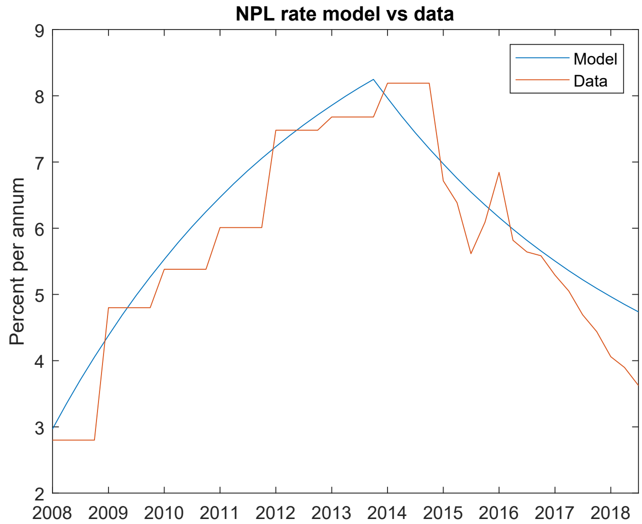

Figure 6: NPL rate shock of the model and development of NPL rate in Europe 2008Q1-2018Q1

thereby reducing credit supply. Banks charge higher risk premia for corporate loans and hence the lending rate increases. As loans drop by approximately 6% over the shock period, investment decreases leading to slower accumulation of capital. The result is a contractionary effect on output of 2%, illustrated in Figure 7. The Figure also shows that the introduction of a Basel III buffer mitigates shock responses only marginally. The same is found for the introduction of a dynamic loan loss provisioning buffer. Figure 8 shows the change in unconditional standard deviation after the non-performing loan shock if either one of the instruments is introduced. The Basel buffer shows a slightly better performance in terms of reducing volatility again.

However, as the impulse response functions in Figure 7 have indicated, the shock responses are not yet fully mitigated through the Basel buffer. Credit losses this substantial require a larger buffer. We can find out the required buffer size by optimising over the Basel rule of Equation (17) in order to minimise the volatility of output. Benes and Kumhof (2015) have taken a similar approach in order to identify the optimal sensitivity of countercyclical capital requirements to changes in economic fundamentals. Grid searching over χ in the Basel rule gives $\chi = 12$. I choose grid sizes of 0.1 to provide an indication of the required parameter.[44] Figure 9 shows the impulse response function of γ_t with this value of $\chi = 12$ after a sequence of non-performing loan rate shocks similar to the financial crisis. It illustrates that minimising output volatility would require the capital buffer to decrease by 26 percentage points to cover losses of this magnitude.

[44] It would be possible to increase accuracy by reducing the grid size further. However, since we are only interested in an indication for the required buffer, the choosen grid size seems appropriate.

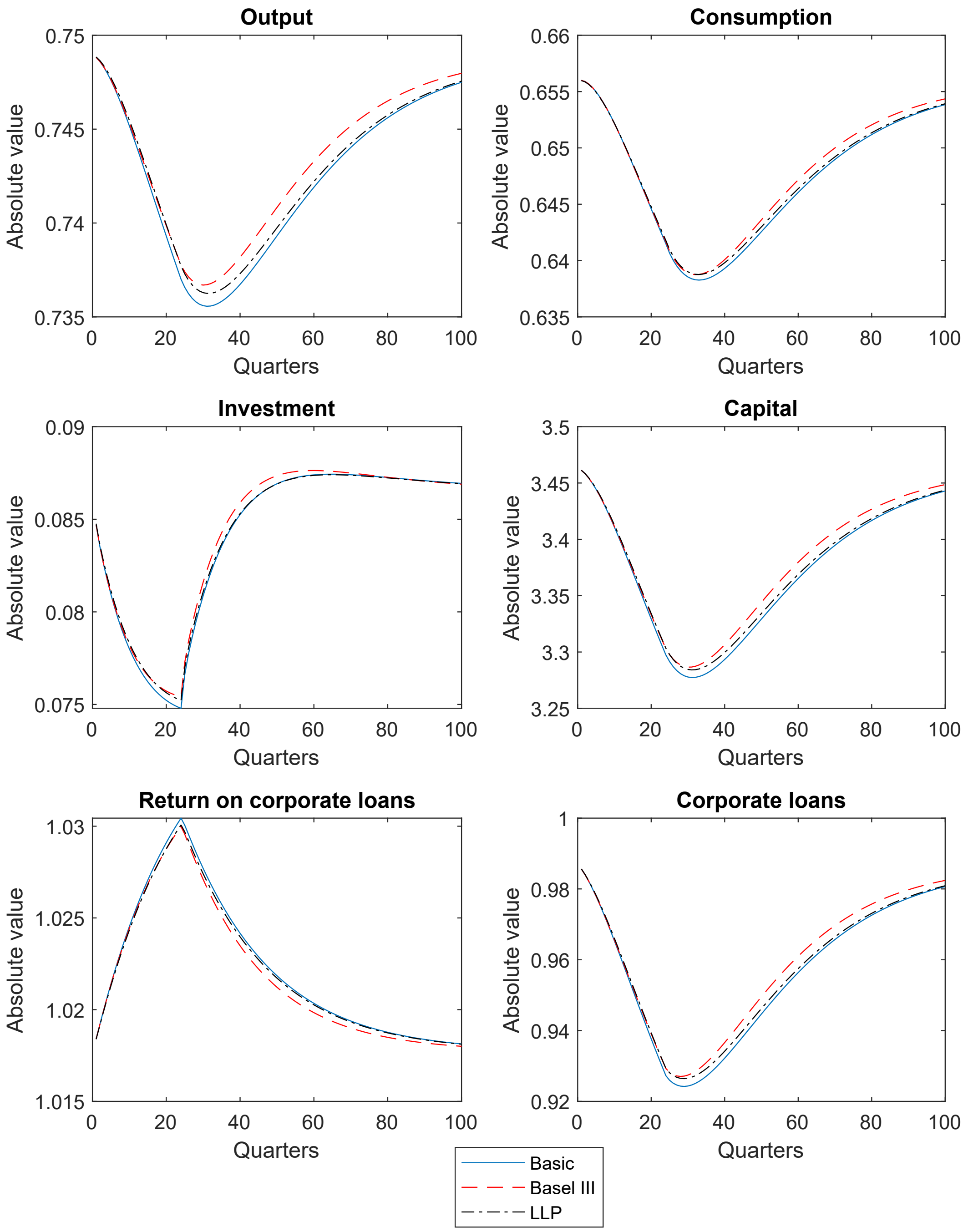

Figure 7: Impulse response functions after a sequence of NPL shocks for different regulatory regimes

1.6 Conclusion

The paper examines the interaction of different countercyclical instruments with business cycle fluctuations in a dynamic stochastic general equilibrium model with imperfections on credit markets. Key imperfections in this model are constraints on bank leverage and an

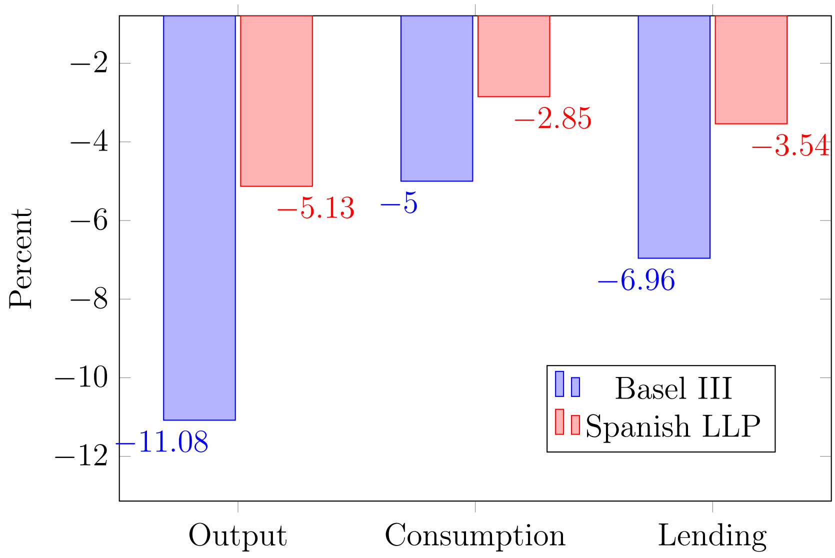

Figure 8: Change in unconditional standard deviation after NPL shock

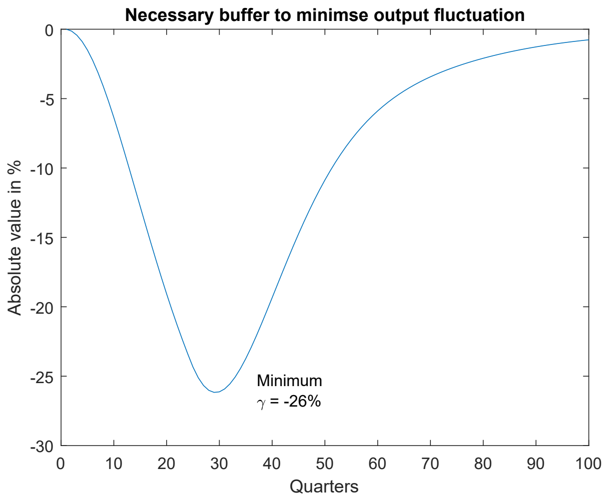

Figure 9: Optimal countercyclical capital buffer minimising output fluctuation after NPL shock

entrepreneurial sector which depends on bank loans for their investment. I have introduced two different macroprudential instruments commonly suggested in the regulatory debate to smoothen economic volatility and corporate lending. The first instrument introduced is a countercyclical capital requirement, which is a prominent feature of the Basel III accords. It is suggested as a backward-looking instrument calibrated according to early warning signals to react to rising systemic risk. This is consistent with the view that bank capital is used to cover unexpected losses. The second instrument considered are dynamic loan loss provisions that are set up as a forward-looking instrument set aside to cover expected losses. I have calibrated the instruments in accordance with their recent policy proposals. Due to the intention of the Basel III capital buffer to react to excessive credit growth, it is tuned to the change in the loan gap. The capital buffer is allowed to range between 0 and 2.5%. Similar numerical experiments show an improvement of the instrument's ability to smoothen macroeconomic volatility by 14 percent. In contrast, dynamic loan loss provisions as introduced by the Bank of Spain reduced output volatility only by 1.3%. As the performance of the Spanish banking sector during the crisis suggested, these provisioning buffers were too small to adequately cover large credit losses and thus did not help to smooth macroeconomic fluctuations.

This result is confirmed if we consider a sequence of non-performing loan shocks similar to the amounting credit losses in the recent crisis. Both instruments fall short in limiting macroeconomic fluctuation significantly although the Basel buffer performs slightly better. A minimisation of output fluctuations would require a substantial Basel III buffer of 26%.

The analysis could be extended further. So far, I have focused on the direct effects of the regulatory instruments. As banks' capital constraint is always binding, banks are not defaulting and hence financial instability has no costs. Consistent with the turmoils subsequent to the financial crisis, it would be interesting to study to which extent the change in regulation could affect the probability of default of the bank itself. This would require to endogenise bank's equity risk premium such that equity funding costs depend on bank's stability or macroeconomic fundamentals. Theory on CAPM suggests that riskier assets require higher return such that capital for banks with higher capital buffer should pay lower premia. Despite the solid theoretical rational, Baker and Wurgler (7) have found empirical evidence that this might not be the case. Additionally, the risk premium is likely to depend on the quality of the loan portfolio, i.e. the non-performing loan rate. Taking this assumption to the data for the Euro area again suggests that this might not have been the case during the crisis. Therefore, more research into this equity premium puzzle would be required in order to account for the costs of financial instability in form of higher equity risk premia. In addition, I have modelled bank loans such that they mature after exactly one period. Banks are thus able to quickly clean up their balance sheets after downturns and recover from loan losses in a short period of time. Considering the banking sector in Italy and Greece after the crisis, this assumption might be quite strong and neglect the effects known as 'Zombie lending'. It would therefore be highly interesting to allow for loans with longer maturities that could either be terminated prematurely or dragged along on bank's balance sheet and evaluate how countercyclical regulation would affect the tendency to keep these loans on the balance sheet.

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1.A Appendix

1.A.1 List of Notations

Variables	
A	Total Factor Productivity
C^P	Household's consumption
C^E	Entrepreneur's consumption
D	Deposits
ϵ_A	Standard deviation of TFP shock
ϵ_J	Standard deviation of NPL shock
γ	Time-varying capital requirement for bank loans
H	Labour demand
I	Investment
J	Non-performing loan rate
K^B	Bank capital
K^E	Firm capital
λ^E	Multiplier on entrepreneur's borrowing constraint
L	Corporate loans
LLP	Loan loss provisions
N	Labour supply
Π	Bank profit
R^D	Deposit rate
R^E	Corporate loan interest rate
R^K	Return on capital
R^{KB}	Return on bank capital
TK	Total capital after LLP expense
W	Wage
Y	Output
Parameters	
α	Share of capital in production function
β_P	Discount factor savers
β_E	Discount factor entrepreneurs
χ	Sensitivity of countercyclical capital requirement
δ	Depreciation of capital
ϵ_A	Standard deviation of TFP shock
$\bar{\gamma}$	Capital requirement for bank loans
$\bar{J}$	Average NPL rate
κ	Collateral value after bankruptcy
m_E	Corporate LTV ratio
ω	Sensitivity of NPLs w.r.t. output gap
ρ_A	Persistence of TFP shock
ρ_γ	Persistence of time-varying capital requirement
ρ_J	Persistence of NPL shock
τ	Weight on leisure in utility function
ξ	Equity risk premium

Table 3: List of Notations

1.A.2 Optimisation problems

HOUSEHOLD: The Lagrangian for the representative household's optimisation problem is

$$\begin{aligned}\mathscr{L}_t = E_t\Big\{ \sum_{t=0}^{\infty} \beta^t[\log(C_t) + \tau\log(1-N_t)] \\ + \lambda_t^H[C_t^P + D_t + K_t^B - W_tN_t - R_{t-1}^D D_{t-1} - R_{t-1}^{K^B} K_{t-1}^B - \Pi_t]\Big\}\end{aligned} \tag{41}$$

The first-order conditions with respect to consumption, labour as well as investments in deposits derived from this optimisation problem are

$$\frac{\partial \mathscr{L}_t}{\partial C_t} = \frac{1}{C_t} + \lambda_t^H = 0 \tag{42}$$

$$\frac{\partial \mathscr{L}_t}{\partial N_t} = \frac{\tau}{1-N_t} - \lambda_t^H W_t = 0 \tag{43}$$

$$\frac{\partial \mathscr{L}_t}{\partial D_t} = \lambda_t^H - \beta E_t[\lambda_{t+1}^H R_t^D] = 0 \tag{44}$$

Rearranging Equation (42) and substituting into Equation (44) yields the usual Euler equation determining the optimal consumption path

$$\frac{1}{C_t} = \beta E_t\left[R_t^D \frac{1}{C_{t+1}}\right]. \tag{45}$$

ENTREPRENEUR: Similarly to Iacoviello (2015) I denote $u_{CE,t}$ as the marginal utility of consumption and $\lambda_t^E u_{CE,t}$ as the normalized borrowing constraint. The Lagrangian for the representative entrepreneur's optimisation problem is

$$\begin{aligned}\mathscr{L}_t =& E_t\Big\{ \sum_{t=0}^{\infty} \beta_E^t\left[\log(C_t^E)\right] + \mu_t^E\Big[C_t^E + K_t^E + (1-J_t)R_{t-1}^E L_{t-1} + J_t m_E K_{t-1}^E + W_t H_t \\ & - Y_t - (1-\delta)K_{t-1}^E - L_t\Big] + \lambda_t^E u_{CE,t}\left[m_E \frac{K_t^E}{R_t^E} - L_t\right]\Big\}\end{aligned} \tag{46}$$

The first-order conditions with respect to consumption, bank loans, capital investment, and labour demand derived from this optimisation problem are given as

$$\frac{\partial \mathscr{L}_t}{\partial C_t^E} = \frac{1}{C_t^E} + \mu_t^E = 0 \tag{47}$$

$$\frac{\partial \mathscr{L}_t}{\partial L_t} = -\mu_t^E - \lambda_t^E u_{CE,t} + \beta_E E_t\Big[\mu_{t+1}^E(1-J_{t+1})R_t^E\Big] = 0 \tag{48}$$

$$\frac{\partial \mathscr{L}_t}{\partial K_t^E} = \mu_t^E + \lambda_t^E u_{CE,t} m_E/R_t^E + \beta_E E_t\Big[\mu_{t+1}^E[J_{t+1}m_E - \alpha Y_{t+1}/K_t^E - (1-\delta)]\Big] = 0 \tag{49}$$

$$\frac{\partial \mathscr{L}_t}{\partial H_t} = \mu_t(W_t - (1-\alpha)Y_t/H_t) = 0 \tag{50}$$

Rearranging Equation (47) and substituting into Equation (48) yields the consumption Euler equation as

$$(1-\lambda_t^E)u_{CE,t} = \beta_E E_t[((1-J_{t+1})R_t^E)u_{CE,t+1}]. \tag{51}$$

Capital demand is given by substituting Equation (47) into Equation (49), using user cost of capital $R_t^K = \alpha Y_t / K_t^E$ and arranging to

$$\begin{aligned}(1-\lambda_t^E\frac{m_E}{R_t^E})u_{CE,t} &= \beta_E E_t[(1-\delta+\alpha Y_{t+1}/K_t^E - J_{t+1}m_E)u_{CE,t+1}]\\ &= \beta_E E_t[(1-\delta+R_{t+1}^K - J_{t+1}m_E)u_{CE,t+1}].\end{aligned} \tag{52}$$

Labour demand is given by Equation (50) as

$$W_t H_t = (1-\alpha)Y_t \tag{53}$$

BANK: Substituting the capital requirement constraint into the bank's optimisation problem yields the Lagrangian as

$$\mathscr{L}_t = E_t\Big\{\sum_{t=0}^{\infty}\beta_P^t\Big[(1-J_t)R_{t-1}^E L_{t-1} + J_t\kappa R_{t-1}^E L_{t-1} - R_{t-1}^D D_{t-1} - R_{t-1}^{KB}\gamma L_{t-1} + \gamma L_t + D_t - L_t\Big]\Big\} \tag{54}$$

The first-order conditions with respect to deposits and lending are given as

$$\frac{\partial \mathscr{L}_t}{\partial D_t} = 1 - \beta_P R_t^D = 0 \tag{55}$$

$$\frac{\partial \mathscr{L}_t}{\partial L_t} = \gamma - 1 + \beta_P\Big[(1-J_{t+1})R_t^E + J_{t+1}\kappa R_t^E - R_t^{KB}\gamma\Big] = 0 \tag{56}$$

1.A.3 List of Equations

The model is described by the following set of equations. I denote with **CCR** and **LLP** switches equal to 1 if the respective instrument is used, 0 if not.[45]

$$C_t^P + D_t - R_{t-1}^D D_{t-1} + K_t^B - R_{t-1}^{KB} K_{t-1}^B - W_t N_t = \Pi_t \tag{57}$$

$$u_{CP,t} = \beta_P u_{CP,t+1} R_t^D \tag{58}$$

$$W_t u_{CP,t} = \tau/(1 - N_t) \tag{59}$$

$$R_t^{KB} = \xi R_t^D \tag{60}$$

$$\begin{aligned} \Pi_t =& (1 - J_t) R_{t-1}^E L_{t-1} + J_t \kappa R_{t-1}^E L_{t-1} + D_t + K_t^B \\ & - R_{t-1}^D D_{t-1} - L_t - R_{t-1}^{KB} K_{t-1}^B \end{aligned} \tag{61}$$

$$LLP_t = \lambda(\bar{J} - J_t) L_t \tag{62}$$

$$K_t^B - \mathbf{LLP} LLP_t = \textbf{(1-CCR)} \bar{\gamma} L_t + \mathbf{CCR} \gamma_t L_t \tag{63}$$

$$J_t = (1 - \rho_J)\bar{J} - \omega \left(\frac{Y_{t-1} - \bar{Y}}{\bar{Y}} \right) + \rho_J J_{t-1} \tag{64}$$

$$K_t^B - \mathbf{LLP} LLP_t + D_t = L_t \tag{65}$$

$$\begin{aligned} R_t^E =& \frac{1}{1 - (1 - \kappa) J_{t+1}} \Big[\textbf{(1-CCR)}(1 - \bar{\gamma}) + \mathbf{CCR}(1 - \gamma_t) \\ & + \textbf{(1-CCR)} \bar{\gamma} R_t^{KB} - \mathbf{CCR} \gamma_t R_t^{KB} + \mathbf{LLP} \left[(\bar{J} - J_t) R_t^{KB} - (\bar{J} - J_t) R_t^D \right] \Big] \end{aligned} \tag{66}$$

$$\gamma_t = (1 - \rho_\gamma)\bar{\gamma} + \chi \left(\frac{L_{t-1} - \bar{L}}{\bar{L}} \right) + \rho_\gamma J_{t-1} \tag{67}$$

[45] These switches are necessary to write matlab and Dynare codes that include all three settings in one code.

$$C_t^E + K_t^E + (1 - J_t)R_{t-1}^E L_{t-1} + J_t m_E K_{t-1}^E + W_t H_t = Y_t + (1 - \delta_K)K_{t-1}^E + L_t \tag{68}$$

$$Y_t = A_t(K_{t-1}^E)^\alpha (N_t)^{1-\alpha} \tag{69}$$

$$L_t = m_E \frac{K_t^E}{R_t^E} \tag{70}$$

$$(1 - \lambda_t^E)u_{CE,t} = \beta_E[(1 - J_{t+1})R_t^E u_{CE,t+1}] \tag{71}$$

$$(1 - \lambda_t^E \frac{m_E}{R_t^E})u_{CE,t} = \beta_E[(1 - \delta_K + R_{t+1}^K - J_{t+1}m_E)u_{CE,t+1}] \tag{72}$$

$$\alpha Y_t = R_t^K K_{t-1}^E \tag{73}$$

$$(1 - \alpha)Y_t = W_t H_t \tag{74}$$

$$H_t = N_t \tag{75}$$

$$\zeta_t = C_t + I_t + m_E(1 - \kappa)J_t K_{t-1}^E - Y_t \tag{76}$$

1.A.4 Steady state

$$R^D = 1/\beta_P \tag{77}$$

$$R^{KB} = \xi R^D \tag{78}$$

$$R^E = \frac{1}{(1 - J(1-\kappa))}\left[(1-\gamma)R^D + \gamma\xi R^D\right] \tag{79}$$

$$\lambda_E = 1 - \beta_E(1-J)R^E \tag{80}$$

$$R^K = (1 - \lambda_E \frac{m_E}{R^E})/\beta_E - (1 - \delta - J m_E) \tag{81}$$

Households consume

$$C^P = (R^D - 1)D + (R^{KB} - 1)K^B + WN + \Pi \tag{82}$$

where capital requirements must be met:

$$D = (1-\gamma)(L), \quad K^B = \gamma L \tag{83}$$

and from Equation (9) loans are given as $L = m_E \frac{K_E}{R^E}$.
Bank profits are given by $\Pi = (1-J)R^E L + J\kappa R^E L - L - (R^D - 1)D - (R^{KB} - 1)\gamma L$ which are equal to zero in the steady state.
This gives consumption of households according to

$$\begin{aligned} C^P &= (R^D - 1)(1-\gamma)L + (R^{KB} - 1)\gamma L + WN \\ &= (R^D - 1)(1-\gamma)m_E\frac{K^E}{R^E} + (\xi R^D - 1)\gamma m_E \frac{K^E}{R^E} + WN \\ &= ((R^D - 1)(1-\gamma) + (\xi R^D - 1)\gamma)m_E\frac{K^E}{R^E} + WN \\ &= oo1 m_E \frac{K^E}{R^E} + WN \end{aligned} \tag{84}$$

with $oo1 = ((R^D - 1)(1-\gamma) + (\xi R^D - 1)\gamma)$. Rearranging Equation (13) gives $K^E = \frac{\alpha}{R^K} Y$ which can be substituted for K^E in Equation (84):

$$C^P = oo1 m_E \frac{\alpha}{R^K R^E} Y + WN \tag{85}$$

Using Equation (12), $WN = (1-\alpha)Y$, since $N = H$ in equilibrium and substituting into the previous equation gives

$$\begin{aligned} C^P &= \left(1 + oo1\frac{m_E}{R^K R^E}\frac{\alpha}{(1-\alpha)}\right) WN \\ &= (1 + oo1oo2)WN \end{aligned} \tag{86}$$

with

$$oo2 = \frac{m_E}{R^K R^E}\frac{\alpha}{(1-\alpha)}. \tag{87}$$

From the Equation (4)

$$\begin{aligned} \frac{W}{C^P} &= \frac{\tau}{1-N} \\ \frac{W}{(1 + oo1oo2)\, WN} &= \frac{\tau}{1-N} \\ N = \frac{1}{1 + (oo1oo2 + 1)\tau} \end{aligned} \tag{88}$$

The remaining steady state variables are calculated as follows

$$\begin{aligned} Y &= A(K^E)^\alpha N^{1-\alpha} \\ &= \left(\frac{\alpha}{R^K} Y\right)^\alpha N^{1-\alpha} \\ &= \left(\frac{\alpha}{R^K}\right)^{\frac{\alpha}{1-\alpha}} N \end{aligned} \tag{89}$$

$$K^E = \frac{\alpha}{R^K} Y \tag{90}$$

$$L = m_E \frac{K^E}{R^E} \tag{91}$$

$$W = (1-\alpha)\frac{Y}{N} \tag{92}$$

$$D = (1-\gamma)(L) \tag{93}$$

$$C^P = (R^D - 1)D + (R^{KB} - 1)K^B + WN \tag{94}$$

$$C^E = Y -^E -((1-J)R^E - 1)L - Jm_E K^E - WN \tag{95}$$

$$K^B = L - D \tag{96}$$

1.A.5 Equilibrium: Walras' Law

Market clearing implied by Walras' Law can be shown by aggregating all budget constraints.

$$C_t^P + D_t + K_t^B = R_{t-1}^D D_{t-1}^D + R_{t-1}^{KB} K_{t-1}^B + W_t N_t + \Pi_t \tag{97}$$

$$C_t^E + K_t^E + (1 - J_t) R_t^E L_{t-1} + J_t m_E K_{t-1}^E + W_t H_t = Y_t + (1 - \delta) K_{t-1}^E + L_t \tag{98}$$

$$\Pi_t = (1 - J_t) R_{t-1}^E L_{t-1} + J_t \kappa R_{t-1}^E L_{t-1} - R_{t-1}^D D_{t-1} - R_{t-1}^{KB} K_{t-1}^B + D_t - L_t + K_t^B \tag{99}$$

Substitute (99) into (97):

$$\begin{aligned} C_t^P + D_t + K_t^B &= R_{t-1}^D D_{t-1}^D + W_t N_t + (1 - J_t) R_{t-1}^E L_{t-1} + J_t \kappa K_{t-1}^E - R_{t-1}^D D_{t-1} + D_t - L_t + K_t^B \\ C_t^P &= W_t N_t + (1 - J_t) R_{t-1}^E L_{t-1} + J_t \kappa K_{t-1}^E - L_t \end{aligned} \tag{100}$$

Rearrange (98) such that

$$(1 - J_t) R_t^E L_{t-1} = -C_t^E - K_t^E - J_t m_E K_{t-1}^E - W_t H_t + Y_t + (1 - \delta) K_{t-1}^E + L_t \tag{101}$$

and substitute into (100)

$$\begin{aligned} C_t^P &= W_t N_t - C_t^E - K_t^E - J_t m_E K_{t-1}^E - W_t H_t + Y_t + (1 - \delta) K_{t-1}^E + L_t + J_t \kappa R_{t-1}^E L_{t-1} - L_t \\ C_t^P &= W_t N_t - C_t^E - K_t^E - (1 - \kappa) J_t m_E K_{t-1}^E - W_t H_t + Y_t + (1 - \delta) K_{t-1}^E \end{aligned} \tag{102}$$

Rearranging yields identity:

$$W_t (H_t - N_t) + (C_t^P + C_t^E + K_t^E - (1 - \delta) K_{t-1}^E + (1 - \kappa) J_t m_E K_{t-1}^E - Y_t) = 0 \tag{103}$$

The economy is characterized by:

$$Y_t = C_t^P + C_t^E + I_t + (1 - \kappa) J_t m_E K_{t-1}^E \tag{104}$$

where investment is comprised by

$$I_t = K_t^E - (1 - \delta) K_{t-1}^E \tag{105}$$

1.A.6 Data used in calibration

- Loans: Consolidated value of long-term and short-term loans in Mio. EUR for the non-financial sector of the European Union, Annual, Eurostat: nasa10fs
- Firm value: Consolidated value of equity and investment shares in Mio. EUR for the non-financial sector of the European Union, Annual, Eurostat: nasa10fs
- Non-performing loan rate: Bank Non-Performing Loans to Gross Loans for Euro Area, Percent, Annual, Not Seasonally Adjusted. Federal Reserve Economic Data: DDSI02EZA156NWD , 1998-2014
- Non-performing loan rate: Bank Non-Performing Loans to Gross Loans for Euro Area, Percent, Quarterly, Not Seasonally Adjusted. Statistical Data Warehouse, 2014-2018
- GDP: Gross Domestic Product (Euro/ECU series) for Euro Area (19 Countries), Millions of Euros, Quarterly. Federal Reserve Economic Data: EUNNGDP
- Credit-to-GDP gap: Credit-to-GDP ratios (actual data) - Euro area - Credit from All sectors to Private non-financial sector. Source: BIS credit-to-GDP gap statistics.
- Lending spread: Bank Lending Deposit Spread for Euro Area (DISCONTINUED), Percent, Annual, Not Seasonally Adjusted. Federal Reserve Economic Data: DDEI02EZA156NWDB
- Return on equity: Bank's Return on Equity for Euro Area (DISCONTINUED), Percent, Annual, Not Seasonally Adjusted. Federal Reserve Economic Data: DDEI06EZA156NWDB

Chapter 2

Deposit funding problems and stabilising effects of countercyclical capital regulation

Linda Kirschner[1]

During the recent financial crisis, banks experienced funding problems on the interbank market that led to a credit crunch in the real economy. Banks without access to household deposit funding were more affected than others. I develop a dynamic general equilibrium model with financial intermediaries that face real costs for attracting deposit funding from households. Optimizing banks use these funds in combination with their scarce capital to lend to the entrepreneurial sector. I analyse the consequences of unexpected loan losses as well as varying access to debt funding and the resulting fluctuations in the real economy and the banking sector. Extending the model by an interbank market allows to additionally examine the consequences of a LIBOR shock. I apply the framework for the analysis of macroprudential policy by estimating the potential of a countercyclical capital requirement to offer relief to bank balance sheets, thereby allowing banks to cut credit less in times of crisis and reducing macroeconomic volatility. The paper shows that countercyclical capital regulation has a stabilising effect, particularly in case of financial shocks to the credit supply side.
JEL Classification: E3, E44, G01, G21

[1]I thank Christian Keuschnigg, Javier Suarez, Jochen Mankart, and seminar participants at University of St.Gallen for helpful discussion and comments.

2.1 Introduction

During the recent financial crisis, banks have faced difficulties in intermediating financial transactions between households and firms as well as amongst each other. Slowed growth led to increases in non-performing loan rates when firms defaulted on obligations towards their banks. These unexpected credit losses needed to be covered by bank capital, which became increasingly scarce. In order to comply with regulation, banks needed to deleverage and reduce credit to the real economy causing a credit crunch and further deterioration of economic growth. Increasing vulnerability in the banking sector towards economic shocks led to a rapid reduction of interbank funding and a credit crunch on the interbank market. Bank's ability to fund themselves with both debt and equity rapidly diminished, introducing the economy to a financial accelerator of reduced investment and net worth as well as higher default rates and decreasing credit supply. In this paper, I analyse how varying access to debt funding affects the banking sector and transmits to the real economy.

Prior to the crisis, macroeconomic models mostly incorporated financial intermediaries as a veil, working without frictions. As the financial crisis unfolded, it became clear that this view was incorrect. As a result, regulators and academics have focussed on bank's equity funding to enhance financial stability.[2] However, a lack of equity funding was not the only pressing issue in the banking sector after the crisis. Banks faced additional trouble in receiving debt funding.[3] This scarcity of funding hit banks differently as they faced different costs in adjusting their debt funding. Banks' ability to attract new deposits depends on several bank-specific and geographic characteristics. Remarkably, empirical research on the recent credit crunch has proven the relevance of banks' access to deposit funding for the cyclicality of credit supply. A study by Ivashina and Scharfstein (29) shows that banks with access to deposit financing cut lending less during the crisis than banks with restricted access to deposit financing. They find that banks with the median deposit-to-asset ratio have reduced their loan origination by 36% during the second half of 2008.[4] In contrast, banks with deposit-to-asset ratios one standard

[2]The crisis has shown that microprudential regulation soley based on the risk of individual financial institutions is insufficient to ensure the stability of the financial system. Researchers agree that microprudential capital regulation as in Basel II has led to a tightening of the credit crunch due to a reluctance of shareholders to increase banks' capital in recessions combined with a strict capital-to-asset requirement. In order to satisfy the capital requirement, banks needed to reduce their assets, i.e., the credit supply to the real economy, exactly at a time when credit would have been necessary to stimulate the economy. This increase in procyclicality of credit supply became one of the central points for macroprudential policy to address.

[3]This lack of funding was particularly severe on the interbank market. The LIBOR-OIS spread, a measure indicating funding conditions on the interbank market, rose by 2 percentage points at the end of 2007, indicating a serious credit crunch.

[4]They focus on the second half of 2008 as the failure of Lehman Brothers initiated a run by short-term creditors, marking the beginning of the troubles on the interbank market and the peak of the financial crisis.

deviation below the median reduced loan origination by 49% at the same time and the group one standard above median cut new lending only by about 21%. The banks with limited access to deposit funding had to rely mainly on short-term financing from the interbank market.[5] To analyse how access to deposit funding affects bank lending, I set up a stylised banking sector in a DSGE model.

The model developed in this paper bases on the seminal work by Bernanke et al. (8) and extends it by implementing a banking sector that is subject to capital regulation and requires real resources to attract deposits. Therefore, there exists a positive interest rate spread between corporate loans and debt funding. The model can be used for an indication on how bank's individual access to deposit funding influences the decision of credit supply. Furthermore, the model explicitly accounts for bank capital regulation. I use this capital requirement to introduce a countercyclical buffer in vein of Basel III to determine whether macroeconomic volatility can be mitigated by the introduction of this macroprudential measure. To examine the impact of the interbank market, I extend the framework to allow for heterogenous access to deposit funding in a monopolistically competitive banking sector. Banks with higher deposit funding costs can approach the interbank market for debt funding, but are hence highly dependent on the conditions on the interbank market.

Firstly, I investigate how the competitive banking sector reacts to business cycle fluctuations and find that adverse shocks to productivity lead to reductions in bank's leverage which in turn reduces investment. Secondly, I examine the consequences of financial shocks from the demand side of credit, illustrated as an increase in borrower's riskiness, and the supply side, modelled as a shock to bank's marginal cost of debt funding and find them to cause macroeconomic contractions. In order to find out whether one of these shocks has more severe effects, I make the shocks comparable and find that a demand-side shock has smaller consequences than a shock to the supply-side of credit. Applying the model, I examine whether the capital buffer proposed under Basel III regulation can reduce macroeconomic volatility.[6] Macroeconomic volatility is captured by the standard deviation of several variables like output, consumption, and lending. I find that output fluctuations after funding cost shocks can be reduced by 10% while there is almost no effect in the case of productivity shocks where fluctuation only decreases by 2% if countercyclical regulation is introduced. In case of a shock to entrepreneur's riskiness, countercyclical capital requirements allow banks to hold even more of these risky loans such that

[5]These findings are confirmed by a similar study by Iyer et al. (30) for the European interbank market.

[6]The focus of this paper is regulation through bank capital, since this is closely related to existing regulatory settings and also the macroprudential focus of the Basel III framework. However, the model presented in this paper lends itself easily to the analysis of monetary policy as well.

output fluctuation actually increases by 23% compared to the basic setting. An increase in entrepreneur's riskiness leads to a rise in defaults and thus losses in the banking sector. Introducing a countercyclical capital requirement that does not take into account this rise in risk allows banks to lower their capital cushion exactly at a time when it should be substantial in order to cover losses. In setting capital rules, regulators face a trade-off between bank's ability to absorb losses and bank's ability to extend credit. An interbank market rate shock is an additional funding cost shock to the credit supply side and also has significant macroeconomic impact. The introduction of a countercyclical buffer also serves to mitigate overall fluctuations in this case.

Overall, if a countercyclical buffer is introduced the fluctuation of lending decreases by 7% in case of non-financial shocks and by more than 20% in case of financial shocks.

2.2 Literature

This paper draws from a large literature about including financial frictions in general equilibrium models, most notably the work by Bernanke et al. (8) commonly quoted as the 'BGG model' or 'financial accelerator model'. Typically, financial frictions have proven to amplify the impact of shocks.[7] BGG have introduced the costly state verification framework by Townsend (40) into a macroeconomic model to study frictions of limited liability and information asymmetries between borrowers and financial intermediaries. Their set up microfounds the use of debt funding and bankruptcy related deadweight losses. I will deviate from BGG and related frameworks in that banks have to share risk with entrepreneurs and therefore face uncertainty in their asset portfolios.

Since 2007, macroprudential policy as well as the implementation of financial sectors into standard DSGE models has gained more and more attention in the political and academic debate. Important recent contributions are Gerali et al. (23); Gertler and Karadi (24); Angeloni and Faia (5); Christiano et al. (13); Angelini et al. (2) and Benes and Kumhof (7). These theoretical models focus on economies where equity funding is scarce but deposit funding from households is always available. Empirical research, however, suggests that this is not necessarily the case in reality and that banks differ in their ability to attract deposits from households, particularly based on geographic areas. Despite the significant trouble on debt markets during the financial crisis, few theoretical papers actually focus on banks' difficulties in receiving deposit funding. The empirical literature has not yet established a clear consensus on the amount and the range of the costs for attracting deposits. One main reason for the lack of a common benchmark

[7] See Brunnermeier et al. (9) for an extensive literature survey.

is that there exist a variety of services which are not associated with explicit fees that influence the costs of attracting new depositors. Various papers have addressed these implicit costs and service fees to provide an approximation. The results provided by Carbo-Valverde et al. (10) prove that banks offer higher deposit rates in areas with a larger fluctuation of residents whereas deposit rates are significantly lower in rural areas where residents tend to stay longer and are hence locked in. According to Fixler et al. (22) the services that lead to dispersion in bank's ability to attract new deposits include convenient locations for branches, the set up and maintenance of electronic payment systems and ATM transaction services. Dick (19) has shown that banks are able to attract customers by increasing branch staffing as well as the geographic density of branches. Egan et al. (20) find that another important factor is the density of the ATM network. Hafstead and Smith (25) aim at estimating these implicit costs by analysing cross sectional wage payments to bank employees managing and advertising deposits. Using monthly data on demand deposits and employees engaged in deposit intermediation at commercial bank level, they measured average bank productivity as hours worked relative to the deposit value. They find that banks differ with respect to the labour intensity of deposit intermediation. While some banks require fewer staff members and branches to manage and advertise deposits, other banks need more staff to act as deposit intermediator and therefore face higher costs for deposit management.

Additionally, this paper is related to several other papers incorporating a banking sector with an interbank market into standard DSGE models. These papers include Gerali et al. (23); Dib (18); Carrera et al. (12); De Walque et al. (16) who set up an interbank market by distinguishing ex-ante into lending and borrowing banks with different optimisation problems. In contrast to these papers, all banks in this paper serve the same dual purpose of intermediation between households and firms as well as exchanging wholesale funds with each other. They have the same optimisation problem ex-ante but they might face different deposit funding costs introducing heterogeneity into the banking sector similarly to the approach developed by Hafstead and Smith (25).

2.3 Model

In this section, I introduce the different sectors of the model economy in order to provide an overview of the basic set up. The model is an extension of the seminal work of Bernanke et al. (8), which contains financial intermediation implicitly. I extend this framework by introducing a banking sector which is subject to several frictions. Firstly, banks face costs for the creation of deposits limiting the amount of debt they are able to receive from the real economy. Secondly, banks lend corporate loans to the real economy where firm's return on capital is sensitive to idiosyncratic risk leaving a fraction of firms unable to repay their loan obligations. Thirdly, banks are required to hold a minimum portion of capital to ensure that they do not take on excessive leverage (i.e. supply too much credit to the real economy). A shock increasing the likelihood that firms default on their loan obligations must be absorbed by bank capital. In order to keep satisfying the capital-to-asset ratio after such a shock, the bank has two options: (i) issue new equity or (ii) reduce the asset position, hence the credit supply. Given expensive equity funding from the household sector, there is only an insufficient increase in the equity position. As a consequence, the immediate reaction of banks is to reduce assets and thus limit the supply of bank credit to the real economy. In turn, this contributes to a deterioration of conditions in the productive sector and thus creates more default, reducing bank capital even further.

2.3.1 Households

Households provide labour to entrepreneurs as well as banks (for deposit production) and receive income. They can decide to spend this income on consumption or on savings in the form of riskless one-period deposits with the bank. In addition, households own bank capital, which they cannot actively invest and disinvest. Households choose consumption, leisure and deposit investment to maximise lifetime utility subject to their intertemporal budget constraint. The representative household's problem is given by:

$$\max_{C_t,H_t,D_{t+1}} E_t \left\{ \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) + \tau \ln(1-H_t) \right] \right\} \tag{1}$$

subject to the intertemporal budget constraint[8]

$$C_t + D_{t+1} + K_{t+1}^B \leq W_t H_t + R_t^D D_t + R_t^{K^B} K_t^B + \Pi_t \tag{2}$$

Utility is separable in consumption (C_t) and leisure where H_t denotes the hours worked. Households receive labour income $W_t H_t$ with W_t denoting the wage per hour. The household enters period t with a stock of K_t^B units of bank capital paying a gross return rate of $R_t^{K^B}$. Moreover, households withdraw their one-period deposits including interest $R_t^D D_t$ and decide on the amount of savings to be placed into the bank in period $t+1$. As a convention, D_t denotes deposits from time $t-1$ to t. The interest rate R_t^D is determined at time $t-1$ and paid in period t. In addition, households receive dividend payments Π_t from both entrepreneurs and

[8] The budget constraint must be binding since individuals receive no utility from holding idle cash. They either spend their income on consumption goods or invest it.

banks such that $\Pi_t = \Pi_t^E + \Pi_t^B$.

Combining the first-order conditions with respect to consumption and saving yields the usual Euler equation determining the optimal consumption path

$$\frac{1}{C_t} = \beta E_t \left[R_{t+1}^D \frac{1}{C_{t+1}} \right]. \tag{3}$$

The household can choose between increasing marginal utility by consuming one more unit today or postponing consumption into the future by depositing one more unit today and receiving interest.

The return on equity investment is exogenously defined as

$$R_t^{KB} = \xi R_t^D, \quad \text{with } \xi > 1 \tag{4}$$

where ξ is the bank capital risk premium which stems from the fact that bank's equity will be used to absorb unexpected loan losses and will thus in turn suffer losses. Viewing bank capital structures from the Modigliani and Miller (34) perspective, both equity and deposit holdings should offer equal returns and households would be indifferent between the two assets. However, this paper assumes that this debt-equity neutrality does not hold because of the bank capital risk premium. Thereby, equity is considered more expensive than debt as households demand a higher return on equity. This is necessary to ensure that i) households are willing to invest a lot in deposits while equity is sparse, and ii) banks are not indifferent between holding equity or deposits but would instead leverage their balance sheets as debt funding is cheaper. Otherwise, there would be no social costs involved in increasing capital requirement ratios significantly. The bank capital risk premium drives a wedge between debt and equity funding in this model setting.[9] I assume that this equity premium is constant over time and does not depend on bank's capital to asset ratio. Markovic (33) and Aguiar and Drumond (1) derived a similar relation between bank capital and the risk free rate, where the premium depended on

[9]Empirically, there exists strong evidence for the existence of such a wedge (Campbell et al 1997, Covas & Den Haan 2012). In the literature, there are a variety of explanations starting from taxation favouring debt over equity (Auerbach 2002), informational frictions introducing a "pecking order" (Myers 1984), vulnerability of equity to misuse by managers (Jensen & Meckling 1976), and adverse selection as issuance of new equity sends signal of poor performance (Myers & Majluf 1984). In my model, the most appropriate explanation would be that deposits benefit from public sector subsidies (i.e., deposit insurance) which gives rise to a spread between debt and equity funding. Though deposit guarantees are not explicitely modelled, bank deposits are assumed to be entirely risk free whereas bank capital might be used to absorb losses on the bank loan portfolio. It is hence reasonable to assume that households will demand a higher return on equity to compensate for the higher risk. This wedge between debt and equity cost ensures that the consequence of loan losses is not just the trivial solution of raising equity.

an exogenously given default risk. Dib (18) and Verona et al. (41) have examined this premium and found that this relationship holds only during normal times. In times of large fincancial distress, the premium is driven by other fundamentals. This is confirmed if we consider data from the Federal Reserve Bank of St. Louis on the return on equity for US banks during the financial crisis. Prior to the crisis, bank equity returns traded at a substantial spread over deposit returns as illustrated in Figure 1. However, as the crisis in the banking sector unfolded in 2008, the spread decreased almost to zero, implying that despite the increase in default risk of banks, other factors were driving the return on bank equity. Since I am considering normal one standard deviation shocks in the quantitative section, the assumption of a constant spread seems appropriate here. However, this simplifying assumption must be treated with caution if considering larger shocks and environments with severe financial distress.[10]

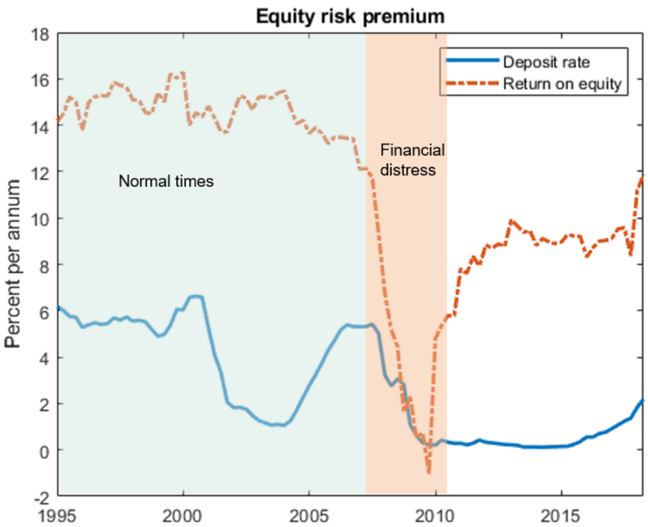

Figure 1: Return on deposits and bank equity in normal times and times of distress

Finally, equation (5) shows the classic trade-off between leisure and consumption where labour supply increases in wage

$$\frac{W_t}{C_t} = \frac{\tau}{1 - H_t}. \tag{5}$$

2.3.2 Final good production

Firms produce a consumption good using identical Cobb-Douglas production functions with capital and labour input. Labour is mobile across firms and the labour market is perfectly

[10]It would be interesting for further research to add a time-varying risk premium that depends on both the risk of default of the borrowing firm as well as the bank's capital to asset ratio. See Dib (18) and Tayler and Zilberman (39) for such studies.

competitive. The capital is rented from the entrepreneurs. This sector is not directly affected by financial frictions. I assume constant returns to scale technology since it allows to focus on aggregate production, i.e., firm size becomes irrelevant for the simulation. The production function follows

$$Y_t = A_t(K_t)^{\alpha}(H_t^P)^{1-\alpha} \tag{6}$$

with Y_t indicating output, A_t total factor productivity (TFP), α an elasticity parameter, K_t aggregate capital and H_t^P households' labour input. TFP follows an AR(1) process according to

$$A_t = (1-\rho_A)\bar{A} + \rho_A A_{t-1} + \epsilon_t^A \tag{7}$$

where $\rho_A \in (0,1)$ gives the persistence of the process and $\epsilon_t^A \sim \mathcal{N}(0, \sigma_{\epsilon^A})$ denotes an aggregate productivity shock.

Firms' optimisation problem is solved by maximising the profit function choosing the quantity of the factor inputs.

$$\max_{K_t, H_t^P} Y_t - W_t H_t^P - r_t^K K_t \tag{8}$$

The factor market is perfectly competitive, thus wages are given by equating the marginal costs of labour with the marginal product of labour:

$$W_t = (1-\alpha)\frac{Y_t}{H_t^P} \tag{9}$$

and marginal costs of capital must equal the marginal product of capital

$$r_t^K = \alpha \frac{Y_t}{K_t} \tag{10}$$

2.3.3 Entrepreneurs

Entrepreneurs are risk neutral and similar in their net worth dynamics to the setting introduced by BGG. However, I use a slightly modified approach for two reasons: Firstly, interest rates on loan obligations are state-contingent in BGG such that idiosyncratic risk is borne by entrepreneurs alone. Bankers hold a fully diversified portfolio and are able to perfectly insure against potential loan losses from aggregate risk. Therefore, it is unnecessary for the financial intermediary in the BGG paper to set aside buffer capital. In this model, risk is borne by both bankers and entrepreneurs similarly to the approaches by Zhang (42) and Benes and Kumhof (7). Secondly, entrepreneurs do not distribute any dividends to the household sector in the BGG model but keep all profits as retained earnings until the firm exits the market and the entrepreneur consumes the remaining net worth. In order to focus on the household sector for the consequences of macroprudential policy on volatility of consumption, I assume that entrepreneurs make regular donations to households.

Entrepreneur's equity at the end of period t+1, V_{t+1}, equals the gross earnings minus loan repayments in absence of any uncertainty ($V_{t+1} = R^K_{t+1}K_{t+1} - R^B_{t+1}B_{t+1}$). In this model, however, the entrepreneur's ability to repay her loan obligations is uncertain and depends on her return on capital. The latter is sensitive to both aggregate as well as idiosyncratic risk. R^K_{t+1} denotes the average return on capital over all firms in the economy (i.e., the aggregate return) *after* a potential shock to TFP (as described in Equation (7)). If productivity of the entire economy is unexpectedly low, the aggregate return on capital decreases. The aggregate return is publicly observed and denoted as

$$R^K_{t+1} = r^K_{t+1} + (1 - \delta) \tag{11}$$

the gross return from one unit of capital for an entrepreneur where capital depreciates at a constant rate δ. In addition to this aggregate shock, individual entrepreneurs are also subject to idiosyncratic risk. The ex-post gross return on capital is $\omega^j R^K_{t+1}$ with ω^j being an idiosyncratic shock to firm j's return. The timing of the two shocks introduces the credit friction. Entrepreneurs choose investment and hence their demand for bank loans *prior to the shock realisation*. The ability of the entrepreneur to repay her bank loan thus depends on her expectation of ω^j prior to the shock realisation.
ω^j is assumed to be independently and individually distributed across firms and time with a density function $f(.)$ and a continuous and once-differentiable cumulative distribution function $F(.)$ following a log-normal distribution with unit mean and standard deviation σ^F_t ($\omega \sim \log\mathcal{N}(1, (\sigma^F_t)^2)$). The standard deviation σ^F_t represents the riskiness of the entrepreneur and varies over time following an AR(1) process:

$$\sigma^F_t = (1 - \rho_F)\bar{\sigma}^F + \rho_F\sigma^F_{t-1} + \epsilon^\sigma_t \tag{12}$$

where ϵ^σ_t denotes an i.i.d process with standard deviation σ_{ϵ^σ}. A positive ϵ^σ_t shock increases σ^F, i.e. the dispersion of firms' return to capital. Higher dispersion leads to an increase in the likelihood that firms default on their loan obligations.

An entrepreneur drawing ω^j greater or equal to an endogenously determined threshold variable $\bar{\omega}$ is able to repay her bank loan, thus optaining a total return of $\omega^j R^K_{t+1}K_{t+1} - R^B_{t+1}B_{t+1}$. The banking sector receives $R^B_{t+1}B_{t+1}$. An entrepreneur drawing ω^j smaller than the cut-off $\bar{\omega}$ will default. Given that default is costless for entrepreneurs, defaulting on the underlying bank loan as a result of the shock is optimal ex-post whenever returns on investment are smaller than loan obligations (i.e., $\omega^j R^K_{t+1} K_{t+1} < R^B_{t+1} B_{t+1}$). The realisation of ω^j is directly observable only by the entrepreneur j. The lender can only observe the realisation if she pays a monitoring cost, which destroys part of the project. Entrepreneurs cannot be held accountable for payment obligations over and above obtained gross returns on investment due to limited liability.[11]

Entrepreneurs choose the threshold value $\bar{\omega}$ when they choose their financial contract. $\bar{\omega}^{j,p}_{t+1}$ denotes the ex-post threshold determined by the following indifference condition for which the entrepreneur is just able to repay her bank loan

$$\begin{aligned} \bar{\omega}^{j,p}_{t+1} R^K_{t+1} K^j_{t+1} &= R^B_{t+1} B^j_{t+1} \\ \bar{\omega}^{j,p}_{t+1} &= \frac{R^B_{t+1} B^j_{t+1}}{R^K_{t+1} K^j_{t+1}}. \end{aligned} \tag{13}$$

The entrepreneur's actual wealth after the shock realisation in period $t+1$ is thus

$$V^j_{t+1} = \int_{\bar{\omega}^{j,p}_{t+1}}^{\infty} \omega^j R^K_{t+1} K^j_{t+1} f(\omega) d\omega - (1 - F(\bar{\omega}^{j,p}_{t+1})) R^B_{t+1} B^j_{t+1} - \int_0^{\bar{\omega}^{j,p}_{t+1}} \omega^j R^K_{t+1} K^j_{t+1} f(\omega) d\omega \tag{14}$$

The first term denotes the gross repayment to the entrepreneur for all draws of ω^j after the shock has realised. The second term is the debt repayment to the bank where $F(\bar{\omega}^{j,p}_{t+1})$ denotes the fraction of bank loans in default. If the entrepreneur defaults, the remaining capital value will be taken over by the bank. This remaining value of capital is denoted by the third term in the equation. In analogy to BGG, the realised value of defaulting firm's remaining capital will be denoted as ϕ^y_{t+1}

$$\phi^{j,y}_{t+1} = \int_0^{\bar{\omega}^{j,p}_{t+1}} \omega^j R^K_{t+1} K^j_{t+1} f(\omega) d\omega = G(\bar{\omega}^{j,p}_{t+1}) R^K_{t+1} K_{t+1} \tag{15}$$

with $G(\bar{\omega}^{j,p}_{t+1}) = \int_0^{\bar{\omega}^{j,p}_{t+1}} \omega^j f(\omega) d\omega$. Definition (14) shows that entrepreneur's wealth is sensitive to both aggregate as well as idiosyncratic risk in the model (as the ex-post threshold might deviate from the anticipated threshold value).

In period t, the entrepreneur j must choose the amount of capital investment for period $t+1$ in order to maximise her wealth. Given that net worth is limited, the entrepreneur also needs to choose the appropriate financial contract for her borrowing decision in period $t+1$. Investments

[11] Bernanke et al. (8) introduce frictions of private information and limited liability to avoid a trivial solution in which the Modigliani Miller theorem applies and the investment decision is independent of the financial structure (and hence the financial structure is indeterminate).

into capital K^j_{t+1} can be made by combining entrepreneur's net worth N^j_{t+1} and bank loans B^j_{t+1}.

$$K^j_{t+1} - B^j_{t+1} = N^j_{t+1} \tag{16}$$

Similar to BGG, entrepreneurs live for a finite number of periods indicated by a constant survival probability η. The entrepreneur therefore has a finite expected horizon for planning purposes and does not accumulate too much wealth. This ensures that she can never self-finance new capital purchases using her own net worth alone. She thus needs additional funds and borrows from banks in order to invest using the existing capital stock as collateral. Equation (16) determines that the entrepreneur borrows all funds over and above the amount of net worth at her disposal. The net worth at the end of period t, N^j_{t+1}, can be derived from the surviving entrepreneur's equity:

$$N^j_{t+1} = \eta V^j_t \tag{17}$$

Entrepreneurs who do not survive donate their entire remaining equity to households:

$$\Pi^{E,j}_t = (1-\eta)V^j_t \tag{18}$$

2.3.4 Financial contract

The entrepreneur observes her actual return on capital *after* the investment decision has been made and the financial contracts have been signed. Depending on the realisation of the shock, either she is able to repay the bank loan or she declares bankruptcy. To choose an optimal debt contract prior to knowing the actual return on capital, the entrepreneur must choose the ex-ante default threshold ($\bar{\omega}^{j,a}_{t+1}$) based on the expectation of her return on capital.

$$\bar{\omega}^{j,a}_{t+1} E_t[R^K_{t+1}] K^j_{t+1} = R^B_{t+1} B^j_{t+1}. \tag{19}$$

Rearranging Equation (19) yields

$$\bar{\omega}^{j,a}_{t+1} = \frac{R^B_{t+1} B^j_{t+1}}{E_t[R^K_{t+1}] K^j_{t+1}} \equiv \frac{x^{j,E}_{t+1}}{E_t[R^K_{t+1}]} \tag{20}$$

with $x^E_{t+1} \equiv \frac{R^B_{t+1} B^j_{t+1}}{K^j_{t+1}}$ denoting the entrepreneurial leverage. It follows that the default threshold depends on entrepreneur's funding structure and her expected return on capital. The lending bank knows ex-ante that the entrepreneur could go bankrupt under certain realisations of idiosyncratic and aggregate shocks, particularly if the firm leverage ratio $x^{j,E}_{t+1}$ is high.

In contrast to BGG, this contract is *not* state-contingent. This means that banks cannot enter into a financial contract that is contingent on the *realisation* of the return on capital. Rather the contract is based on the parties' *expectation* of the capital return in period $t+1$. Therein lies the important deviation from the BGG framework: Contracts offered by the entrepreneur are based on an ex-ante default threshold depending on $E_t[R^K_{t+1}]$ instead of possible realisations of R^K_{t+1}.[12] Fluctuations in R^K_{t+1} produce fluctuations in entrepreneurial default rates. Thereby, banks are not fully insured against uncertainty. A forecast error in return on capital creates a wedge between expected and actual default ratio, causing a profit or loss for the bank.

The entrepreneur *actually* repays her loan whenever the idiosyncratic shock ω^j exceeds the ex-post default threshold. In period $t+1$, when the loan rate R^B_{t+1} and the realised return on capital R^K_{t+1} are given, the ex-post default threshold can be determined by Equation (13). This yields

$$\bar{\omega}^{j,p}_{t+1} = \frac{R^B_{t+1} B^j_{t+1}}{R^K_{t+1} K^j_{t+1}} = \bar{\omega}^{j,a}_{t+1} \frac{E_t[R^K_{t+1}]}{R^K_{t+1}}. \tag{21}$$

This expression shows that any forecast errors in capital returns drive a wedge between the actual ex-post and the ex-ante default rate. I will demonstrate how this wedge influences the banking sector and the real economy. First, however, I determine how the entrepreneur chooses a financial contract based on her expected default rate.

The entrepreneur chooses the investment in new capital as well as the financial contract. In the financial contract, entrepreneurs maximise their expected profit subject to bank's participation constraint. Banks will accept the debt contract as long as it satisfies their zero profit constraint. From the entrepreneurial equity in Equation (14), we can derive that banks expect to receive $(1 - F(\bar{\omega}^a_{t+1}))R^B_{t+1}B_{t+1}$ as debt repayment and firms expect to loose $G(\bar{\omega}^a_{t+1})E_t[R^K_{t+1}]K_{t+1}$ in collateral in case of default. Since firms secure the loans with their capital as collateral, banks expect to seize the assets in case of bankruptcy. If there was perfect information between the entrepreneur and the bank, the marginal costs of borrowing would simply be equal to the marginal cost of borrowing. In this case, the leverage ratio of the entrepreneur would be indeterminate and there would be no financial accelerator.[13]

BGG introduced information asymmetry to the model in order to ensure that an optimal entrepreneurial leverage ratio exists. Similarly to the costly state verification model by Townsend (40), an entrepreneur has an incentive to underreport the return on capital in case of default. Therefore, the bank needs to incur auditing or monitoring costs in order to accurately estimate

[12]For a similar approach, see Zhang (42)
[13]See below.

the return on capital and hence the value of the remaining assets.[14] These monitoring costs are equal to a constant fraction μ of the remaining asset value. Banks thus do not receive the full amount of assets, they only receive the fraction $(1-\mu)$. Bank's expected return $\bar{R}^E_{t+1}$ per unit of corporate loan can hence be defined as

$$\bar{R}^E_{t+1}B_{t+1} = (1 - F(\bar{\omega}^a_{t+1}))R^B_{t+1}B_{t+1} + (1-\mu)G(\bar{\omega}^a_{t+1})E_t[R^K_{t+1}]K_{t+1} \tag{22}$$

Equation (22) states that expected net payments by entrepreneurs to banks are equal to the payments by the expected fraction $(1 - F(\bar{\omega}^a_{t+1}))$ of non-defaulting entrepreneurs plus expected asset value of the defaulting entrepreneurs $G(\bar{\omega}^a_{t+1})E_t[R^K_{t+1}]K_{t+1}$ minus the bankruptcy costs $\mu G(\bar{\omega}^a_{t+1})E_t[R^K_{t+1}]K_{t+1}$.

Using indifference Equation (19), $R^B_{t+1}B_{t+1} = \bar{\omega}^a_{t+1}E_t[R^K_{t+1}]K_{t+1}$ yields

$$\begin{aligned}
\bar{R}^E_{t+1}B_{t+1} &= (1 - F(\bar{\omega}^a_{t+1}))\bar{\omega}^a_{t+1}E_t[R^K_{t+1}]K_{t+1} + (1-\mu)G(\bar{\omega}^a_{t+1}))E_t[R^K_{t+1}]K_{t+1} \\
&= \Big[(1 - F(\bar{\omega}^a_{t+1}))\bar{\omega}^a_{t+1} + G(\bar{\omega}^a_{t+1})) - \mu G(\bar{\omega}^a_{t+1}))\Big]E_t[R^K_{t+1}]K_{t+1} \\
&= \Big[\Gamma(\bar{\omega}^a_{t+1}) - \mu G(\bar{\omega}^a_{t+1})\Big]E_t[R^K_{t+1}]K_{t+1}
\end{aligned} \tag{23}$$

with $\Gamma(\bar{\omega}^a_{t+1}) = \bar{\omega}^a_{t+1}[1 - F(\bar{\omega}^a_{t+1})] + G(\bar{\omega}^a_{t+1})$. In this equation, $\Gamma(\bar{\omega}^a_{t+1}) - \mu G(\bar{\omega}^a_{t+1})$ can be interpreted as the share of entrepreneurial earnings which are obtained by banks where $\mu G(\bar{\omega}^a_{t+1})$ denotes the share of bankruptcy costs. Equation (23) hence represents the bank's zero profit condition where the marginal return on corporate loans must equal the marginal cost of corporate loans.

The optimal debt contract is the contract that maximises the expected share of the payoff for the entrepreneur (which is given by $1 - \Gamma(\bar{\omega}^a_{t+1})$) by choosing the cut-off value[15] $\bar{\omega}^a_{t+1}$ and the amount of capital investment

$$\max_{\bar{\omega}^a_{t+1}, K_{t+1}} \left[\Big(1 - \Gamma\big(\bar{\omega}^a_{t+1}\big)\Big)E_t[R^K_{t+1}]K_{t+1}\right] \tag{24}$$

subject to bank's participation constraint

$$\bar{R}^E_{t+1}B_{t+1} = \left(\Gamma\Big(\bar{\omega}^a_{t+1}\Big) - \mu G\Big(\bar{\omega}^a_{t+1}\Big)\right)E_t[R^K_{t+1}]K_{t+1} \tag{25}$$

[14]This implies that the financial structure matters for investment decisions because of the expected costs of bankruptcy.

[15]It is simpler to write the problem in terms of $\bar{\omega}^a_{t+1}$ instead of the expected face value of the loan amount

Solving the optimal debt contract[16] yields the credit demand equation

$$s_t \equiv \frac{E_t[R^K_{t+1}]}{\bar{R}^E_{t+1}} = S\Big(\frac{K_{t+1}}{N_{t+1}}\Big) \quad \text{with } S'(.) > 0 \tag{26}$$

where $s_t = \frac{E_t[R^K_{t+1}]}{\bar{R}^E_{t+1}}$ denotes the expected discounted return on capital. Entrepreneurs choose to buy capital in equilibrium as long as $s_t \geq 1$. Rearranging Equation (26) yields

$$E_t[R^K_{t+1}] = S\Big(\frac{K_{t+1}}{N_{t+1}}\Big)\bar{R}^E_{t+1}. \tag{27}$$

Since the entrepreneur cannot fully self-finance her investments, the marginal expected return on capital in equilibrium must be equal to the marginal expected costs of external funding. Costs arise from the expected lending rate set by the bank as well as entrepreneur's leverage ratio. As K_{t+1}/N_{t+1} increases, the entrepreneur relies more on debt funding. This dependence increases entrepreneur's incentive to misreport the outcome of a project, thus loans become riskier and cost of borrowing rise. BGG show that $S(.)$ captures the wedge (driven by the existence of bankruptcy costs μ) between firm's and bank's cost of funds. The ratio s_t hence denotes not only the discounted expected return on capital but also the firm's external finance premium, as it indicates the spread between the return on capital and the bank funding costs. This external finance premium has a negative relationship with firm's net worth. The higher firm's net worth, the lower its leverage ratio and thus the lower its cost of external financing. Assuming $s_t \geq 1$, BGG derive optimal capital purchases as

$$K_{t+1} = \varphi(s_t)N_{t+1}, \quad \text{with } \varphi(1) = 1, \varphi'(.) > 0 \tag{28}$$

Equation (28) is one of the key results of the BGG model. It illustrates the proportional relationship between capital expenditures and entrepreneur's net worth, with the proportionality factor increasing in the expected discounted return on capital. Higher expected return on capital reduces the expected probability of default on the bank loan. This allows the entrepreneur to take on more debt. Higher firm leverage leads to increasing expected default costs such that firms cannot increase in size indefinitely.

BGG show that the external finance premium introduces a financial accelerator into the model. If banks faced no monitoring costs ($\mu = 0$), there would be no incentive for firms to misreport their return on capital and the entrepreneur would choose the debt contract that offered the same lending rate as her expected return on capital $E_t[R^K_{t+1}] = \bar{R}^E_{t+1}$.[17] The external finance

[16]Derivation of the first-order conditions of the optimal debt contract in Appendix 2.A.2.

[17]The derivation can be found in Appendix 2.A.3.

premium s_t would thus be equal to one.
A shock to the return on capital would then imply a reduction in capital expenditure as only those projects could be realised that yielded sufficient return to satisfy $E_t[R^K_{t+1}] = \bar{R}^E_{t+1}$.
The reaction to a similar shock is different with BGG's financial accelerator. Capital demand is given by Equation (27) as $E_t[R^K_{t+1}] = S\left(\frac{K_{t+1}}{N_{t+1}}\right)\bar{R}^E_{t+1}$, which depends on firm's leverage ratio. Firm's optimal capital itself depends on the spread between return on capital and borrowing costs in Equation (28). A shock to the expected return on capital thus decreases capital expenditure which, in turn, leads to a lower leverage ratio $\frac{K_{t+1}}{N_{t+1}}$. Capital demand depends positively on the leverage ratio such that lower leverage means even lower capital demand. BGG therefore show that the existence of an optimal leverage ratio leads to increased volatility in response to shocks.

2.3.5 Competitive banking sector

The banks maximise the sum of their discounted cash flows subject to a balance sheet constraint and a borrowing constraint. Bank's balance sheet constraint simply requires bank's assets to equal the sum of bank's liabilities and equity at all times implying that losses on bank assets (i.e., loan losses) must be covered by bank's equity. The borrowing constraint is determined by the regulator setting a capital-to-asset ratio. Fulfilling an intermediary function in the economy, the bank receives deposits from households and lends funds to entrepreneurs. Regarding the bank's ability to attract deposits, empirical research has shown that banks face different costs for attracting new depositors, particularly based on geographic areas. I assume that banks use labour H^D to manage household deposits D, modeled for simplicity as a linear technology. These labour costs introduce real costs to financial intermediation. Optimal deposit labour is thus an increasing function of total deposits:

$$H^D_t = \gamma^D_t D_{t+1} \tag{29}$$

I allow for potential funding shocks by letting the deposit productivity γ^D_t vary over time, following an AR(1) process around the steady state value:

$$\gamma^D_t = (1-\rho_D)\gamma^D + \rho_D \gamma^D_{t-1} + \epsilon^D_t \tag{30}$$

where ρ_D denotes the shock persistence parameter and the shock ϵ^D_t is i.i.d. with standard deviation σ_{ϵ^D}. A positive shock to γ^D_t implies that the bank will be less productive in attracting deposits. The banking sector is competitive such that banks take interest rates as given and choose the amount of deposit demand and corporate loan supply accordingly. Bank's balance-sheet constraint takes the following form:

$$B_{t+1} = D_{t+1} + K^B_{t+1} \tag{31}$$

The left hand side of Equation (31) shows that bank's assets consist of loans to entrepreneurs B_{t+1}. For the bank's accounts to balance, assets must equal liabilities, which are on the right hand side of the equation and comprise household deposits D_{t+1} as well as bank capital K^B_{t+1}.

In addition to the balance-sheet constraint, the regulator sets a constraint in form of a capital adequacy requirement. Specifically, the regulator defines a minimum capital-to-risky-asset ratio equal to γ^{CR}, which the bank must satisfy. The only risky asset in this setting is the corporate loan, so that the capital requirement constraint becomes

$$\frac{K^B_{t+1}}{B_{t+1}} \geq \gamma^{CR} \tag{32}$$

In other words, the capital-to-asset ratio must be greater or equal to the exogenous rate γ^{CR} chosen by the regulator. Given that equity pays a premium and receiving debt funding is always "cheaper" than equity funding, this constraint binds in equilibrium. Notice that $K^B_{t+1} = 0$ in absence of capital requirements as banks have no incentive to hold capital. If, however, the regulator sets a capital requirement constraint as in Equation (32), the banks' best course of action is to set K^B_{t+1} at its minimum.[18]

Substituting the capital requirement condition (32) into the balance sheet constraint (31) gives the bank's borrowing constraint:

$$D_{t+1} = (1 - \gamma^{CR})B_{t+1} \tag{33}$$

In period t, banks choose deposits and loans for period $t+1$ to maximise the expected discounted sum of cash flows

$$\begin{aligned} \Pi^B_t =& (1 - F(\bar{\omega}^a_t))R^B_t B_t + (1-\mu)G(\bar{\omega}^a_t)R^K_t K_t - R^D_t D^H_t - R^{K^B}_t K^B_t \\ &+ D_{t+1} - \gamma^D_t W_t D_{t+1} - B_{t+1} + K^B_{t+1} \end{aligned} \tag{34}$$

The issuance of new deposits is subject to the labour cost proportional to the newly created deposits, $\gamma^D_t W_t D_{t+1}$. $F(\bar{\omega}^a_t)$ denotes the previously anticipated fraction of entrepreneurs who

[18] I assume a simple capital requirement ratio with risk weights equal to one (for risky assets) or zero (for risk-free assets) to keep the number of parameters as low as possible. However, in order to make this setting more similar to Basel II it would be possible to introduce risk weightings to mimic an risk-weighted asset (RWA) approach.

fail to repay their loan obligations $R_t^B B_t$. $R_t^{K^B} K_t^B$ describes the bank's return on equity shares paid to households. $(1-\mu)G(\bar{\omega}_t^a)R_t^K K_t$ is the return on defaulted loans $G(\bar{\omega}_t^a)R_t^K K_t$ after payment of monitoring costs μ.

We can substitute for bank capital K_{t+1}^B since the capital constraint is always binding. In addition, we know from the optimal debt contract that banks' zero profit constraint (23) is $\bar{R}^E B_t = (1 - F(\bar{\omega}_t^a))R_t^B B_t + (1-\mu)G(\bar{\omega}_t^a)R_t^K K_t$. Substitution in the optimzation problem yields the Lagrangian as

$$\begin{aligned}\mathscr{L}_t = E_t\Bigg\{ \sum_{t=0}^{\infty} \lambda_t \Big[\bar{R}_t^E B_t - R_t^D D_t^H - R_t^{K^B} \gamma^{CR} B_t + D_{t+1} \\ - \gamma_t^D W_t D_{t+1} - B_{t+1} + \gamma^{CR} B_{t+1} \Big] + \mu_t \Big[D_{t+1} - (1-\gamma^{CR}) B_{t+1} \Big] \Bigg\}\end{aligned} \tag{35}$$

where $\lambda_t = \beta^t (C_t / C_{t+1})$ is the stochastic discount factor of households and μ_t the multiplier on bank's borrowing constraint. For simplicity's sake set $\lambda_{t=1} = 1$ as numeraire, giving the following first order conditions:

$$\frac{\partial \mathscr{L}_t}{\partial D_{t+1}} = 1 - \gamma_t^D W_t + \mu_t - E_t[\lambda_{t+1} R_{t+1}^D] = 0 \tag{36}$$

$$\frac{\partial \mathscr{L}_t}{\partial B_{t+1}} = -1 + \gamma^{CR} - \mu_t (1-\gamma^{CR}) + E_t[\lambda_{t+1}[\bar{R}_{t+1}^E - R_{t+1}^{K^B} \gamma^{CR}]] = 0 \tag{37}$$

μ_t denotes the shadow value of deposits, which is equal to the marginal costs of attracting a deposit:

$$\mu_t = \gamma_t^D W_t + E_t\Big[\beta\Big(\frac{C_t}{C_{t+1}}\Big) R_{t+1}^D\Big] - 1 = \gamma_t^D W_t + 1 - 1 = \gamma_t^D W_t \tag{38}$$

If the costs of attracting deposits increase, the interest rate spread between lending and borrowing increases. Substituting Equation (36) into Equation (37) yields the spread between expected return on loans and debt funding

$$\bar{R}_{t+1}^E = (1-\gamma^{CR})\Big(R_{t+1}^D + \frac{W_t \gamma_t^D}{\lambda_{t+1}}\Big) + \gamma^{CR} R_{t+1}^{KB} \tag{39}$$

The expected discounted interest rate spread is a function of the marginal costs of financial intermediation. The introduction of a binding capital adequacy constraint implies that the required return on bank loans must be equal to the weighted average of its funding costs. The net interest rate for loans is such that marginal return on loans equals the marginal cost of making loans. In equilibrium, $\bar{R}_{t+1}^E$ is the marginal cost of a bank loan to the bank. If the banker can attract deposits at low costs, her required return on corporate loans decreases. If the capital adequacy rate γ^{CR} increases, bank's funding costs increase as equity is always more expensive than debt since it pays a risk premium as shown in Equation (4).

Substituting Equation (22) back for $\bar{R}^E_{t+1}$ gives the corporate loan interest rate as

$$R^B_{t+1} = \frac{(1-\gamma^{CR})(R^D_{t+1} + \gamma^D_t W_t/\lambda_{t+1}) + \gamma^{CR} R^{KB}_{t+1} - (1-\mu) G(\bar{\omega}^a_{t+1}) E_t[R^K_{t+1}] K_{t+1}/B_{t+1}}{1 - F(\bar{\omega}^a_{t+1})} \tag{40}$$

From Equation (40), the following partial effects are straight forward:

- A higher debt funding cost $R^D_{t+1} + \gamma^D_t W_t/\lambda_{t+1}$ raises corporate loan interest rates.
- Higher capital requirement γ^{CR} leads to higher corporate loan interest rates.
- Higher expected corporate default rates $F(\bar{\omega}^a_{t+1})$ lead to higher corporate loan interest rates. Banks know ex-ante that entrepreneurs can go bankrupt and account for this possibility by charging a risk premium based on the expected default rate.
- Higher expected collateral values per unit of debt $(1-\mu)G(\bar{\omega}^a_{t+1})E_t[R^K_{t+1}]K_{t+1}/B_{t+1}$ reduces the corporate loan interest rate. Even if the corporation defaults on its loan obligation, the bank can limit its losses by receiving the remaining corporate assets.

2.3.6 Monopolistic competition with interbank market

The study by Ivashina and Scharfstein indicates that frictions to banks' access to deposits matter particularly since these banks are more dependent on the interbank market. In order to analyse this phenomenon, I extend the model by allowing for heterogeneity in the banking sector such that banks face different costs for deposit creation. Those banks facing lower costs of deposit creation can lend their funds on the interbank market to banks that have difficulty to access deposit funding. This is related to the approach by Hafstead and Smith (25). In contrast to Hafstead and Smith, however, the banking sector suffers losses in case of firm defaults and is hence regulated by setting a capital requirement ratio. Due to the heterogeneity of the banking sector, the model generates positive interbank trading in equilibrium. To allow for heterogeneity in the banking sector, I assume monopolistic competition while the rest of the model set up remains the unchanged. In modelling monopolistic competition in the banking sector, I follow the set up used in Gerali et al. (23). Profit maximising banks set gross interest rates on deposits and corporate loans. Standard Dixit-Stiglitz aggregation functions ensure that all banks serve *all entrepreneurs* such that default rates are the same for all banks. The

Dixit-Stiglitz demand schedules for deposits and corporate loans are:

$$D_{t+1}(i) = D_{t+1}\Big(\frac{R^D_{t+1}}{R^D_{t+1}(i)}\Big)^{-\eta_d} \tag{41}$$

$$B_{t+1}(i) = B_{t+1}\Big(\frac{R^B_{t+1}}{R^B_{t+1}(i)}\Big)^{\eta_b} \tag{42}$$

The deposit demand by bank i depends negatively on the aggregate deposit rate and positively on the deposit rate of bank i as well as aggregate deposit demand. In monopolistic competition, the banks choose the interest rates $R^D(i)$ and $R^B(i)$ taking these demand schedules into account.

In contrast to other DSGE models incorporating interbank markets[19], all banks serve the same dual purpose of intermediation between households and firms as well as exchanging wholesale funds with each other. Banks differ with respect to their ability of attracting deposits from the real economy. In case of a funding shortage, banks are able to approach the unsecured interbank market where they can receive funding without being required to pledge collateral.[20]

As before, optimal deposit labour is an increasing function of total deposits:

$$H^D_t = \gamma^D_t(i)D_{t+1}(i) \tag{43}$$

but now I allow the parameter of heterogeneity γ^D_t to vary across banks. With the same amount of labour input H^D_t, each bank i is able to create an individual amount of new deposits $D_{t+1}(i)$ based on its draw of $\gamma^D_t(i)$. To bridge funding gaps, the bank has access to additional funds through the interbank market.[21] Banks take the interbank rate as fixed. Intuitively, the interbank lending rate follows a benchmark set by the monetary authority and hence remains constant as long as there is no change in monetary policy.[22] With increasing uncertainty, the interbank loan rate can deviate from the benchmark rate leading to a spread similar to the one observed between the LIBOR and OIS rate in the crisis. The LIBOR rate is the average interest rate that banks charge for short-term, unsecured loans on the interbank market. Meanwhile,

[19]See Gerali et al. (23); De Walque et al. (16); Dib (18)

[20]Prior to the financial crisis, this scenario was realistic as the unsecured money market was substantially larger than the secured money market. However, in the course of the last decade, the unsecured money market decreased significantly in size whereas secured interbank funding received more attention. It would hence be interesting to study the changes between this unsecured scenario compared to one with a collateralised interbank market.

[21]I will denote any one-period mutual bank claim as "interbank loans". Such loans include intraday debits, overnight, term interbank lending, and contingent claims like OTC traded interest rate derivatives.

[22]The framework includes a monetary authority only implicitely, although it would easily lend itself to the application. This would require the introduction of price levels and degree of price stickyness to show transmission mechanism of monetary policy.

the OIS describes a country's central bank rate, with the same maturity, here the 3-months FED's fund rate. Typically, the spread between the two rates is fairly small. For a maturity of three months, the spread was approximately 0.1% prior to the financial crisis. Figure 2 shows that the spread rose suddenly to 2.2% at the end of 2007. While the OIS rate is not determined by credit risk, the LIBOR rate has proven to depend upon systemic and counterparty risk as well as concerns regarding market liquidity during the financial crisis.[23] The LIBOR-OIS spread thus represents the difference between an interest rate with certain risk and a risk-free rate. The widening of the gap between the two interest rates clearly illustrated the turmoils on the interbank market. Given the focus of this paper on deposit funding problems, I want to focus on the shock from rising interbank funding costs on the economy. I thus assume that the interbank lending rate is subject to an exogenous shock ϵ_t^{IB}

$$R_{t+1}^{IB} = (1-\rho_{IB})\bar{R}^{IB} + \rho_{IB} R_t^{IB} + \epsilon_t^{IB} \tag{44}$$

such that interbank funding costs rise unexpectedly, leading to a shortage of market liquidity.[24]

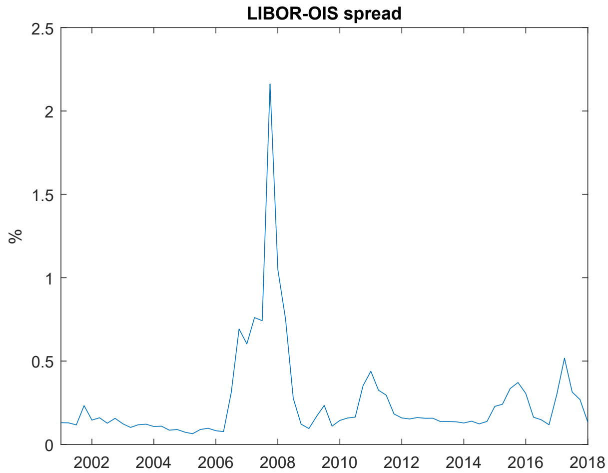

Figure 2: LIBOR-OIS SPREAD AS INDICATOR FOR FUNDING PROBLEMS ON THE INTERBANK MARKET

[23]See Eichengreen et al. (21), Iyer et al. (30), and Cui et al. (15).

[24]However, it would be interesting for future research to exploit the potential of this model further by also exploring the other sources for the rising spread. Particularly, it would be interesting to study the rising systemic and counterparty risk in the interbank market by allowing for different types of banks, large and small. Large banks could face different regulatory requirements in order to limit the occurence of systemic risk but lower counterparty risk as they are considered too big to fail. Due to the heterogeneity this framework allows for in the banking system, this could be implemented relatively easily.

Bank i's actual profit function (with a binding capital requirement constraint) becomes

$$\begin{aligned}\Pi^B =&(1 - F(\bar{\omega}_t^p))R_t^B B_t(i) + \left(\frac{B_t(i)}{B_t}\right)(1-\mu)\int_0^{\bar{\omega}_t^p} \omega R_t^K K_t f(\omega) d\omega \\ &- R_t^D(i) D_t^H(i) - R_t^{KB}\gamma^{CR} B_t(i) - R_t^{IB} D_t^B(i) + D_{t+1}(i) \\ &- \gamma^D(i) W_t D_{t+1}(i) + D_{t+1}^B(i) - B_{t+1}(i) + \gamma^{CR} B_{t+1}(i)\end{aligned} \tag{45}$$

Banks only receive a fraction $\left(\frac{B_t(i)}{B_t}\right)$ of the collateral value depending on their market share. They can borrow or lend on the interbank market at interest rate R^{IB} and on *aggregate*, interbank lending must equal interbank borrowing. Banks take aggregate interest rates R_{t+1}^D and R_{t+1}^B and the interbank lending rate as given as well as aggregate loans and deposits. They choose individual rates $R_{t+1}^D(i)$ and $R_{t+1}^B(i)$ such that they maximise their expected profit subject to the balance sheet and the capital requirement constraint. Optimisation[25] yields

$$R_{t+1}^D(i) = \left(\frac{\eta_d + 1}{\eta_d}\right)\left[R_{t+1}^{IB}(i) - \gamma^D(i) W_t / E_t[\lambda_{t+1}]\right] \tag{46}$$

$$\bar{R}_{t+1}^E(i) = (1 - \gamma^{CR}) R_{t+1}^{IB}(i) + \gamma^{CR} R_{t+1}^{KB} \tag{47}$$

The optimal deposit rate is equal to the interbank funding rate minus the discounted marginal costs of deposit production multiplied by an optimal mark-up. In contrast, the net loan rate implies that the marginal return on loans must equal its marginal funding costs in equilibrium. Assuming high values for η_d and η_b yields very small monopolistic mark-ups and interest rates close to the basic setting.

2.3.7 Description of countercyclical capital requirements (CCR)

So far, I have assumed the capital requirement ratio γ^{CR} to be time-invariant and given exogenously by the regulator. In order to mitigate the procyclicality of credit supply, I now assume that the capital requirement ratio varies in a countercyclical way over time. The basic idea of a countercyclical capital requirement γ_t^{CR} is that it increases during good times and decreases during recessions. There is, however, no consensus in the academic literature with respect to the appropriate cyclical component of the instrument, i.e., what exactly distinguishes good from bad times. It is in fact possible to define good times in terms of positive output gap, positive credit growth, or even positive credit-to-output gap. Both in the literature and in the policy arena, the debate is still ongoing.[26] Angelini et al. (3, 4) define a countercyclical regulatory rule with respect to output growth and explore it in the Gerali et al. (23) framework using

[25] Details in Appendix 2.A.4.

[26] See Saurina and Repullo (38); Benes and Kumhof (7).

Bayesian estimation techniques. They find that a countercyclical capital requirement works well in mitigating credit supply's procyclicality if the capital is required to vary with respect to the business cycle, particularly with respect to output. Kannan et al. (32) uses credit growth and finds that it also serves as a countercyclical measure, but they do not compare the effectiveness of this measure relative to alternative ones like GDP growth. The proposals under Basel III require adjustments of the cyclical component related to the deviations of the loan-to-output ratio from its steady state.[27] To be in line with actual policy rules, this paper follows the Basel III approach and assumes that capital requirements are adjusted in response to deviations in the credit-to-GDP ratio, hence according to:

$$\gamma_t^{CR} = (1-\rho_{CR})\gamma^{CR} + (1-\rho_{CR})\left(\frac{B_t/Y_t}{B/Y}\right)^{\chi_{CR}} + \rho_{CR}\gamma_{t-1}^{CR} \tag{48}$$

γ^{CR} measures the steady state level of capital requirements and χ_{CR} indicates its sensitivity to the business cycle. In boom periods with an expansion of lending, the bank is required to hold more capital for the amount of loans they supply. The analysis of Equation (40) has shown that higher capital requirements increase the cost of borrowing for corporations and thus mitigate credit expansion in boom times. In the steady state, the results will equal the results of the basic setting since Equation (48) affects only the cyclical pattern of the capital requirement not its steady state. In contrast during times of recession, the capital requirements are lowered and thus reduce the incentive for banks to shrink their balance sheets by decreasing assets. The instrument hence captures one of the pivotal characteristics of macroprudential policy in preventing a credit crunch.[28]

2.3.8 Market clearing and equilibrium

The consumption goods market clears if:

$$Y_t = C_t + I_t + \mu\phi_t^y \tag{49}$$

the economy's aggregated output must be equal to overall consumption by households and entrepreneurs, investments in capital, and the monitoring costs in case of firm default.[29] The stock of capital follows the law of motion $K_t = (1-\delta)K_{t-1} + I_t$.

Since wages are equal for households working in the entrepreneurial or the banking sector, households are indifferent between employment sectors. The labour market clearing condition

[27] Basel Committee on Banking Supervision (6)

[28] See Hanson et al. (26)

[29] Please refer to proof of Walras' Law in Appendix 2.A.7

states that labour supply by households equals the overall labour demanded by firms, $H_t^P = ((1-\alpha)Y_t/W_t$, and banks, H_t^D:

$$H_t = H_t^P + H_t^D \tag{50}$$

Deposits held by households must be equal to the demand for deposit funding by banks:

$$D_t = D_t \tag{51}$$

Bank capital provided by households must be equal to the demand for bank capital by banks according to the capital requirement:

$$K_t^B = \gamma^{CR} B_t \tag{52}$$

2.4 Quantitative Analysis

In this section, I examine the potential of countercyclical capital regulation to stabilise the economy. For this reason, I compare the economy's responses to different shock scenarios in the basic setting featuring a time invariant capital rule to the responses in a setting incorporating a countercyclical capital requirement ratio. For the comparison, it is important to note that the steady state of the two regulatory settings is the same. Differences only occur after the shock hit the economy.

2.4.1 Calibration

The model is calibrated at the quarterly frequency using macroeconomic and financial data for the US over the period of 1990:1-2017:4. Table 1 indicates the targets used for the calibration.[30] Since entrepreneurs default due to both idiosyncratic and aggregate shocks, the stochastic average of the variables are affected by both types of shocks. I calibrate the parameters such that the first moments of some pivotal variables approximately correspond to data.

Description	Definition	Data	Model
Bank equity return % p.a.	$(R^{KB}-1)*400$	11.5	11.5
Deposit rate % p.a.	$(R^D-1)*400$	3.1	3.04
Firm default rate % p.a.	$F(\bar{\omega})*400$	2.5	2.5
Corporate loan spread % p.a.	$(R^B-R^D)*400$	2.8	3.4

Table 1: Steady state properties, Model vs. Data

[30] See Appendix 2.A.8 for a description of the respective time series and data sources.

In order to be consistent with the literature, I calibrate some parameters in accordance with conventional values. Table 2 shows the parameters based on quarterly data. I set the quarterly household discount factor β to 0.9925, implying an annual interest rate on deposits of 3%. The share of capital in the production function, α, is 1/3 and capital depreciates at δ of 0.025, i.e. 10% p.a. These values are conventionally used in the literature. Disutility of work, τ, is set to 2 so that households work one third of their time.[31]
The financial accelerator variables σ^F, μ and η are jointly determined to provide steady state values of firm default rate of 2.5% p.a.[32], firm capital-to-net worth ratio of 1.2 and aggregate rate of return on capital expenditures of 8% p.a. The bankruptcy cost parameter of 0.3 in within the range of 0.2-0.36 that Carlstrom and Fuerst (11) found to be empirically relevant. The steady state variance of the log-normal idiosyncratic shock distribution σ^F is 0.699 and the likelihood of survival of the entrepreneur η is 0.9845. Both parameters are slightly above the results found in Christiano et al. (13) (0.67 and 0.9762) who estimate the BGG model with US data.

While Basel regulation requires banks' capital ratio to be at least 8 percent, many banks hold an additional voluntary capital buffer over and above the minimum threshold. Researchers agree that this voluntary buffer is held partly because of the dire consequences of falling below the threshold and facing the costs of bankruptcy and partly due to its signalling effect to attract funding.[33] Demirguc-Kunt et al. (17) study capital ratios of banks in 12 different OECD countries. They find that risk weighted capital adequacy ratios vary across banks. The average lies at 12 percent for large banks while very few banks (25%) hold less than 10.6 percent. The basic setting of this model thus assumes a strict capital to asset ratio γ^{CR} of 12 percent.[34] For the countercyclical buffer, I assume high persistence ($\rho_{CR} = 0.92$) as suggested by Angelini et al. (3)
The risk premium of bank's capital in equilibrium is set such that the return on bank equity matches US bank's average return on equity of 11.5%. This implies bank's funding costs at 4.7% and the corporate loan interest rate at 5.6% which is slightly below the average of 5.9% suggested by the data.

The technology shock is calibrated in accordance with standards in the literature. The persistence parameter ρ_A is set to 0.95 to indicate that changes in productivity are fairly persistent in

[31] In line with Iacoviello and Neri (28)
[32] Average US NPL rate accoring to Federal Financial Institutions Examination Council, FRED: NPTLTL
[33] Ross (36); Myers and Majluf (35); Gerali et al. (23)
[34] This simplification is common in the literature.

Description	Value	Empirical evidence in literature
	Real economy	
Discount factor β	0.9925	Iacoviello (27)
Capital share of output α	0.35	Jermann and Quadrini (31)
Capital depreciation rate δ	0.025	Jermann and Quadrini (31)
Disutility of work τ	2	Iacoviello and Neri (28)
Bankruptcy costs μ	0.3	Carlstrom and Fuerst (11)
Idiosyncratic shock distribution σ^F	0.699	Christiano et al. (13)
Likelihood of firm survival η	0.9845	Christiano et al. (13)
	Banking sector	
Costs of attracting deposits γ^D	$6.69 * 10^{-4}$	Data
Bank capital risk premium st.st. ξ	1.02	Data
	Regulation	
Capital-to-asset ratio γ^{CR}	0.12	Demirguc-Kunt et al. (17)
Persistence of capital rule ρ_{CR}	0.92	Angelini et al. (3)
Sensitivity of capital rule χ_{CR}	0.001	calibrated to match Basel III
	Shock process	
Autocorrelation of productivity ρ_A	0.95	Covas and Den Haan (14)
St.dev. of productivity shock σ_{ϵ^A}	0.01	Covas and Den Haan (14)
Autocorr. of deposit productivity $\hat{\rho}_D$	0.85	Estimation
St.dev. of deposit productivity $\hat{\sigma}_{\epsilon^D}$	0.0006	Estimation
Autocorr. of riskiness ρ_F	0.97	Christiano et al. (13)
St.dev. of idiosyncratic volatility σ_{ϵ^σ}	0.07	Christiano et al. (13)

Table 2: Parameters of steady state calibration

the economy whereas the standard deviation is set to σ_{e^A} equal to 0.0108.[35] (13) estimate the riskiness of the entrepreneur with ρ_F equal to 0.97 and σ_{ϵ^σ} as 0.07. For the deposit productivity shock, I use monthly data on demand deposits from the database of the Federal Reserve Bank of St. Louis in addition to data on the number of credit officers engaged in deposit intermediation in order to construct a parameter for the productivity of the banking sector in attracting new deposits. I assume that each credit officer works 40 hours per week, i.e. 160 hours per month to receive the productivity in terms of hours worked. I convert the monthly time series into quarterly data, remove the seasonal trend and HP-filter the data. Subsequently, I estimate an AR(1) process from the time series to receive $\hat{\rho}_D$ and $\hat{\sigma}_{\epsilon^D}$.[36] This gives the variable γ_t^D with an average value of $6.69 * 10^{-4}$, following an autoregressive process with $\hat{\rho}_D = 0.85$ and $\hat{\sigma}_{\epsilon^D} = 0.0006$.

The calibration of the interbank shock process is difficult since there have not been any LIBOR-OIS shocks prior to the financial crisis making it difficult to properly determine the ex-ante

[35]See Covas and Den Haan (14)
[36]Details on the estimation in Appendix 2.A.9

distribution. As previosuly discussed, the literature on the LIBOR-OIS shock suggested that the three main reasons for the large shock in 2018 were rising systemic and counterparty risk as well as concerns on market liquidity. In this model, I focus on the latter and have set up the interbank shock as a shock to the cost of funding due to unexpected liquidity shortage. The only other source of disturbance of funding costs and thus liquidity shortage on the credit-supply side in this model comes from unexpected increases in deposit funding costs. Due to the aim of this paper to evaluate the consequences of different types of shocks and the effectiveness of countercyclical capital regulation to mitigate the shocks, I am particularly interested in whether shocks to the interbank funding rate affect the economy differently than shocks to deposit funding. In order to make these shock comparable, I use the parameters $\rho_{IB} = \rho_D = 0.85$ and $\epsilon^{IB} = \epsilon^{D}$.

I solve the model using two separate steps. Firstly, I find the steady state values of the variables.[37] Secondly, I use Dynare for a second-order approximation to the structural equations to find the policy functions and simulate the economy's response to an adverse TFP shock, an increase in firm's riskiness and a shock to costs of financial intermediation.[38]

2.4.2 Non-financial shock to TFP

Firstly, I am interested in the potential of macroprudential measures to limit the transmission of typical business cycle fluctuation. Figure 3 presents the economy's impulse responses for an exogenous reduction in aggregate productivity of 10%. As an immediate consequence of the shock, the realised return on capital is lower than expected by 0.4 percentage points. The unexpectedly low return on capital increases defaults by entrepreneurs since the optimal debt contracts were settled upon higher expectations regarding the return on capital. From a banking perspective, this shock is akin to a sudden loss of bank assets since the number of impaired bank loans rises over and above the expected level. This loss has to be absorbed by bank equity weakening the bank's capital position, which in turn leads to a reduction of the loan supply. On the other hand, an unexpected shock to the return on capital reduces capital demand as per Equation (27). As capital expenditure is reduced, firm's net wort falls and hence firm's leverage ratio rises. Higher leverage ratios cause firms to face higher agency costs in the credit market. As firm's external finance premium is tied to its leverage, the costs for obtaining a loan rise. In turn, rising costs for loans lead to lower demand for capital. This financial accelerator

[37] For details, see Appendix Section 2.A.6.

[38] The literature on welfare analysis in DSGE models agrees that due to the increased accuracy of the results, second-order approximation is preferable in determining welfare effects and fluctuations (e.g. Rubio and Carrasco-Gallego (37)). Therefore, I use second-order approximation to examine the effects of the shocks on economic volatility.

effect is strong if banks face high monitoring costs and agency costs are particularly important.[39]

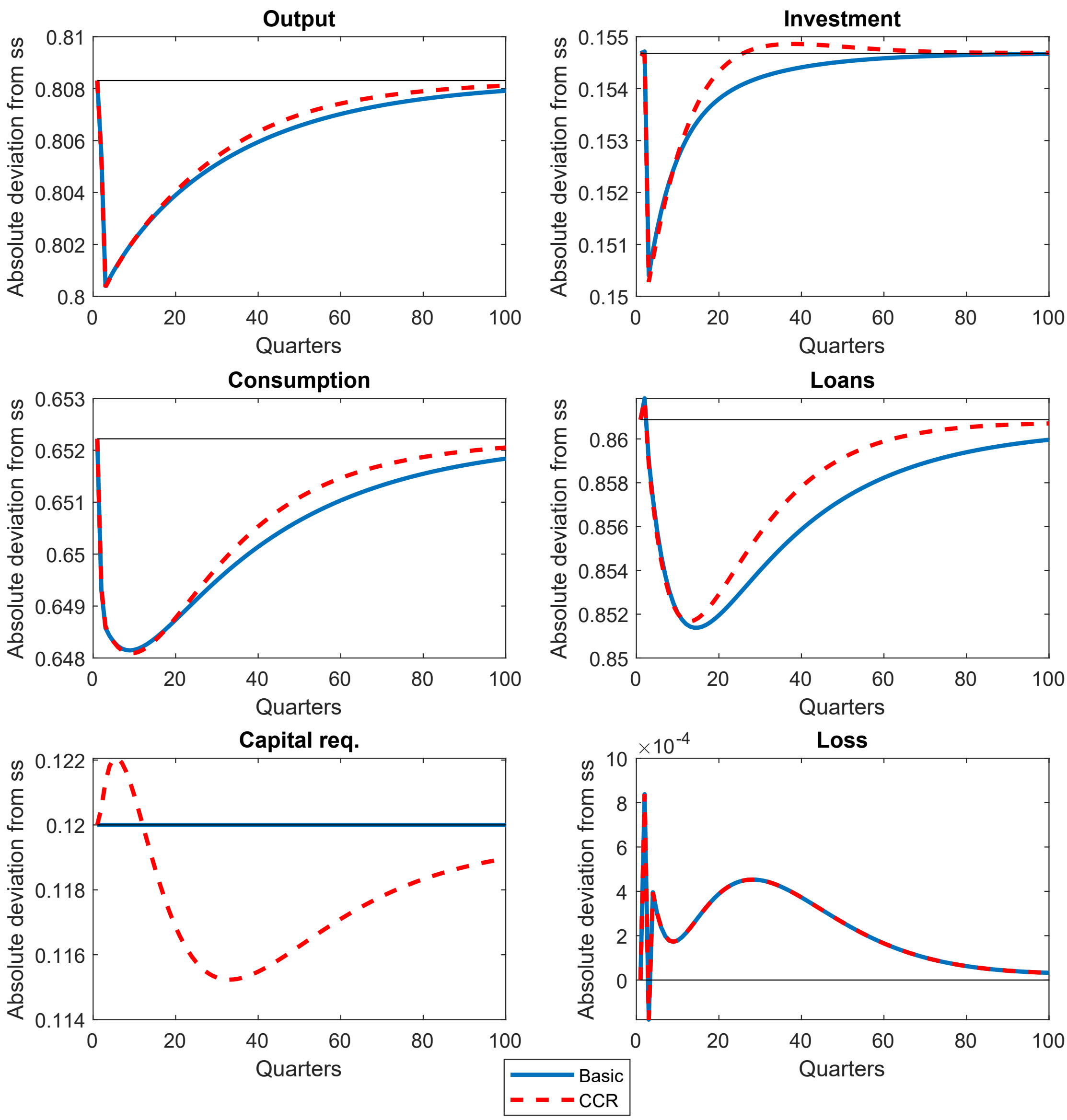

Figure 3: Impulse response functions after a 10% decrease in productivity

Introducing a countercyclical capital requirement affects capital demand via bank's lending rate in Equation (27). If banks are allowed to fund their loans with less equity, their funding costs decrease. However, banks do not simply charge entrepreneurs their funding costs but they also require a risk premium for the potential of defaults. The sudden loan losses lead to rising corporate loan rates such that the reduction in funding costs cannot compensate for the overall increase in lending rates. Figure 4 shows the increase in the corporate loan rate after

[39]See next section.

the shock for both, the base case and the countercyclical capital regulation setting. The sharp increase in the lending rate show that the increase in risk is larger than the reduction of the funding costs. The introduction of countercyclical capital regulation has only limited use for the reduction of business cycle fluctuation.

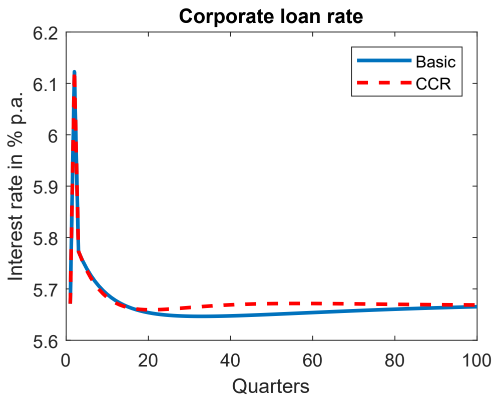

Figure 4: LENDING RATE AND SPREAD AFTER A 10% DECREASE IN PRODUCTIVITY

This statement is confirmed by the impulse response functions in Figure 3. The contractionary effects from both the banking sector and the entrepreneurial sector drive down lending by 1%. This credit shortage drives an investment slump which, in turn, decreases output and consumption by 1.1% and 0.6%, respectively. While the blue lines illustrate the economy's response in the basic setting, the red dashed lines show responses with a countercyclical capital requirement. The simulations show that a countercyclical capital requirement can limit the drop in corporate credit only marginally. Bank capital actually increases slightly immediately after the shock before it is allowed to decrease. This is due to the dependence of the regulatory rule on the credit-to-GDP gap. As GDP decreases due to the shock, the credit-to-GDP ratio briefly increases above its steady state ratio. The subsequent reduction of bank's capital requirement reduces bank's funding costs and hence corporate loan rates.

2.4.3 Financial accelerator effects

As discussed in section 2.3.4, BGG have shown that a financial accelerator exists if banks have to monitor entrepreneurs in order to find out the actual return on capital. If the return on capital decreases unexpectedly, entrepreneurs lower their capital expenditure as shown in Equation (28). Lower capital expenditure leads to reduced investment and shrinking net worth in Equations (14) and (17). The reduction in net worth causes the firm's leverage ratio to rise. As an increase in leverage ratio yields increasing agency costs, the firm's external finance premium rises. While external funding becomes more expensive, firms decrease their capital expenditure even further starting the financial accelerator mechanism. In contrast, if banks have full information and do not have to monitor entrepreneurs, this financial accelerator does not exist. A reduction in the return on capital simply translates into a reduction of investment but since capital demand does not depend on an optimal leverage ratio, there is no feedback to the return on capital. The shock responses should therefore be lower in the case of full information. Figure 5 shows the impulse response functions for the same TFP shock with different monitoring costs. Lower monitoring costs show lower volatility of output and consumption around the steady state. We can conclude that better informed banks ('stronger banks') reduce the volatility in the economy.

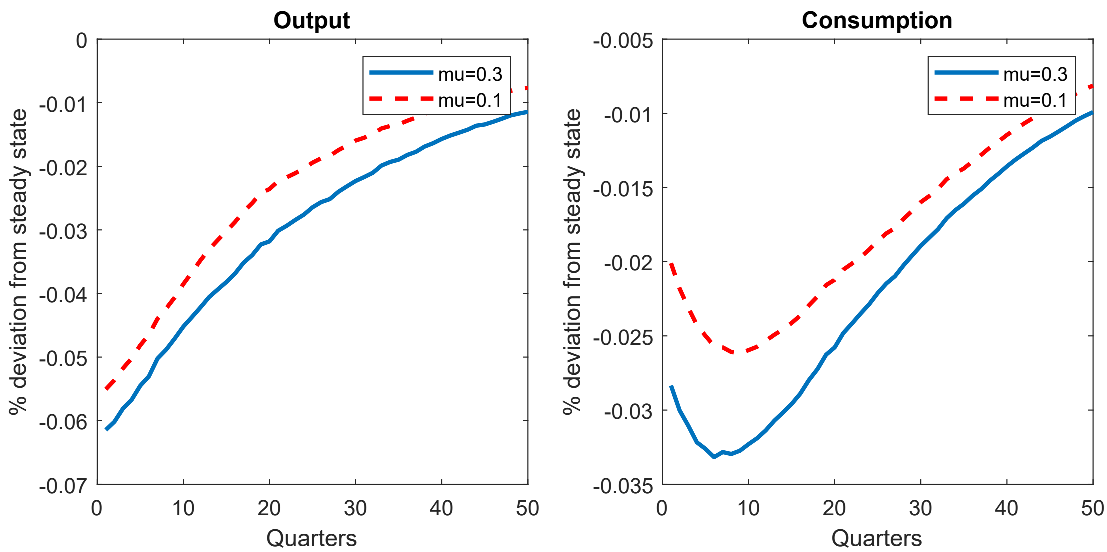

Figure 5: Impulse response functions after a 10% decrease in productivity for different monitoring costs

2.4.4 Demand side financial shock to riskiness

In the BGG model as well as in Christiano et al. (13), demand side financial shocks are characterized as shocks to the riskiness of corporate loans. Shocks to riskiness are captured as shocks to σ^F, the standard deviation of the distribution of entrepreneur's idiosyncratic shocks, in Equation (12). When entrepreneurial risk is high, there exist a large credit spread and banks lending volume is low. Low credit extension leads to fewer financial resources for the entrepreneur to purchase capital and thus investment falls. Figure 6 shows impulse response functions to a 10 percent increase in riskiness. As riskiness increases, the debt contracts are more likely to fail. After an initial drop in the return on corporate loans due to the unexpected losses, banks increase their lending rates and borrowing becomes more expensive for the entrepreneur. Entrepreneur's capital-to-wealth ratio drops when borrowing becomes more expensive. This decline leads to a reduction in investment and output, while the drop in investment introduces the financial accelerator: the value of capital falls which lowers wealth, lowering investments again. In the banking sector, banks charge higher interest rates to compensate for the default risk. The non-performing loan rate increases from 2.5% p.a. to 3.0% p.a. such that banks make a loss that must be covered by equity. As bank capital decreases, banks deleverage to continue to satisfy their capital requirement ratio. Consequently, credit is reduced by 1.5% and investment decreases, having further contractionary effects on output.

The introduction of a countercyclical capital requirement can mitigate the contraction in lending. As the capital requirement rate decreases after the inital reduction in lending, banks can extend more credit with their remaining capital. Bank's funding costs decrease. Therefore, the loan interest rates do not rise as much as in the basic setting. In fact, the lending rate stays well below the equilibrium rate as long as the capital requirement rate is lower than the steady state rate. This allows firms to invest more and thus firm's net worth and capital value are higher than in the alternative setting. This, in turn, yields lower default rates and higher output. Credit is cut only by 1.3% and thus investment and output slumps are mitigated.

In addition, the increase in riskiness changes the distribution of entrepreneurs' return on capital. While it becomes more likely for the entrepreneur to default, she receives higher returns in case of success. With increased returns, she can invest more in the subsequent periods and investment and output rise. Due to limited liability, the entrepreneur cannot lose more in case of default than her collateral minus the monitoring costs. The increase in risk is therefore owned by the banks who should prepare for this increase in risk by setting aside more equity capital to absorb higher potential losses. However, the countercyclical buffer allows them to do exactly the opposite by reducing capital standards, making the economy more volatile and causing fluctuation to rise. It is therefore important to note that the introduction of countercyclical capital regulation can actually *increase* the volatility in the economy instead of reducing it. The reason for this increase in fluctuation is that the countercyclical capital rule does not account for the rising riskiness of the loans but only depends on changes in credit-to-GDP growth.[40] In setting capital rules, regulators face a trade-off between bank's ability to absorb losses and bank's ability to extend credit.

2.4.5 Supply side financial shock to cost of bank intermediation

The parameter γ_t^D, which determines bank's ability to produce deposits, varies over time according to an AR(1) process shown in Equation (30). Figure 7 shows the impulse response functions to a 10% increase in γ_t^D. A positive shock to γ_t^D leads to a decrease in deposit

[40] It would be interesting for further research to investigate how these results change if a risk weighted capital to asset ratio was introduced and bank's equity funding depended on bank's riskiness.

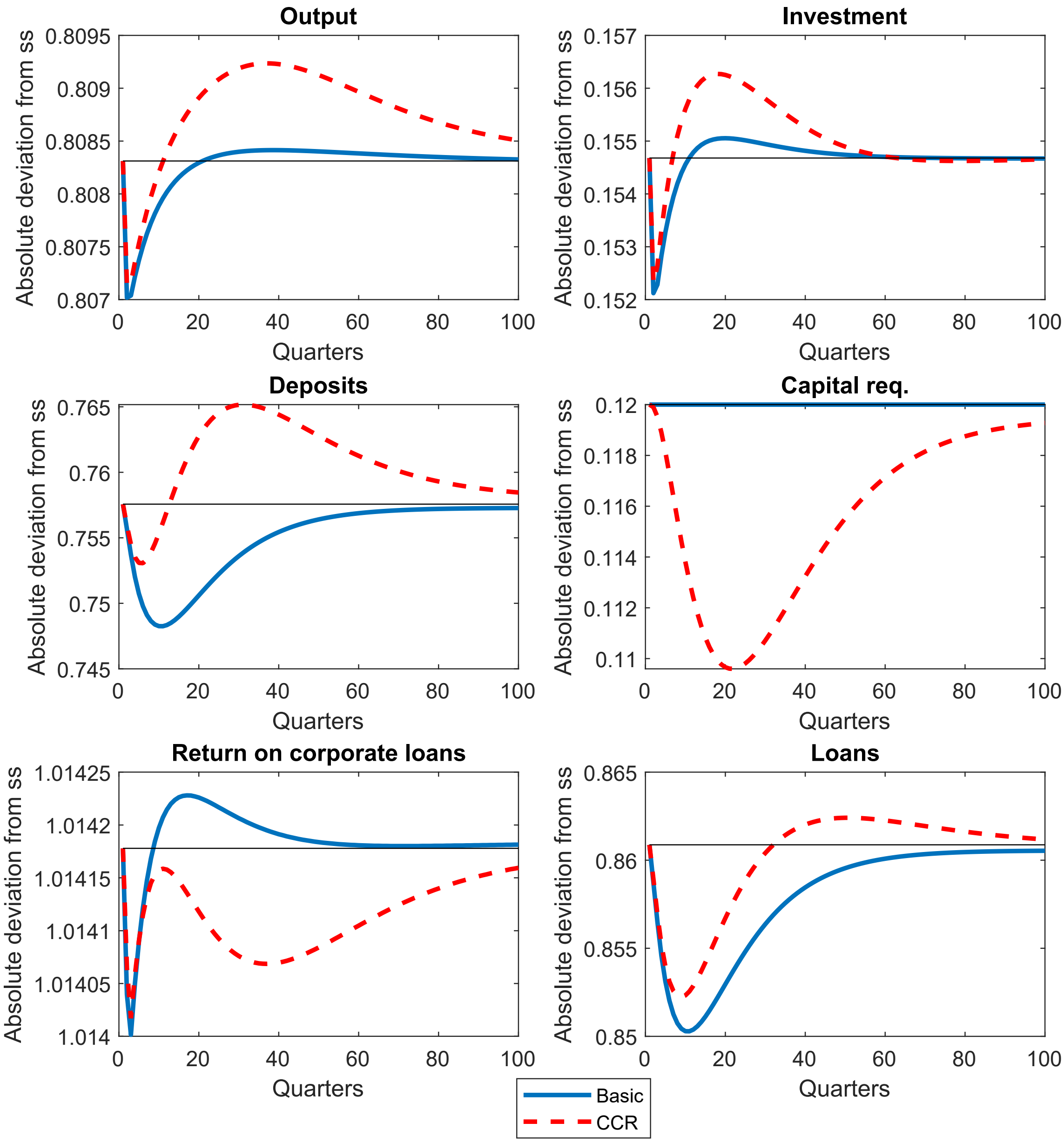

Figure 6: Impulse response functions after a 10% increase in entrepreneur's riskiness

collection through an increase in the cost of bank intermediation. Deposits drop by 1.5% in response to the shock. As attracting deposits becomes more expensive for banks, banks demand higher corporate loan rates which rise from 5.6% p.a. to 5.7% p.a. Through an increase in debt funding costs, lending in the economy decreases by 1.7%, which implies a decrease in investment and output. The contraction in the real economy in turn affects firms' capital and default risk. Figure 7 illustrates the results and shows that a decrease in capital requirements can provide relief in this situation. As capital requirements are reduced, banks are allowed to hold less expensive equity in favour of deposits. As long as deposit funding is cheaper than equity funding, this measure reduces overall funding costs. In this model, equity pays a constant premium over deposit funding such that any increase in deposit funding increases the cost of equity, too. Therefore, deposit funding is always cheaper than equity funding. The introuction of countercyclical capital regulation thus influences precisely the variable which is affected by the shock, $\bar{R}^E_{t+1}$. A reduction in funding costs translate into a reduction of the lending rate which can be seen in Fgure 7. This mitigates the increase in lending rates and allows banks to lend more than in the basic setting.

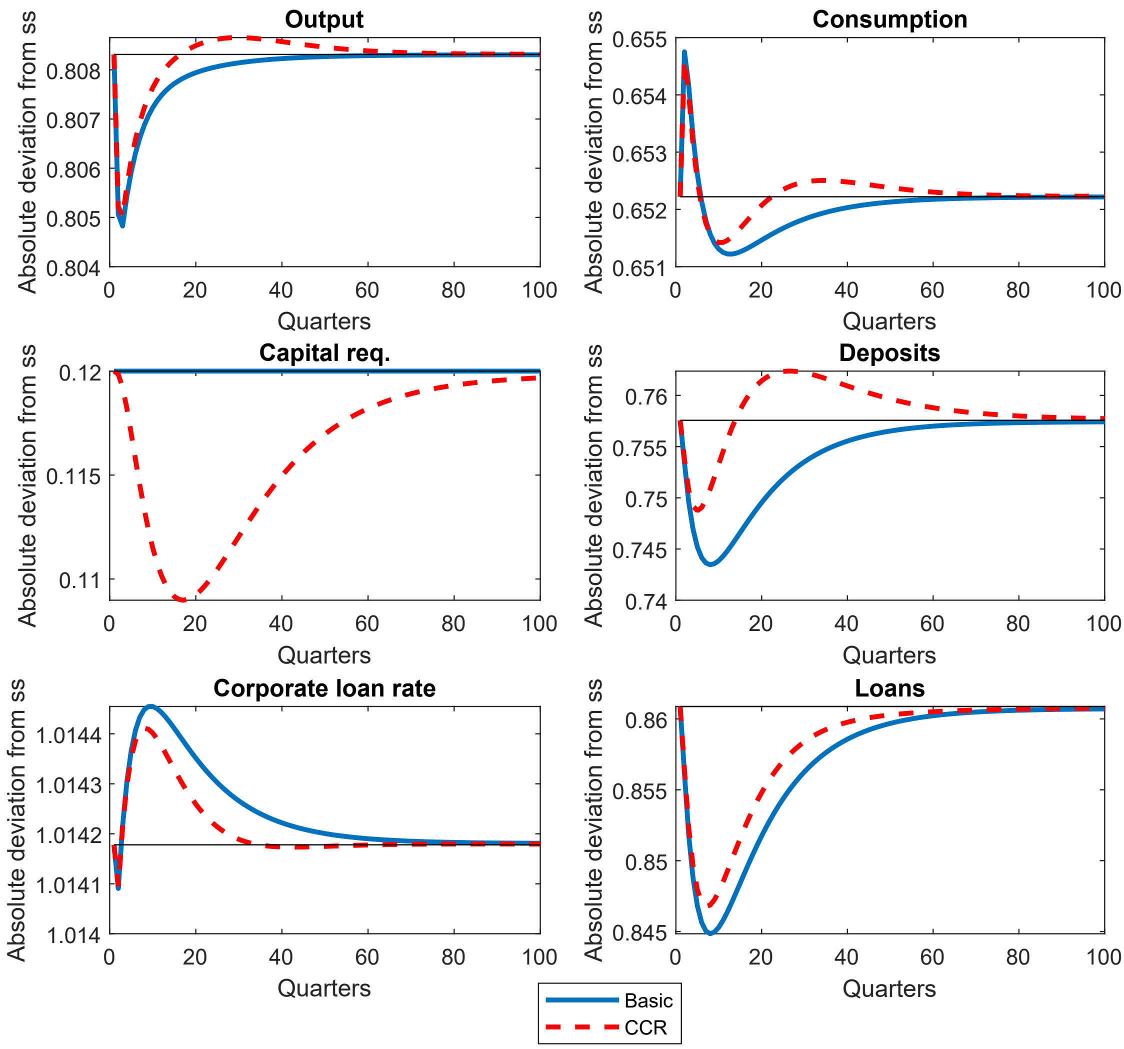

Figure 7: Impulse response functions after a 10% increase in bank's deposit funding costs

2.4.6 Comparison of financial shocks

The previously analysed financial shocks indicated that a shock to banks' debt funding costs had larger macroeconomic consequences than an increase in entrepreneurs' riskiness. To check that this is not only due to the calibration of the model, I normalise the size of the two finanial shocks. I model both of them with a persistence parameter 0.9 and standard deviation of 0.0006 (the standard deviation of γ_t^D). Figure 8 shows the effects of both shocks in comparison. It illustrates clearly that the funding cost shock has larger impact on the economy. An increase in entrepreneurs' riskiness leads to an increase in defaulting loans and a parallel rise in banks' corporate loan interest rate to compensate for the loan losses. The two effects more or less cancel each other out. A shock to banks' intermediation costs, however, leads to an increase in the corporate loan rate without any compensation on the entrepreneurial side. Higher interest rates lead to reduced investment and output. In turn, this has consequences on firm's net worth and repayment rates, enforcing the contractionary effect.

2.4.7 Interbank funding cost shock

I use the monopolistically competitive banking sector to analyse the consequences of a shock to the interbank loan rate to mimic the increasing funding problems banks experienced in 2008. Figure 9 show a 1 percent shock to the interbank loan rate, which implies an increase in bank's funding costs of 0.2 percentage points. Lending to the real economy becomes more expensive and as a consequence, output, investment, entrepreneur's net worth and consumption drop. The mechanism, however, is different. The rise in interbank rates leads to a simulatenous increase in deposit rates R^D and funding costs $\bar{R}_t^E$ such that the spread between them remains constant. As R^D increases, household's postpone spending on consumption which leads to a decrease in output, income and return on capital. The latter leads to a decrease in entrepreneur's equity and thus net worth by 0.5%. At the same time, an increase in $\bar{R}_t^E$ leads to a decrease in lending by 2.2%, which also reduces investment and output. In combination, the increase in both return rates lead to a decrease in investment and net worth which leads the financial accelerator mechanism of reduced wealth leading to lower investments again. Overall, investment is reduced by 4.7% and output by 0.5%.

The countercyclical capital buffer implies that the increase in corporate lending rates is not as severe and hence mitigates the contractionary consequences. Lending only decreases by 2% allowing firms to invest more than in the basic setting. In comparison to the basic setting, entrepreneurial equity and thus net worth is higher, leading to lower default rates and consequently higher capital expenditure and more investment.

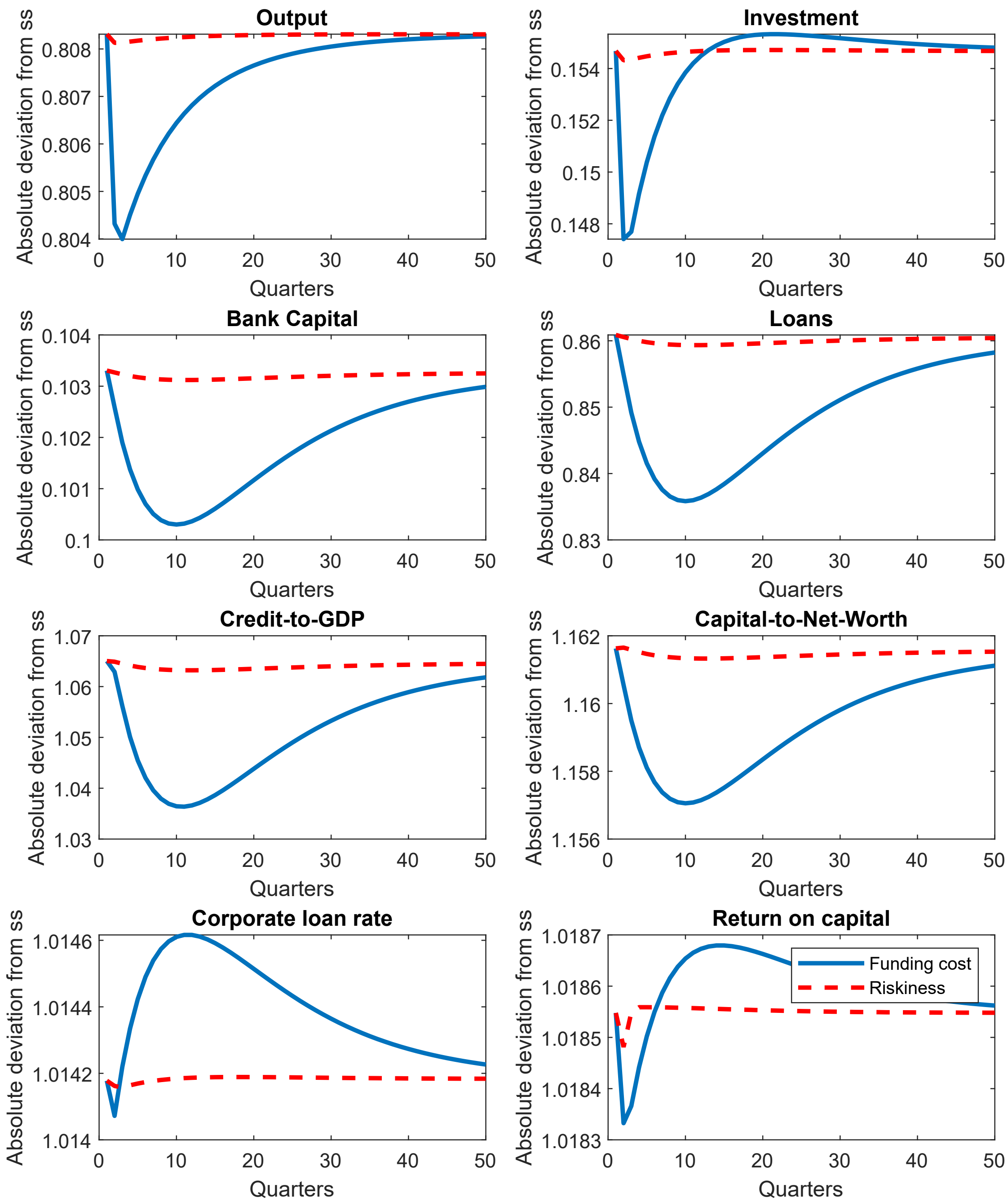

Figure 8: Comparison of the two financial shocks

2.4.8 Effects on economic volatility

The impulse response functions already indicate that macroprudential policy acts as a stabiliser for the economy. Table 3 illustrates the effect of countercyclical regulation on the volatility of

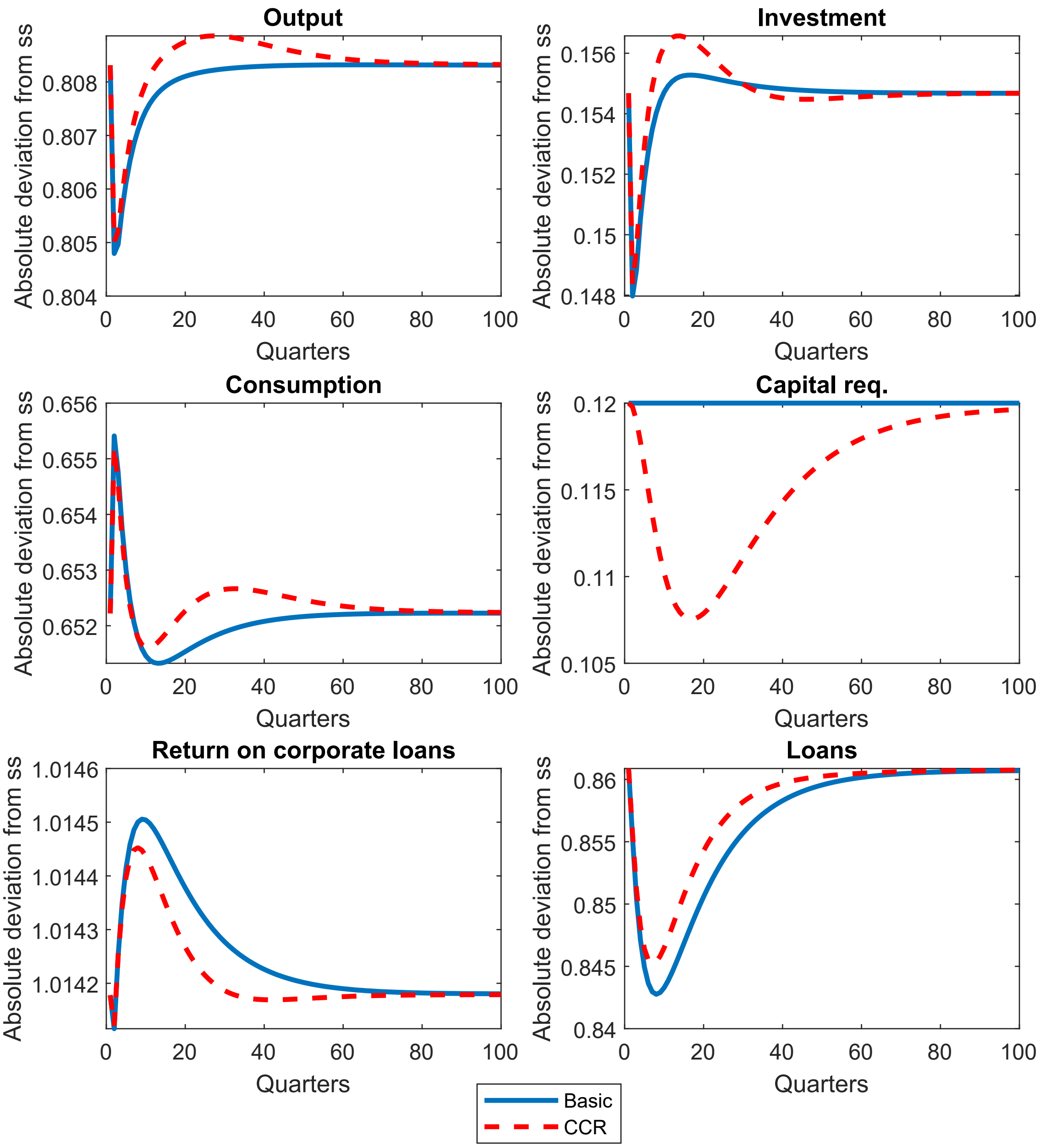

Figure 9: Impulse response functions to 1% shock to interbank lending rate

selected economic variables. The table shows the unconditional standard deviation of output (σ_Y), consumption (σ_C), and corporate lending (σ_B). This approach allows to examine closer whether the introduction of a countercyclical capital requirement reduces macroeconomic volatility.

Countercyclical capital regulation seems to reduce economic volatility particularly if we consider a financial shock from the credit supply side like the funding cost shock. As funding costs rise

unexpectedly and hence banks reduce their credit supply, countercyclical capital requirements depending on the credit-to-GDP ratio drop and offer relief to banks. The volatility of output decreases by 10% whereas the volatility of lending even drops by 22%.
The regulation works equally well when considering an interbank market shock. The introduction of countercyclical capital regulation yields a reduction in output volatility by 6%, volatility of consumption by 15%, and lending by 22%. The reason for the success of a countercyclical capital rule is that it reduces bank's funding costs exactly at a point in time, when funding costs increase due to a shock. The instrument is thus well serving in targeting these problems.

Considering a shock to the riskiness of corporate loans, we find that the introduction of a countercyclical capital rule only reduces the fluctuation of credit whereas all other economic indicators become increasingly volatile. As default rates become increasingly volatile, entrepreneur's net worth and hence investment, output, and consumption increase in volatility.

	σ_Y	σ_C	σ_B
TFP shock			
Basic setting	0.2492	0.1802	0.3432
CCR	0.2451	0.1761	0.3207
Change	**-1.6%**	**-2.3%**	**-6.6%**
Funding cost shock			
Basic setting	0.1514	0.1033	1.2149
CCR	0.1367	0.082	0.9489
Change	**-9.7%**	**-20.6%**	**-21.9%**
Riskiness shock			
Basic setting	0.0248	0.0215	0.3232
CCR	0.0304	0.0224	0.2495
Change	**22.6%**	**4.2%**	**-22.8%**
Interbank loan rate shock			
Basic setting	0.0951	0.0753	0.9897
CCR	0.0896	0.0641	0.7727
Change	**-5.8%**	**-14.9%**	**-21.9%**

Table 3: Effects of countercyclical capital regulation on economic volatility

2.5 Conclusion

In this paper, I extend the standard financial accelerator model by Bernanke et al. (8) by introducing a banking sector where bank's access to deposit funding requires real resources. The model allows to study the macroeconomic consequences of several financial and non-financial shocks to the banking sector and the resulting feedback for the availability and cost of bank credit as well as macroeconomic volatility. Within this framework, I am able to address the impact of idiosyncratic and aggregate shocks on corporate default for the banking sector as well as increases in bank intermediation costs and assess the effectiveness of countercyclical regulation in stabilizing the economy.

In case of non-financial shocks, the buffer is only able to reduce overall fluctuation marginally by 1.6% for output and 6.6% for lending. In contrast, I find that countercyclical capital regulation decreases economic volatility significantly after financial shocks from the supply-side of credit like funding-costs shocks. In this case, the volatility of output decreases by 10% if a buffer is introduced while lending fluctuation is even 22% lower. The countercyclical buffer has ambiguous effects if the financial shock stems from the demand-side of credit. An increase in the riskiness of entrepreneurs leads to an increasingly volatile loan portfolio. Reducing capital requirements at the same time allows banks to hold even more of these risky loans thereby increasing the volatility of output and consumption. In favour of a countercyclical buffer speaks the finding that shocks from the supply side of credit have more severe consequences for the economy as a whole than similar shocks from the credit demand-side. Therefore, the instrument would serve properly to address the type of shock most likely to hurt the overall economy severly.

Furthermore, empirical research has shown that banks with limited access to deposit funding are more dependent on conditions on the interbank market. If conditions on the interbank market deteriorate, these banks cut credit more than others, thereby worsening the credit crunch in the real economy. Extending the model to include an interbank market allows to investigate the consequences of another financial shock to the supply side of credit, namely a shock to the interbank loan rate similar to the widening of the LIBOR-OIS spread in 2008. This shock results in higher borrowing costs between banks and the resulting credit crunch has contagionous effects on the real economy. This model confirms the contractionary effects of such a shock and shows that also here, a countercyclical capital buffer is able to reduce the economic volatility by 6% and lending fluctuates 22% less. Policymakers, whose aim it is to reduce macroeconomic volatility, are well advised to introduce a countercyclical buffer to mitigate the effects of shocks to the supply side of credit. Such a tool is, however, less effective in dealing with non-financial shocks and may even amplify economic volatility in case of shocks to the credit demand side.

Since empirical research has shown that lower access to deposit funding makes banks more dependent on conditions on the interbank market, it would be highly interesting to use this framework in order to examine an economy with a number of heterogenous banks who trade on the interbank market. If banks were allowed to differ in size as well as their ability to attract debt funding, it would be possible to analyse the effectiveness of additional regulatory requirements for systemically important financial institutions (SIFIs) in this framework.

Integrating frictions to the interbank market or allowing banks to default on interbank credit would also be of interest. With dependence of the banking sector on interbank funding increasing, such extension would allow to study the resulting credit crunch and the transmission mechanism to the real economy.
I have centered the policy analysis on capital requirements for banks thus disregarding monetary policy applications. However, by introducing nominal rigidities, the model would lend itself easily to assess the joint effectiveness of macroprudential regulation and monetary policy.

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2.A Appendix

2.A.1 List of Notations

Parameters	
α	Share of capital in production function
β_P	Discount factor savers
β_E	Discount factor entrepreneurs
χ_{CR}	Sensitivity of countercyclical capital requirement
δ	Depreciation of capital
σ_{ϵ^A}	Standard deviation of TFP shock
σ_{ϵ^D}	Standard deviation of deposit productivity shock
σ_{ϵ^σ}	Standard deviation of risk shock
η	Likelihood of firm survival
η_b	Elasticity of substitution loan market
η_d	Elasticity of substitution deposit market
γ^{CR}	Capital requirement for bank loans
μ	Bankruptcy costs
ρ_A	Persistence of TFP shock
ρ_D	Persistence of deposit productivity shock
ρ_{CR}	Persistence of time-varying capital rule
ρ_F	Persistence of risk shock
τ	Weight on leisure in utility function
ξ	Equity risk premium
Functions and Definitions	
$f(\omega)$	Density function of idiosyncratic productivity
$F(\omega)$	Cumulative distribution function of idiosyncratic productivity
$\Gamma(\bar{\omega})$	Share of payoff to banks
Φ^N	Cumulative distribution function
$G(\bar{\omega})$	Share of asset value after bankruptcy

Table 4: List of Notations I

Variables	
A_t	Total Factor Productivity
B_t	Corporate loans
B_t^B	Interbank loans
C_t	Household's consumption
D_t	Deposits
D_t^B	Interbank debt
ϵ_t^A	TFP shock
ϵ_t^D	Deposit productivity shock
ϵ_t^A	Shock to idiosyncratic volatility
γ_t^{CR}	Time-varying capital requirement for bank loans
γ_t^D	Costs for attracting deposits
H_t	Total labour demand
H_t^B	Labour demand banks
H_t^P	Labour demand firms
I_t	Investment
K_t^B	Bank capital
K_t^E	Firm capital
λ_t	Household's stochastic discount factor
λ_t^E	Multiplier on the optimal debt contract
N_t	Surviving entrepreneur's net worth
μ_t	Multiplier on bank's borrowing constraint
μ_t^E	Multiplier on entrepreneur's borrowing constraint
$\bar{\omega}_t^a$	Ex-ante threshold
$\bar{\omega}_t^p$	Ex-post (actual) threshold
ϕ_t^y	Value of assets of defaulted entrepreneurs
Π_t^E	Entrepreneur's profit
Π_t^B	Bank profit
R_t^D	Deposit rate
R_t^B	Corporate loan interest rate
R_t^K	Return on capital
R_t^{IB}	Interbank loan rate
R_t^{KB}	Return on bank capital
σ_t^F	Idiosyncratic shock distribution
V_t	Entrepreneur's equity
W_t	Wage
Y_t	Output

Table 5: List of Notations II

2.A.2 The optimal debt contract

In section 2.3.4 we have found that the entrepreneur solves Equation (24)

$$\max_{\bar{\omega}^a_{t+1},K_{t+1}} \left[\Big(1-\Gamma\big(\bar{\omega}^a_{t+1}\big)\Big) E_t[R^K_{t+1}]K_{t+1} \right] \tag{53}$$

subject to bank's participation constraint (25)

$$\bar{R}^E_{t+1}B_{t+1} = \left(\Gamma\Big(\bar{\omega}^a_{t+1}\Big) - \mu G\Big(\bar{\omega}^a_{t+1}\Big)\right) E_t[R^K_{t+1}]K_{t+1} \tag{54}$$

Substituting for entrepreneur's resource constraint Equation (16), $B_{t+1} = K_{t+1} - N_{t+1}$, gives the Lagrangian

$$\begin{aligned} \mathscr{L}_t = &\left(1-\Gamma\Big(\bar{\omega}^a_{t+1}\Big)\right) E_t[R^K_{t+1}]K_{t+1} \\ &+ \lambda^E_t \left[-\bar{R}^E_{t+1}(K_{t+1}-N_{t+1}) + \Big[\Gamma\Big(\bar{\omega}^a_{t+1}\Big) - \mu G\Big(\bar{\omega}^a_{t+1}\Big)\Big] E_t[R^K_{t+1}]K_{t+1} \right] \end{aligned} \tag{55}$$

The first-order conditions with respect to the cut-off value $\bar{\omega}^a_{t+1}$ and capital K_{t+1} are:

$$\frac{\partial \mathscr{L}_t}{\partial \bar{\omega}^a_{t+1}} = -\Gamma'(\bar{\omega}^a_{t+1})E_t[R^K_{t+1}]K_{t+1} + \lambda^E_t \left(\Big[\Gamma'(\bar{\omega}^a_{t+1}) - \mu G'(\bar{\omega}^a_{t+1})\Big] E_t[R^K_{t+1}]K_{t+1} \right) = 0 \tag{56}$$

which gives

$$\lambda^E_t = \frac{\Gamma'(\bar{\omega}^a_{t+1})}{\Gamma'(\bar{\omega}^a_{t+1}) - \mu G'(\bar{\omega}^a_{t+1})} \tag{57}$$

$$\frac{\partial \mathscr{L}_t}{\partial K_{t+1}} = \big(1-\Gamma(\bar{\omega}^a_{t+1})\big)E_t[R^K_{t+1}] + \lambda^E_t \Big[-\bar{R}^E_{t+1} + \big(\Gamma(\bar{\omega}^a_{t+1}) - \mu G(\bar{\omega}^a_{t+1})\big) E_t[R^K_{t+1}] \Big] = 0 \tag{58}$$

thus

$$\big((1-\Gamma(\bar{\omega}^a_{t+1})\big)E_t[R^K_{t+1}] = -\frac{\Gamma'(\bar{\omega}^a_{t+1})}{\Gamma'(\bar{\omega}^a_{t+1}) - \mu G'(\bar{\omega}^a_{t+1})} \left[\Big(\Gamma(\bar{\omega}^a_{t+1}) - \mu G(\bar{\omega}^a_{t+1})\Big) E_t[R^K_{t+1}] - \bar{R}^E_{t+1} \right] \tag{59}$$

For more convenient interpretation, I combine the two first-order conditions to determine the external finance premium $s_t = \frac{E_t[R^K_{t+1}]}{\bar{R}^E_{t+1}}$, the expected discounted return on capital.

Rearranging (58) yields

$$s_t = \frac{\lambda_t^E}{1 - \Gamma(\bar{\omega}_{t+1}^a) + \lambda_t^E(\Gamma(\bar{\omega}_{t+1}^a) - \mu G(\bar{\omega}_{t+1}^a))} \tag{60}$$

Hence there is a linear relationship between the external finance premium and the chosen threshold value.

Rewriting the zero-profit constraint (23) yields

$$\Gamma(\bar{\omega}_{t+1}^a) - \mu G(\bar{\omega}_{t+1}^a) = \frac{\bar{R}_{t+1}^E}{E_t[R_{t+1}^K]}\Big(1 - \frac{N_{t+1}}{K_{t+1}}\Big) \tag{61}$$

Equations (60) and (61) pin down the optimal debt contract variables $\bar{\omega}_{t+1}^a$ and K_{t+1}. $s_t \geq 1$ in the competitive equilibrium, otherweise entrepreneurs do not purchase capital. Given that $s \geq 1$, BGG show that the first-oder conditions yield optimal capital purchases

$$K_{t+1} = \Psi(s_t)N_{t+1} \tag{62}$$

with $\Psi(1) = 1$ and $\Psi'(.) > 0$.

Equation (61) yields

$$\frac{K_{t+1}}{N_{t+1}} = \frac{1}{1 - (\Gamma(\bar{\omega}_{t+1}^a) - \mu G(\bar{\omega}_{t+1}^a))s_t} \equiv \Psi(s_t) \tag{63}$$

By inversion, we get

$$s_t = \frac{1 - 1/(K_{t+1}/N_{t+1})}{\Gamma(\bar{\omega}_{t+1}^a) - \mu G(\bar{\omega}_{t+1}^a)} \equiv S\left(\frac{K_{t+1}}{N_{t+1}}\right) \tag{64}$$

with $S'(.) > 0$. This implies that the higher the leverage ratio, the higher the external finance premium.

To solve for the optimal threshold value $\bar{\omega}_{t+1}^a$ and the optimal leverage ratio, BGG derive analytical expressions for $\Gamma(\bar{\omega}_{t+1}^a)$ and $\Gamma(\bar{\omega}_{t+1}^a) - \mu G(\bar{\omega}_{t+1}^a)$ for log-normally distributed ω. To stay as close as possible to BGG, I set the distribution of ω such that $\ln(\omega_{t+1}) \sim \mathcal{N}(-0.5(\sigma_t^F)^2, (\sigma_t^F)^2)$ which yields $E_t(\omega_{t+1}) = 1$. On expectation, the return on capital for each firm is equal to the aggregate return on capital.

Given this distributional assumption, the optimal default threshold can be expressed in the standardised form

$$z^*_{t+1} = \frac{\ln(\bar{\omega}^a_{t+1}) + 0.5(\sigma^F_t)^2}{\sigma^F_t}. \tag{65}$$

BGG show that for log-normally distributed ω, $E_t(\omega_{t+1} \mid \omega_{t+1} \geq \bar{\omega}^a_{t+1}) = \frac{1-\Phi^N(z_{t+1}-\sigma^F_t)}{\Phi^N(z_{t+1})}$ where Φ^N is the standard normal cumulative distribution function. The optimal contract specifies $\bar{\omega}^a$ such that if $\omega \geq \bar{\omega}^a$, the borrower pays the lender the fixed amount $\bar{\omega}^a R^K K$ and keeps the equity $(\omega - \bar{\omega}^a)R^K K$. Therefore, the share of profit going to the entrepreneur can be expressed as $1 - \Gamma(\bar{\omega}^a_{t+1}) = (E_t(\omega_{t+1} \mid \omega_{t+1} \geq \bar{\omega}^a_{t+1}) - \bar{\omega}^a_{t+1})\Pr(\omega_{t+1} \geq \bar{\omega}^a_{t+1})$. The probability of no default $\Pr(\omega_{t+1} \geq \bar{\omega}^a_{t+1}) = 1 - F(\bar{\omega}^a_{t+1})$ corresponds to $1 - \Phi^N(z_{t+1})$. In other words, $\Phi^N(z_{t+1})$ quantifies the probability of default and hence corresponds to $F(\bar{\omega}^a_{t+1})$ in Equation (22). BGG use this to show that the exact analytical expressions for lender's and entrepreneur's payoff functions are:

$$\Gamma(\bar{\omega}^a_{t+1}) = \Phi^N(z_{t+1} - \sigma^F_t) + \bar{\omega}^a_{t+1}(1 - \Phi^N(z_{t+1})), \tag{66}$$

$$G(\bar{\omega}^a_{t+1}) = \Phi^N(z_{t+1} - \sigma^F_t) \tag{67}$$

$$\Gamma(\bar{\omega}^a_{t+1}) - \mu G(\bar{\omega}^a_{t+1}) = (1-\mu)\Phi^N(z_{t+1} - \sigma^F_t) + \bar{\omega}^a_{t+1}(1 - \Phi^N(z_{t+1})), \tag{68}$$

$$G'(\bar{\omega}^a_{t+1}) = \frac{1}{\sigma^F_t\sqrt{2\pi}}\exp\left(-\frac{(\ln(\bar{\omega}^a_{t+1}) + 0.5(\sigma^F_t)^2)^2}{2(\sigma^F_t)^2}\right), \tag{69}$$

and

$$\Gamma'(\bar{\omega}^a_{t+1}) = 1 - \Phi^N(z_{t+1}). \tag{70}$$

Using these analytical expressions, we can solve the optimal debt contract for the values of the external finance premium s_t, the idiosyncratic shock variance σ^F_t, and the bankruptcy parameter μ. In particular, we substitute Equation (65) through Equations (69) and (70) into (60) to solve for $\bar{\omega}^a_{t+1}$. The result as well as Equations (16) and (25) yield the optimal leverage ratio B_{t+1}/N_{t+1}.

2.A.3 No financial accelerator

$$\max_{\bar{\omega}^a_{t+1}, K_{t+1}} \left[\left(1 - \Gamma\left(\bar{\omega}^a_{t+1}\right)\right) E_t[R^K_{t+1}]K_{t+1}\right] \tag{71}$$

subject to bank's participation constraint

$$\bar{R}^E_{t+1}B_{t+1} = \Gamma\left(\bar{\omega}^a_{t+1}\right) E_t[R^K_{t+1}]K_{t+1} \tag{72}$$

Substituting for entrepreneur's resource constraint Equation (16), $B_{t+1} = K_{t+1} - N_{t+1}$, gives the Lagrangian

$$\begin{aligned}\mathscr{L}_t = &\left(1 - \Gamma\Big(\bar{\omega}^a_{t+1}\Big)\right)E_t[R^K_{t+1}]K_{t+1} \\ &+ \lambda^E_t\bigg[-\bar{R}^E_{t+1}(K_{t+1} - N_{t+1}) + \Gamma\Big(\bar{\omega}^a_{t+1}\Big)E_t[R^K_{t+1}]K_{t+1}\bigg]\end{aligned} \tag{73}$$

The first-order conditions with respect to the cut-off value $\bar{\omega}^a_{t+1}$ and capital K_{t+1} are:

$$\frac{\partial \mathscr{L}_t}{\partial \bar{\omega}^a_{t+1}} = -\Gamma'(\bar{\omega}^a_{t+1})E_t[R^K_{t+1}]K_{t+1} + \lambda^E_t\Gamma'(\bar{\omega}^a_{t+1})E_t[R^K_{t+1}]K_{t+1} = 0 \tag{74}$$

which gives

$$\lambda^E_t = 1 \tag{75}$$

$$\frac{\partial \mathscr{L}_t}{\partial K_{t+1}} = \big(1 - \Gamma(\bar{\omega}^a_{t+1})\big)E_t[R^K_{t+1}] + \lambda^E_t\bigg[-\bar{R}^E_{t+1} + \big(\Gamma(\bar{\omega}^a_{t+1}) - \mu G(\bar{\omega}^a_{t+1})\big)E_t[R^K_{t+1}]\bigg] = 0 \tag{76}$$

thus

$$E_t[R^K_{t+1}] = \bar{R}^E_{t+1} \tag{77}$$

2.A.4 Interbank model

The description of the interbank market follows along the lines of (23; 25). Aggregate deposits and corporate loans according to Dixit Stiglitz

$$D_{t+1} = \Big[\int D_{t+1}(i)^{\frac{\eta_d-1}{\eta_d}} di\Big]^{\frac{\eta_d}{\eta_d-1}} \tag{78}$$

$$B_{t+1} = \Big[\int B_{t+1}(i)^{\frac{\eta_b-1}{\eta_b}} di\Big]^{\frac{\eta_b}{\eta_b-1}} \tag{79}$$

with aggregate interest rates

$$(R^D_{t+1})^{-1} = \Big[\int (R^D_{t+1}(i)^{-1})^{1-\eta_d} di\Big]^{\frac{1}{1-\eta_d}} \tag{80}$$

$$R^B_{t+1} = \Big[\int (R^B_{t+1}(i))^{1-\eta_b} di\Big]^{\frac{1}{1-\eta_b}} \tag{81}$$

with η_d and η_b denoting the elasticities of substitution in deposit and loan markets. Price in deposit function is inverted as banks see increasing demand for rising interest rates. Following Dixit-Stiglitz, the aggregate demand schedules are given as $D_{t+1}(i) = D_{t+1}\Big(\frac{R^D_{t+1}}{R^D_{t+1}(i)}\Big)^{-\eta_d}$ and $B_{t+1}(i) = B_{t+1}\Big(\frac{R^B_{t+1}}{R^B_{t+1}(i)}\Big)^{\eta_b}$.

Optimal deposit labour is given by $H^D_t = \gamma^D_t(i)D_{t+1}(i)$ and in addition, banks can approach the interbank market for to lend or borrow funds. The interbank market rate R^{IB}_{t+1} is taken as given. Bank i's balance sheet constraint takes the following form:

$$B_{t+1}(i) = D_{t+1}(i) + D^B_{t+1}(i) + K^B_{t+1}(i) \tag{82}$$

The left hand side of Equation (82) shows bank i's assets $B_{t+1}(i)$ and household deposits $D_{t+1}(i)$, interbank debt $D^B_{t+1}(i)$, as well as bank capital $K^B_{t+1}(i)$. Note that the interbank position could be either positive or negative depending on whether the bank acts as lender or borrower on the interbank market.

The only risky asset in this setting is still the corporate loan, such that the capital requirement constraint remains similar to the basic setting $\frac{K^B_{t+1}(i)}{B_{t+1}(i)} \geq \gamma^{CR}$. In period t, bank i maximises its discounted profits subject to the balance sheet and the capital requirement constraints. Bank

i's optimzation problem hence becomes

$$\begin{aligned}\mathscr{L}_t(i) = E_t\Bigg\{ \sum_{t=0}^{\infty} \lambda_t \Bigg[&(1-F(\bar{\omega}_t^a))R_t^B B_t(i) + \left(\frac{B_t(i)}{B_t}\right)(1-\mu)\int_0^{\bar{\omega}_t^a} \omega R_t^K K_t f(\omega) d\omega \\ &- R_t^D(i) D_t^H(i) - R_t^{K^B}\gamma^{CR} B_t(i) - R_t^{IB} D_t^B(i) + D_{t+1}(i) \\ &- \gamma^D(i) W_t D_{t+1}(i) + D_{t+1}^B(i) - B_{t+1}(i) + \gamma^{CR} B_{t+1}(i) \Bigg] \\ &+ \mu_t(i) \Big[D_{t+1}(i) + D_{t+1}^B(i) - (1-\gamma^{CR}) B_{t+1}(i) \Big] \Bigg\}\end{aligned} \tag{83}$$

where $\lambda_t = \beta^t(C_t/C_{t+1})$ is the stochastic discount factor of households and μ_t the multiplier on bank's borrowing constraint. For simplicity's sake set $\lambda_{t=1} = 1$ as numeraire, giving the following first order conditions.

$$1 - \gamma^D(i) W_t + \hat{\mu}_t(i) = \Big(\frac{\eta_d + 1}{\eta_d}\Big) E_t[\lambda_{t+1} R_{t+1}^D(i)] \tag{84}$$

$$\begin{aligned}(1 + \mu_t(i))(1 - \gamma^{CR}) = E_t\Big[&\lambda_{t+1}[(1 - F(\bar{\omega}_{t+1}^p))\Big(\frac{\eta_b - 1}{\eta_b}\Big) R_{t+1}^B(i) \\ &+ B_{t+1}^{-1}(1-\mu)\phi_{t+1}^y - R_{t+1}^{K^B}\gamma^{CR}]\Big]\end{aligned} \tag{85}$$

$$\mu_t(i) = E_t[\lambda_{t+1} R_{t+1}^{IB}] \tag{86}$$

Similar to the basic setting, I define $\bar{R}_{t+1}^E$ as the expected net return to bank i for each unit of entrepreneurial loan:

$$\bar{R}_{t+1}^E = \Big(\frac{\eta_b - 1}{\eta_b}\Big)(1 - F(\bar{\omega}_{t+1}^p)) R_{t+1}^B(i) + B_{t+1}^{-1}(1-\mu)\phi_{t+1}^y \tag{87}$$

which can be substituted back into Equation (85) to receive the first-order conditions as

$$R_{t+1}^D(i) = \Big(\frac{\eta_d + 1}{\eta_d}\Big)\Big[R_{t+1}^{IB}(i) - \gamma^D(i) W_t / E_t[\lambda_{t+1}]\Big] \tag{88}$$

$$\bar{R}_{t+1}^E(i) = (1 - \gamma^{CR}) R_{t+1}^{IB}(i) + \gamma^{CR} R_{t+1}^{KB} \tag{89}$$

2.A.5 List of Equations

1. **ENTREPRENEURS**
   $K_{t+1} = I_t + (1-\delta)K_t$, Capital accumulation

2. $B_{t+1} = K_{t+1} - N_{t+1}$, Entrepreneur is required to borrow everything she cannot pay out of net worth

3. $Y_t = A_t K_t^{\alpha}(H_t^P)^{1-\alpha}$, Production function

4. $R_{t+1}^K = \alpha(Y_{t+1}/K_{t+1}) + (1-\delta)$, Marginal product of capital

5. $W_t = (1-\alpha)(Y_t/H_t^P)$, Marginal product of labour

6. $V_{t+1} = R_{t+1}^K K_{t+1} - R_{t+1}^E B_{t+1} - \mu\phi_{t+1}^y$, Entrepreneur's equity

7. $\phi_{t+1}^y = G(\bar{\omega}_{t+1}^p)R_{t+1}^K K_{t+1}$, Value of assets of defaulted entrepreneur

8. $N_{t+1} = \eta V_t$, Surviving entrepreneur's net worth

9. $\Pi_t^E = (1-\eta)V_t$, Not-surviving entrepreneurs donate their equity to households

10. **DEBT CONTRACT:**
    $B_{t+1}R_{t+1}^E = (\Gamma - \mu G)E_t[R_{t+1}^K]K_{t+1}$, Expected return based on expectation of capital return

11. $R_{t+1}^E(\Gamma'/(\Gamma - \mu G')) = (1-\Gamma)E_t[R_{t+1}^K] + (\Gamma'/(\Gamma' - \mu G'))(\Gamma - \mu G)E_t[R_{t+1}^K]$, Combination of both FOCs

12. $z_{t+1}(\bar{\omega}_{t+1}^a) = \frac{\ln(\bar{\omega}_{t+1}^a) + 0.5(\sigma_t^F)^2}{\sigma_t^F}$,

13. $G(\bar{\omega}_{t+1}^a) = \Phi^N(z_{t+1} - \sigma_t^F)$,

14. $\Gamma(\bar{\omega}_{t+1}^a) = \Phi^N(z_{t+1} - \sigma_t^F) + \bar{\omega}_{t+1}^a(1 - \Phi^N(z_{t+1}))$,

15. $B_t R_t^E = ((\Gamma(\bar{\omega}_t^p) - \mu G(\bar{\omega}_t^p))R_t^K K_t$, Actual return based on current capital return

16. $z_t(\bar{\omega}_t^p) = \frac{\ln(\bar{\omega}_t^p) + 0.5(\sigma_t^F)^2}{\sigma_t^F}$,

17. $G(\bar{\omega}_t^p) = \Phi^N(z_t - \sigma_t^F)$,

18. $\Gamma(\bar{\omega}_t^p) = \Phi^N(z_t - \sigma_t^F) + \bar{\omega}_t^p(1 - \Phi^N(z_t))$,

19. **HOUSEHOLDS:**
    $1/C_t = \beta(R_{t+1}^D/C_{t+1})$, Euler equation consumption / deposits

20. $H_t = 1 - \tau C_t/W_t$, Labour supply

21. $\lambda_t = \beta(C_t/C_{t+1})$,

22. $R_t^{KB} = \xi R_t^D$,

23. **BANKING:**
$H_t^D = \gamma_t^D D_{t+1}$, Technology involved in producing deposits

24. $\bar{R}_t^E = (1-\gamma_t^{CR})\Big(R_t^D + \frac{W_t\gamma_t^D}{\lambda_{t+1}}\Big) + \gamma_t^{CR} R_t^{KB}$, Spread between required return for risky loans and interbank assets

25. $\Pi^B = (1-F(\bar{\omega}_t^p))R_t^B B_t + (1-\mu)\phi_t^y - R_t^D D_t - R_t^{KB} K_t^B + D_{t+1} - W_t\gamma_t^D D_{t+1} - B_{t+1} + K_{t+1}^B$, Bank profit

26. $K_{t+1}^B = \gamma_t^{CR} B_{t+1}$, Capital requirement constraint

27. **MARKET CLEARING:**
$H_t = H_t^P + H_t^D$, Labour market clearing

28. $C_t + D_{t+1} + K_{t+1}^B = R_t^D D_t + R_t^{KB} K_t^B + W_t H_t + \Pi_t^E + \Pi_t^B$, Household budget constraint

29. $Y_t = C_t + I_t + \mu\phi_t^y$, Goods market clearing - Serves as check for Walras' Law

30. **SHOCKS:**
$A_t = (1-\rho_A)\bar{A} + \rho_A A_{t-1} + \epsilon_{t,A}$, Shock to productivity

31. $\sigma_t^F = (1-\rho_F)\bar{\sigma}^F + \rho_F \sigma_{t-1}^F + \epsilon_{t,F}$, Shock to entrepreneur's riskiness

32. $\gamma_t^D = (1-\rho_D)\gamma^D + \rho_D \gamma_{t-1}^D + \epsilon_{t,D}$, Shock to bank intermediation costs

2.A.6 Steady state

Jointly determine $\bar{\omega}$ and σ^F such that $F(\bar{\omega})$, the default rate, is equal to 2.5% p.a. This yields

$$z = \frac{\ln(\bar{\omega}) + 0.5(\sigma^F)^2}{\sigma^F} \tag{90}$$

$$G(\bar{\omega}) = \Phi^N(z - \sigma^F) \tag{91}$$

$$\Gamma(\bar{\omega}) = \Phi^N(z - \sigma^F) + \bar{\omega}(1 - \Phi^N(z)) \tag{92}$$

$$G'(\bar{\omega}) = \frac{1}{\sigma^F\sqrt{2\pi}}\exp\left(-\frac{(\ln(\bar{\omega}) + 0.5(\sigma^F)^2)^2}{2(\sigma^F)^2}\right) \tag{93}$$

$$\Gamma'(\bar{\omega}) = 1 - \Phi^N(z) \tag{94}$$

$$\lambda^E = \Gamma'(\bar{\omega})/(\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})) \tag{95}$$

$$F(\bar{\omega}) = 1 - (\Gamma(\bar{\omega}) - G(\bar{\omega}))/(\bar{\omega}) \tag{96}$$

Bank's funding costs can be determined by the cost of deposit and equity funding.

$$\lambda = \beta \tag{97}$$

$$R^D = 1/\beta \tag{98}$$

$$R^{KB} = \xi R^D \tag{99}$$

Starting with an initial guess for W, we can solve for

$$R^E = (1 - \gamma^{CR})(R^D + \gamma^D W/\lambda) + \gamma^{CR} R^{KB} \tag{100}$$

The first-order conditions of the optimal debt contract yield the return on capital as

$$R^K = \lambda^E R^E/(1 - \Gamma(\bar{\omega}) + \lambda^E(\Gamma(\bar{\omega}) - \mu G(\bar{\omega})) \quad \text{with } \lambda^E = \Gamma'/(\Gamma' - \mu G') \tag{101}$$

Marginal cost of capital are given by

$$r^k = R^K - 1 + \delta \tag{102}$$

and the survival rate of the entrepreneur can be calculated as

$$\eta = N/V = (K - B)/V = (1 - (\Gamma - \mu G)R^K/R^E)/((1 - \Gamma)R^K). \tag{103}$$

From household's budget constraint, we know that consumption is equal to

$$C = (R^D - 1)D + (R^{KB} - 1)K^B + WH + \Pi \tag{104}$$

Substituting for $D = (1-\gamma^{CR})B$, $K^B = \gamma^{CR}B$ and $B = (\Gamma - \mu G)R^K K/R^E$ gives consumption as

$$C = (R^D - 1)(1-\gamma^{CR})(\Gamma - \mu G)R^K K/R^E + (R^{KB} - 1)\gamma^{CR}(\Gamma - \mu G)R^K K/R^E + WH + \Pi \tag{105}$$

Given that $\Pi^E = (1 - \eta)V = (1 - \eta)(1 - \Gamma)R^K K$, $H = H^P + H^D$ and $H^D = \gamma^D D = \gamma^D(1 - \gamma^{CR})(\Gamma - \mu G)/R^E R^K K$, household's consumption becomes

$$C = (oo5 + W\gamma^D oo4)R^K K + WH^P \tag{106}$$

for
$oo1 = (R^D - 1)(1 - \gamma^{CR})(\Gamma - \mu G)/R^E$
$oo2 = (R^{KB} - 1)\gamma^{CR}(\Gamma - \mu G)/R^E$
$oo3 = (1 - \eta)(1 - \Gamma)$
$oo4 = (1 - \gamma^{CR})(\Gamma - \mu G)/R^E$
$oo5 = oo1 + oo2 + oo3$
From firm's production, we know that $K = \frac{\alpha}{1-\alpha}\frac{WH^P}{r^K}$ which we can substitute above yielding

$$C = (oo5 + W\gamma^D oo4)R^K \frac{\alpha}{1-\alpha}\frac{WH^P}{r^K} + WH^P = (1 + oo6)WH^P \tag{107}$$

From household's first-order condition, we know that labour supply is equal to

$$\frac{W}{C} = \frac{\tau}{1 - H} = \frac{\tau}{1 - (H^P + H^D)} = \frac{\tau}{1 - H^P - \gamma^D oo4 R^K/r^K \alpha/(1-\alpha)WH^P} = \frac{\tau}{1 - (1 + oo7)H^P} \tag{108}$$

Substituting for consumption yields optimal labour input in productive sector as

$$H^P = \frac{1}{1 + oo7 + \tau(1 + oo6)} \tag{109}$$

From there, we can determine

$$Y = \frac{WH^P}{1-\alpha} \tag{110}$$

and solve for the wage rate W that satisfies

$$Y = K^{\alpha}(H^P)^{1-\alpha} \tag{111}$$

Subsequently, we can determine the other variables relatively straight forward

$$K = (Y/((H^P)^{(1-\alpha)})^{1/\alpha} \tag{112}$$

$$\phi^y = GR^K K \tag{113}$$

$$B = (\Gamma - \mu G)R^K K/R^E \tag{114}$$

$$R^B = (R^E - (1-\mu)\phi^y)/(1 - F(\bar{\omega})) \tag{115}$$

$$I = \delta K \tag{116}$$

$$N = K - B \tag{117}$$

$$V = R^K K - R^E B - \mu\phi^y \tag{118}$$

$$\Pi^E = (1-\eta)V \tag{119}$$

$$K^B = \gamma^{CR} B \tag{120}$$

$$D = B - S \tag{121}$$

$$H^D = \gamma^d D \tag{122}$$

$$H = H^D + H^P \tag{123}$$

$$C = (R^D - 1)D + (R^{KB} - 1)K^B + WH + \Pi^E \tag{124}$$

$$Y = C + I + \mu\phi^y \tag{125}$$

2.A.7 Equilibrium: Walras Law

Section 2.3.8 indicates the market clearing conditions of the model economy. Market clearing is implied by Walras' law by aggregating all the budget constraints. Taking the budget constraints of the model economy yields the following equations:
Households:

$$C_t + D_{t+1} + K^B_{t+1} = W_t H^P_t + W_t \gamma^D_t D_{t+1} + R^D_t D_t + R^{KB}_t K^B_t + \Pi^E_t + \Pi^B_t \tag{126}$$

Bank:

$$\begin{aligned}\Pi^B_t = {} & (1 - F(\bar{\omega}^p_t)) R^B_t B_t + (1-\mu)\phi^y_t - R^D_t D_t - R^{KB}_t K^B_t \\ & + D_{t+1} - W_t \gamma^D D_{t+1} - B_{t+1} + K^B_{t+1}\end{aligned} \tag{127}$$

Entrepreneur:

$$\begin{aligned}K_{t+1} - B_{t+1} &= N_{t+1} \\ &= V_t - \Pi^E_t \\ &= R^K_t K_t - (1 - F(\bar{\omega}^p_t)) R^B_t B_t - \phi^y_t - \Pi^E_t \\ &= (r^K_t + (1-\delta)) K_t - (1 - F(\bar{\omega}^p_t)) R^B_t B_t - \phi^y_t - \Pi^E_t\end{aligned} \tag{128}$$

Consumption good firm:

$$0 = Y_t - W_t H^P_t - r^K_t K_t \tag{129}$$

Subsituting Equation (127) into (126) and given that deposit market clearing requires $D_t = D_t$ yields:

$$\begin{aligned}C_t + D_{t+1} + K^B_{t+1} = {} & W_t H^P_t + W_t \gamma^D_t D_{t+1} + R^D_t D_t + R^{KB}_t K^B_t + \Pi^E_t \\ & + (1 - F(\bar{\omega}^p_t)) R^B_t B_t + (1-\mu)\phi^y_t - R^D_t D_t - R^{KB}_t K^B_t \\ & + D_{t+1} - W_t \gamma^D D_{t+1} - B_{t+1} + K^B_{t+1} \\ C_t = {} & W_t H^P_t + \Pi^E_t + (1 - F(\bar{\omega}^p_t)) R^B_t B_t + (1-\mu)\phi^y_t - B_{t+1}\end{aligned} \tag{130}$$

The total demand for household's labour by the firm, $(1-\alpha)Y/W$, plus the demand by banks, H^D, must be equal to the labour supply by households. Labour market clearing:

$$H = H^P + H^D \tag{131}$$

Substituting Equations (128) and simplifying gives:

$$\begin{aligned} C_t &= W_t H_t^P + (r_t^K + (1-\delta))K_t - (1 - F(\bar{\omega}_t^p))R_t^B B_t - \phi_t^y - K_{t+1} + B_{t+1} \\ &\quad + (1 - F(\bar{\omega}_t^p))R_t^B B_t + (1-\mu)\phi_t^y - B_{t+1} \\ C_t &= W_t H_t^P + (r_t^K + (1-\delta))K_t - K_{t+1} - \mu\phi_t^y \end{aligned} \tag{132}$$

Finally, inserting Equation (129) yields goods market clearing:

$$Y_t = C_t + K_{t+1} - (1-\delta)K_t + \mu\phi_t^y = C_t + I_t + \mu\phi_t^y \tag{133}$$

2.A.8 Data used in Calibration

- Bank Equity Return: Return on Average Equity (ROAE) for all US banks, Quarterly, Percent, 1988-2018. Source: FRED USROE
- Non-performing loans: Nonperforming Total Loans (past due 90+ days plus nonaccrual) to Total Loans, US, Quarterly, Percent, 1988-2018. Source: FRED NPTLTL
- Corporate loan rate: Lending interest rate, US, Quarterly, Percent, 1988-2018. Source: Worldbank FR.INR.LEND
- Demand deposits: Total US demand deposits, Monthly, Billions of USD, 1990-2018. Source: FRED DEMDEPNS
- Working Hours for Deposit Production: All Employees - Financial Activities - Depository Credit Intermediation, Monthly, Thousands of Persons,1990-2018. Source: FRED CEU5552210001. Assuming that each worker works 40 hours per week and four weeks per month yields the number of hours worked in deposit production.
- LIBOR OIS Spread: Spread between LIBOR rate and OIS rate, USD, Percent, 2001-2018. Source: Bloomberg BICLOISS Index

2.A.9 Regression results: AR(1) process of γ_t^D

I use monthly time series data for demand deposits from the database of the Federal Reserve Bank St. Louis in addition to data on the number of credit officers engaged in deposit intermediation. Assuming that each credit office works 40 hours per week, hence 160 hours per month, I can construct γ_t^D as the time series H_t^D/D_{t+1}. By converting the time series into quarterly data, it is possible to match the frequency of the model. Considering the left panel of Figure 10, we find that the time series exhibits a strong downward trend. While hours worked appear to be almost stationary during the examined time period, deposits exhibit a strong upward trend therefore counting responsible for the trend in the combined series. In order to use the data in the DSGE model, I seasonally adjust the time series and subsequently use an HP-filter to remove the trend. The resulting time series is depicted on the right panel in Figure 10. To receive values for the persistence and variance of deposit productivity, I estimate a first-order autoregressive process using least squares regression:

$$\gamma_t^D = \rho_D \gamma_{t-1}^D + \epsilon_D \tag{134}$$

I find that deposit productivity is highly persistent with $\hat{\rho}_D = 0.85$.

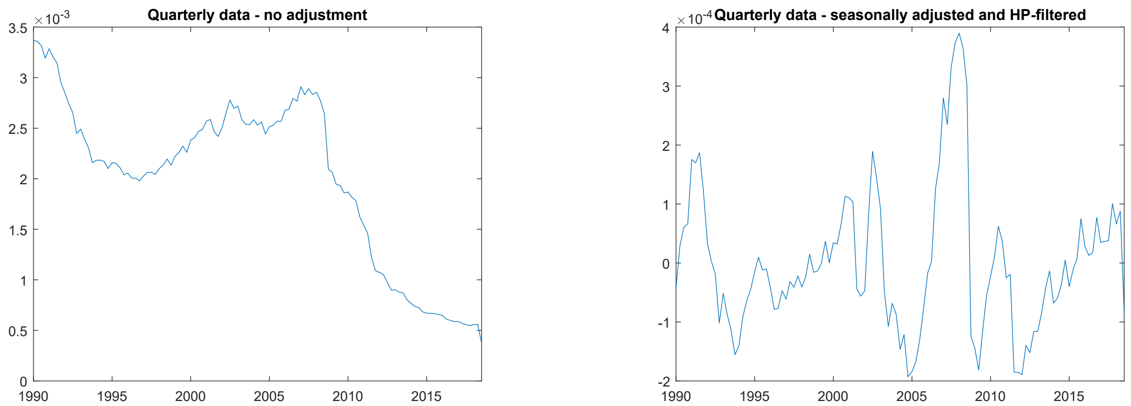

Figure 10: γ^D: Time series with trend and after seasonal adjustment and HP-filtering

Variable	
ρ_D	0.85189***
	(0.04978)
cons	$-2.6e^{-07}$
	$(6.0e^{-06})$
N	114
R^2	0.72

$^{***}p < 0.01$

Table 6: AR(1) PROCESS γ_t^D

Chapter 3

Italy in the Eurozone

Christian Keuschnigg, Linda Kirschner, Michael Kogler and Hannah Winterberg[1]

Using a DSGE model with nominal wage rigidity, we investigate two scenarios for the Italian economy. The first considers sustained policy commitment to reform. The results indicate the possibility of 'growing out of bad initial conditions', if fiscal consolidation is combined with a program for bank recovery and for competitiveness and growth. The second scenario involves a strong asymmetric recession. It is likely to be very severe under the restrictions of the currency union. A benign exit from the Eurozone with stable investor expectations could substantially dampen the short-run impact. Stabilization is achieved by monetary expansion, combined with exchange rate depreciation. However, investor panic may lead to escalation. Capital market reactions would offset the benefits of monetary autonomy and much delay the recovery.
JEL Classification: E42, E44, E60, F30, F36, F45, G15, G21
Keywords: Italy, competitiveness, sovereign debt, bad loans, bank recapitalization, Eurozone crisis.

[1]We appreciate constructive comments by seminar participants of the Tuebingen workshop on International Economic Integration on May 22, 2019, and of the CESifo Venice Summer Institute 2019 on the Future of Europe on June 6, 2019. We appreciate special comments by the discussant Kai Gehring and by Guido Cozzi and Jesus Crespo Cuaresma.

3.1 Introduction

The global financial crisis revealed large imbalances in the Eurozone. Banks were highly leveraged and unable to absorb large shocks, requiring government support. With the increase in public debt, doubts emerged about the solvency of several member states, leading to substantially higher borrowing costs for those governments. Banks, which typically hold large amounts of domestic sovereign debt, and other investors faced the risk of sovereign default. In addition, some countries in the Eurozone periphery had gradually lost competitiveness in the pre-crisis boom during the early 2000s and have experienced stagnant growth thereafter. The latter significantly constrains the borrowing capacity of governments and hampers the role of the fiscal budget in stabilizing the economy during a recession. Instead of providing fiscal relief, governments may be forced to pursue a policy of fiscal consolidation. This reinforces the downturn and ultimately magnifies the share of non-performing loans thereby further weakening the banking sector.

Italy arguably comes close to the Eurozone trilemma of fiscal solvency issues, problems in the banking sector and stagnant growth. On all three fronts, the country starts from unfavorable initial conditions and is especially vulnerable to shocks. First, public debt is excessively high and accounts for 130 percent of GDP. The chronically high debt level is mainly a result of the 1980s and early 1990s. Between the late 1990s and 2008, it remained stable around 100 percent of GDP. However, the financial crisis led to an increase in the public debt ratio by roughly 30 percentage points. Second, the Italian banking sector suffers from many non-performing loans. Their share increased from 6 to 16 percent of total loans between 2006 and 2013 (Schivardi et al., 2017). Since Italian banks were not severely hit by the first wave of the financial crisis due to their low exposure to the US subprime market, fiscal support with equity injections or the creation of bad banks was limited. These measures would have allowed banks to restructure non-performing loans. Instead, they kept those loans and continued to finance distressed borrowers. Another potential source of financial instability is that banks have traditionally held large amounts of domestic sovereign bonds, more than 11 percent of bank assets in 2017 according to ECB data. Third, the Italian economy suffers from sluggish growth and low productivity. In 2017, real GDP per capita was virtually the same as in 2000. An important reason for this pattern is stagnant or declining labor productivity since the 1990s, which contributed to rising unit labor costs and deteriorating competitiveness.

The paper formulates a dynamic stochastic general equilibrium (DSGE) model. We first simulate how sustained policy commitment to fiscal and banking reforms within the monetary union can help Italy overcome the bad initial conditions and converge to a new steady state. Subsequently, we compare the consequences and policy options in case of severe, asymmetric recession in Italy. We specifically consider three scenarios, namely, (i) continued membership within the Eurozone, (ii) a 'benign' exit from the Eurozone, and (iii) an 'escalating' exit. The exit introduces a flexible exchange rate between the Euro and the new currency (Lira) and allows for an autonomous monetary policy tailored to the needs of the Italian economy. These scenarios and our focus on events following a recession reflect the widely accepted view that money and exchange rates affect real economic activity in the short and medium run due to nominal rigidities but are largely neutral in long-run equilibrium. Given the uncertainty about how an exit from the Eurozone could be organized, we consider two distinct cases. The 'benign' scenario pictures the best case without severe short-run disruptions such as a widespread loss of confidence. In contrast, the 'escalating' scenario corresponds to the worst case. It introduces runs on Italian banks and a flight to safety with a large sell-off of Italian sovereign bonds. Short-run effects are much more damaging.

The paper develops a three-region DSGE model with money and nominal rigidities. It pictures Italy, the rest of the Eurozone and the rest of the world. The main focus is on Italy. While the other two regions are kept rather stylized, the model of the Italian economy includes a banking sector, a government, and a real sector and thereby captures three reinforcing driving forces of a crisis within the Eurozone. The regions are connected with trade in goods and capital flows. Nominal wage stickiness allows for real effects of monetary policy. Importantly, our analysis includes a regime change from monetary union to a new currency with flexible exchange rates and renationalization of monetary policy making. The model is empirically implemented: The initial steady state is calibrated to match the Italian economy in the early 2000s prior to the crisis. Adding structural shocks to the model and using Bayesian estimation procedures allows us to track past performance and approximately replicate time series until 2017.

Our quantitative analysis yields three main results: First, we show that a 'reform package' consisting of tax- and expenditure based fiscal consolidation, a shift to productivity enhancing fiscal spending, tax incentives for investment, as well as labor market and banking reform could help Italy to overcome unfavorable initial conditions and gradually reach a new long-run equilibrium with higher income and consumption and lower public debt. Second, the short- and medium-term response of the Italian economy to an asymmetric recession markedly differs depending on whether the country continues to be part of the Eurozone or exits. An exit would allow Italy to conduct an independent monetary policy more tailored to the specific needs of its economy and to depreciate its new currency. Nominal rigidities are critical for this result as monetary expansion may immediately depreciate real wages, thereby increasing employment. In general, the recession reduces real variables like domestic output, employment and capital stock less strongly in the short but more strongly in the medium run if Italy exits compared to continued membership. Third, an escalating exit accompanied with investor panic would eliminate any such short-term gains from having access to a more flexible monetary policy and would magnify the recession. An important driver is the sudden increase in risk premia for banks and governments, which translates into higher borrowing costs and significantly lowers investment and capital stock.

The existing literature on the Eurozone is large and predominantly relates to specific aspects of the crisis. The aim of the present paper is to capture vicious spirals and reinforcing feedback loops in a DSGE model and evaluate alternative policy scenarios. Specifically, it compares the recovery following a recession under continued membership in the monetary union with developments in two exit scenarios. Closest to our endeavor is the research by Gourinchas et al. (2016) and Chodorow-Reich et al. (2019) who suggest an open economy New Keynesian DSGE model to explain the evolution of the Greek economy during the crisis. Martin and Philippon (2017) develop a stylized two-country model to analyze the contrasting behavior of the periphery and core countries and to investigate macroprudential policies. They also include amplifying feedback mechanisms in reduced form. Gilchrist et al. (2017) introduce a DSGE model with two financially heterogeneous regions where financial frictions prevent price adjustments. Apart from differences in modeling, none of these papers considers an exit scenario implying a complete regime shift, that is, moving from fixed to flexible exchange rates and from common to national monetary policy. Part of this scenario resembles the break-up of currency pegs. Schmitt-Grohe and Uribe (2016), for example, show how downward wage rigidity combined with free capital mobility cause overborrowing in booms and unemployment during recessions, resembling key aspects of the Eurozone crisis.

The present paper emphasizes a trilemma of high public debt, weak banks, and deteriorating competitiveness (see Shambough, 2012). Our approach is motivated by the importance of these three reinforcing driving forces of the Eurozone crisis, which are well documented in empirical research: First, a systemic banking crisis entails severe macroeconomic and fiscal costs. Laeven and Valencia (2012) analyze a range of banking crises since 1970 and estimate a 32 percent median cumulative output loss relative to the pre-crisis trend over four years in advanced economies. A weakened banking sector tends to prolong the crisis. Under-capitalized banks continue to finance distressed firms because they cannot absorb the short-term restructuring costs. Schivardi et al. (2017) find that banks with a below-median capital ratio are more likely to lend to highly indebted, unproductive firms. A banking crisis typically leads to a massive increase in public debt. Reinhart and Rogoff (2013) suggest that government debt is on average 86 percent higher three years after a major banking crisis. On top of bailout costs, this figure accounts for stimulus packages and a shortfall of tax revenue. As the Irish experience has shown, a banking crisis can rapidly transform into a public debt crisis (e.g., Acharya et al., 2014).

Second, a sovereign debt crisis undermines financial stability. European banks typically hold large amounts of domestic sovereign bonds (e.g., Acharya and Steffen, 2015; Altavilla et al., 2016; Ongena et al., 2016). Given this exposure, a public debt crisis leads to a massive contraction of private credit especially if banks' sovereign bond holdings are large and they are highly leveraged (Gennaioli et al., 2014). Bofondi et al. (2018) show that, during the sovereign debt crisis, domestic Italian banks reduced credit significantly more than foreign banks that operate in Italy. Related papers highlight that banks' sovereign bond purchases crowded out corporate lending, for example, Becker and Ivashina (2018) and Popov and Van Horen (2015).

Third, a lack of competitiveness can become an obstacle for economic growth and lead to persistent employment problems. Declining tax revenues magnify budget deficits and render fiscal consolidation more painful and less effective in stabilizing public debt. Furthermore, the share of non-performing loans tends to rise under such circumstances, making private defaults more frequent. The empirical literature on the macroeconomic determinants of non-performing loans emphasizes the role of growth and unemployment (e.g., Louzis et al., 2012; Salas and Saurina, 2002) or the specific impact of recessions (Quagliariello, 2007). A large stock of non-performing loans, in turn, hurts banks, weakens growth by constraining reallocation, and is a source of financial instability.

The remainder of this paper is organized as follows: Section 2 sets out the DSGE model. Section 3 reports on calibration and illustrates how the model tracks the performance of Italy since the introduction of the Euro. It then turns to the three recession scenarios, with and without Eurozone exit. Section 4 concludes.

3.2 The Model

The monetary DSGE model includes three regions. The focus is on Italy. The rest of the Eurozone is modeled in much less detail but is sufficient to explain trade and capital flows. Italy and the Eurozone may run independent or common monetary policy, with fixed or flexible exchange rates. The rest of the world (RoW) is represented by export demand functions. Goods are differentiated by geographic origin, with the RoW good serving as numeraire. The presentation is meant to provide an overview.[2]

3.2.1 Production Sector

Investment firms accumulate capital. *Monopolistic input firms* rent capital and hire labor to produce differentiated intermediate goods (inputs). Competitive *final goods producers* assemble

[2]For a complete documentation, we refer to the Technical Appendix in Keuschnigg (2020).

intermediate inputs y_{vt} to produce a final good using the technology $Y_t^g = \left[\int_0^1 y_{vt}^{(\sigma_v-1)/\sigma_v} dv\right]^{\sigma_v/(\sigma_v-1)}$. Given aggregate demand Y_t^g, expenditure minimization results in demand for inputs and a final goods price index P_t,

$$y_{v,t} = (P_t/p_{vt})^{\sigma_v} Y_t^g, \quad P_t = \left[\int_0^1 p_{vt}^{1-\sigma_v} dv\right]^{1/(1-\sigma_v)}, \quad P_t Y_t^g = \int_0^1 p_{vt} y_{vt} dv. \tag{1}$$

Aggregate spending is $P_t Y_t^g$, and the price elasticity of demand for components is $\sigma_v > 1$. Input suppliers are specialized in a single variety v and use technology $y_{vt} = z_t k_{vt}^{\alpha} l_{vt}^{1-\alpha}$. They rent capital k_{vt} at a price w_t^K from investment firms, and employ labor l_{vt} at a uniform price w_t^L . Labor is a bundle of specialized services with unit cost w_t^L, see below. In a first stage, firms minimize cost per unit of output, giving $m_t^c = \min_{l_{vt},k_{vt}} w_t^L l_{vt} + w_t^K k_{vt}$ s.t. $y_{vt} = 1$. Since components y_{vt} are close substitutes, firms enjoy local monopoly power and earn $\chi_{vt}^m = \max_{p_{vt}} (p_{vt} - m_t^c) y_{vt}$. In a second stage, they set a profit maximizing price p_{vt} subject to the perceived demand elasticity in (1). Since all firms face identical factor prices, production is symmetric. The price is a mark up over marginal costs,

$$p_t = \frac{\sigma_v}{\sigma_v - 1} \cdot m_t^c, \quad \chi_t^m = (p_t - m_t^c) Y_t^g. \tag{2}$$

Due to symmetry, $p_t = P_t$ and $y_t = Y_t^g$. Aggregate monopoly profit is χ_t^m.
By linear homogeneity, factor use is linear in output and must exhaust factor supply, $K_{t-1} = k_t^u Y_t^g$ and $L_t = l_t^u Y_t^g$. The unit isoquant $1 = z_t (k_t^u)^{\alpha} (l_t^u)^{1-\alpha}$ implies final output

$$Y_t^g = z_t K_{t-1}^{\alpha} L_t^{1-\alpha}, \quad z_t = (1-\rho^z) \bar{z}_t + \rho^z z_{t-1} + \varepsilon_t^z, \tag{3}$$

where z_t is a standard productivity shock and $\bar{z}_t$ is specified in (24) below.
Total costs are $m_t^c Y_t^g = w_t^L L_t + w_t^K K_{t-1}$. Noting (2), the value of final output is competitive earnings of labor and capital, augmented by monopoly profits,

$$P_t Y_t^g = w_t^L L_t + w_t^K K_{t-1} + \chi_t^m. \tag{4}$$

Finally, employment is a CES composite $L_t = \left[\int_0^1 L_{j,t}^{(\sigma_l-1)/\sigma_l} dj\right]^{\sigma_l/(\sigma_l-1)}$ of differentiated services $L_{j,t}$ supplied by specialized individuals. Firms face wages $w_{j,t}$ set by households and, to minimize labor costs, adjust the use of labor services according to

$$L_{j,t} = \left(w_t^L / w_{j,t}\right)^{\sigma_l} L_t, \quad w_t^L = \left[\int_0^1 w_{j,t}^{1-\sigma_l} dj\right]^{1/(1-\sigma_l)}. \tag{5}$$

Total costs are $w_t^L L_t = \int_0^1 w_{j,t} L_{j,t} dj$ and w_t^L is a nominal wage index.

3.2.2 Household Sector

Households supply labor, consume goods, and demand real money balances. Households of region i consume final goods C_t^{ij}. The index $j \in \{i, e, o\}$ refers the origin country. We think of Italy i (home), the rest of the Eurozone e, and other countries o (RoW). In most cases, we suppress the index i so that $C_t = C_t^{ii}$ is demand for home goods, and C_t^{ie} and C_t^{io} are imports. Assuming that final goods are differentiated by origin, households consume a basket $\bar{C}_t = \left[{}_j \left(s^j\right)^{1/\sigma_r} \left(C_t^{ij}\right)^{(\sigma_r-1)/\sigma_r}\right]^{\sigma_r/(\sigma_r-1)}$, and optimally demand

$$C_t^{ij} = s^j \left(\bar{P}_t / P_t^{ij}\right)^{\sigma_r} \bar{C}_t, \quad \bar{P}_t = \left[{}_j s^j \left(P_t^{ij}\right)^{1-\sigma_r}\right]^{1/(1-\sigma_r)}, \tag{6}$$

where $\bar{P}_t$ is the price index and minimum spending is ${}_j P_t^{ij} C_t^{ij} = \bar{P}_t \bar{C}_t$. Exchange rates relate import prices in domestic currency to foreign producer prices in foreign currency,

$$P_t^{ie} = e_t^{ie} \cdot P_t^e, \quad P_t^{io} = e_t^{io} \cdot P^o. \tag{7}$$

Suppose i (Italy) uses Lire, e uses Euros and o Dollars. Exchange rates convert 1 Euro and 1 Dollar into e_t^{ie} and e_t^{io} Lire. Lira prices for imports are P_t^{ie} and P_t^{io} where foreign prices P_t^e and $P^o = 1$ (numeraire) are in foreign currency. The inverse rate converts 1 Lira into $1/e_t^{ie}$ Euros and $1/e_t^{io}$ Dollars. By transitivity, the Euro Dollar exchange rate is $e_t^{eo} \equiv e_t^{io}/e_t^{ie}$. When Italy is part of the Euro Area, the exchange rate $e_t^{ie} = 1$ is fixed.

The household is an extended family with individuals $j \in [0, 1]$, each offering labor services $N_{j,t}$. Household size is H, and $N_{j,t}$ is labor supply per capita. Type j is a monopolist over her specialized services and sets a wage $w_{j,t}$. Once wage and labor supply are optimally determined, the family pools all income. Preferences for consumption, labor supply and *real* money balances $\bar{M}_t$ are

$$V_t^h = E_t \sum_{s=0}^{\infty} \beta^s u\left(\bar{C}_{t+s}, \bar{M}_{t+s}, \{N_{j,t+s}\} H\right). \tag{8}$$

Preferences are homothetic and separable. Instantaneous utility is

$$u_t = \frac{X_t^{1-\sigma_c}}{1-\sigma_c} - \phi_t \cdot \frac{\int_0^1 N_{j,t}^{1+\eta} H dj}{1+\eta}, \quad X_t = \left[s_c \bar{C}_t^{1-\sigma_m} + (1-s_c)\bar{M}_t^{1-\sigma_m}\right]^{1/(1-\sigma_m)}. \tag{9}$$

The process $\phi_t = \left(1-\rho^\phi\right)\bar{\phi} + \rho^\phi \phi_{t-1} + \varepsilon_t^\phi$ introduces fluctuations in labor supply and converges to $\bar{\phi}$ in the absence of shocks. Changing the taste parameter $\bar{\phi}$ captures, in reduced form, 'institutional' changes affecting the willingness to work.

Labor earnings derive from differentiated services $N_{j,t}$ at wages $w_{j,t}$. Insurance within the family perfectly smooths income risk. The family cares only about total earnings. Households pay a wage income tax at rate τ_t and a consumption tax at rate τ_t^c, and are able to reduce tax liability by T_t^l (see the fiscal budget). They collect dividends χ_t and χ_t^b from firms and banks, respectively, and receive transfers from social spending E_t and seignorage T_t^M. Income from bank deposits S_t^d includes interest plus repayment of deposits, net of any new savings. Net earnings on government debt holdings are $\left(1-\tilde{s}^b\right) S_t^G$. We assume that households directly hold a share $1-\tilde{s}^b$ of government debt, and banks hold the rest. Residual savings in bonds is subject to the nominal budget constraint

$$\begin{aligned} A_t/\left(1+i_t\right) &= A_{t-1}+\int_0^1\left(1-\tau_t\right) w_{j,t} N_{j,t} H dj+E_t+T_t^l+\chi_t+\chi_t^b \\ &+ S_t^d+\left(1-\tilde{s}^b\right) S_t^G+\left(M_{t-1}-M_t\right)+T_t^M-\left(1+\tau_t^c\right) \bar{P}_t \bar{C}_t . \end{aligned} \tag{10}$$

All variables are measured at the beginning of period, except for stocks M_t and A_t which are dated at the end. Nominal money holdings are M_{t-1} at the beginning of period t, giving real money balances $M_{t-1}/\bar{P}_t \equiv \bar{M}_{t-1}$. Finally, the inflation rate π_t must also account for changes in commodity tax rates. Real and nominal interest rates, r_t and i_t, are related by the Fisher equation

$$1+i_t=\left(1+r_t\right)\left(1+\pi_t\right), \quad 1+\pi_t=\frac{\left(1+\tau_{t+1}^c\right) \bar{P}_{t+1}}{\left(1+\tau_t^c\right) \bar{P}_t}. \tag{11}$$

In period t, the family maximizes expected utility in (8-9) by choosing consumption, real money balances, and a wage w_t^* for the fraction of individuals receiving a new wage setting opportunity. With details set out in the separate Technical Appendix, optimal consumption growth follows a standard Euler equation

$$u_{C,t}=\beta E_t\left(1+r_t\right) \cdot u_{C,t+1}, \quad \frac{u_{M,t}}{u_{C,t}}=\frac{i_t}{\left(1+\tau_{t+1}^c\right)\left(1+r_t\right)}. \tag{12}$$

Marginal utilities are defined as $u_{C,t} \equiv du_t/d\bar{C}_t$ and $u_{M,t} \equiv du_t/d\bar{M}_t$.[3] A higher real interest tilts consumption to the future, implying larger savings today. The tangency condition for money implies that money demand is a fraction of consumption, $\bar{M}_t = m_t\bar{C}_t$,[4] where the desired money consumption ratio m_t is declining in nominal interest. Money demand depends on the opportunity cost, the return that could have been obtained if it were invested in the market at a rate i_t, or $i_t/\left(1+r_t\right)$ in present value.

Turning to wage setting and labor supply, individual j faces demand $L_{j,t}$ for her labor type as in (5). Being a monopolist, $N_{j,t}H = L_{j,t}$, she sets a wage to exploit market power. Being one

[3]Given functional forms, $u_{C,t}=s_c x_t^{\sigma_m-\sigma_c}/\bar{C}_t^{\sigma_c}$ and $u_{M,t}=\left(1-s_c\right) x_t^{\sigma_m-\sigma_c}/\left(m_t^{\sigma_m}\bar{C}_t^{\sigma_c}\right)$ where x_t is given by $x_t=\left[s_c+\left(1-s_c\right) m_t^{1-\sigma_m}\right]^{1/(1-\sigma_m)}$.

[4]Given the specification of utility, the ratio is $m_t=\left(\frac{1-s_c}{s_c}\frac{\left(1+\tau_{t+1}^c\right)\left(1+r_t\right)}{i_t}\right)^{1/\sigma_m}$.

among many close substitutes, she takes the wage index w_t^L and aggregate demand L_t as given which implies a perceived demand elasticity σ_l. To account for wage rigidity, we assume that, in any period t, only a *random selection* of workers, a fraction $1-\omega$, can optimally set wages (see, e.g., Gali 2015), $w_{t,t}=w_t^*$. The remaining fraction ω is stuck with a wage set in the past, $w_{t-i,t}=w_{t-i}^*$. Consequently, wages are heterogeneous, and agents satisfy labor demand at the relevant wage.

In general, the households' required compensation for labor effort is equal to the marginal rate of substitution $MRS_{j,t}=-u_{N_{j,t}}/u_{C,t}$.[5] Being endowed with unique skills in performing specialized tasks, individuals enjoy limited market power and would set a wage so that the real wage is equal to a mark-up over $MRS_{j,t}$, an individual's competitive valuation of marginal effort, if wages were flexible. In a stationary state, new and old wages as well as the marginal valuations are all the same, so that wage setting collapses to the very same static solution,

$$\frac{(1-\tau)\,w^*}{(1+\tau^c)\,\bar{P}}=\frac{\sigma_l}{\sigma_l-1}\cdot MRS. \tag{13}$$

However, given wage stickiness, households are locked into the currently set wage until the next wage setting opportunity arrives. The new wage determines not only current, but also future earnings resulting from labor demand at that wage. Wage setting thus becomes forward looking, replacing the right hand side of (13) by a present value of marginal valuations. Wage setting today equates the current real wage with an average of present and future valuations $MRS_{t,t+i}$, discounted with the real interest, and weighted by the probabilities that the wage in period $t+i$ is still unchanged. Wage stickiness implies that the real wage does not move one to one with variations in marginal rates of substitution. Upon aggregating the household sector, sticky wages cause a slow adjustment of the wage index that determines labor demand of firms and unit costs,

$$w_t^L=\left[(1-\omega)\cdot w_{t,t}^{1-\sigma_l}+\omega\cdot\left(w_{t-1}^L\right)^{1-\sigma_l}\right]^{1/(1-\sigma_l)}. \tag{14}$$

3.2.3 Investment and Private Debt

Investment firms own intermediate goods producers, accumulate capital stock, and rent back services on an 'internal capital market', charging a competitive price w_t^K. Noting (4), revenues are $w_t^K K_{t-1}+\chi_t^m=P_tY_t^g-w_t^L L_t$. Firms invest to accumulate the capital stock, $K_t=I_t+(1-\delta)\,K_{t-1}$, where δ is the depreciation rate. Investment I_t requires a basket of final goods $\bar{Z}_t=I_t+\frac{\psi}{2}K_{t-1}\left(I_t/K_{t-1}-\delta\right)^2$. New capital goods, including installation costs, consist of both domestic and imported final goods and are composed in the same way as in (6). Investment

[5] Given functional forms, $MRS_{j,t}=-u_{N_{j,t}}/u_{C,t}=\phi\cdot N_{j,t}^{\eta}\bar{C}_t^{\sigma_c}/\left(s_c x_t^{\sigma_m-\sigma_c}\right)$. Again, a detailed derivation of wage setting is offered in the Technical Appendix.

spending is thus $\bar{P}_t\bar{Z}_t$. Finally, the required return on equity is $i_t^k = \theta_t^k i_t$. Compared to a safe benchmark interest i_t, households demand an equity premium $\theta_t^k = \left(1-\rho^\theta\right)\bar{\theta}^k + \rho^\theta\theta_{t-1}^k + \varepsilon_t^k$ that fluctuates around $\bar{\theta}^k \geq 1$.

Firms finance investment with retained earnings and bank credit. In the beginning of the period, they repay loans S_t^l, giving outstanding debt of $B_{t-1}^l - S_t^l$. Noting interest payments $i_t^l\left(B_{t-1}^l - S_t^l\right)$, external debt amounts to $B_t^l = B_{t-1}^l - S_t^l + i_t^l\left(B_{t-1}^l - S_t^l\right)$ at the end of the period, or $B_t^l/\left(1+i_t^l\right) = B_{t-1}^l - S_t^l$. Subtracting wages, investment, debt service and taxes from total earnings leaves dividends equal to

$$\chi_t = P_tY_t^g - w_t^LL_t - \bar{P}_t\bar{Z}_t - S_t^l - \tau_tT_t^k, \tag{15}$$

where $T_t^k = P_tY_t^g - w_t^LL_t - t^z\bar{P}_t\bar{Z}_t - i_t^l\left(B_{t-1}^l - S_t^l\right)/\left(1+i_t^k\right)$ is the business tax base. Firms may deduct an investment tax credit at rate t^z and interest on debt (discounted to the beginning of period, using the firm's discount rate i_t^k). For simplicity, we lump together corporate and personal taxes on capital income which gets taxed with the overall income tax rate τ_t. Note finally that the cash-flow $P_tY_t^g - w_t^LL_t = w_t^KK_{t-1} + \chi_t^m$ stems from a competitive return to capital plus monopoly profits, see (4).

A firm's debt capacity is limited and constrains the use of debt. We assume that debt is restricted to a fixed fraction b^l of the replacement cost of preexisting capital,

$$B_t^l/\left(1+i_t^l\right) = b^l\cdot\left(1+i_t^k\right)\left(1-t^z\tau_t\right)\bar{P}_tK_{t-1}, \tag{16}$$

where private investment cost is reduced by a factor $1-t^z\tau_t$ by the tax subsidy.

Firm value V_t is dated at the beginning of period. Using $V_t = V\left(K_{t-1}, B_{t-1}^l\right)$, value maximization $V_t = \max_{I_t}\chi_t + V_{t+1}/\left(1+i_t^k\right)$ gives optimal investment and new debt. The *net* investment rate $x_t^I \equiv I_t/K_{t-1} - \delta$ is determined by

$$x_t^I = \left(Q_t - 1\right)/\psi, \quad Q_t \equiv \frac{\lambda_{t+1}^K/\left(1+i_t^k\right)}{\left(1-t^z\tau_t\right)\bar{P}_t}. \tag{17}$$

Tobin's Q_t is the shadow price or market value $E_t\lambda_{t+1}^K/\left(1+i_t^k\right)$ per unit of capital, divided by the tax adjusted acquisition cost of capital $\left(1-t^z\tau_t\right)\bar{P}_t$. End of period debt follows from (16) and determines repayment S_t^l to banks.

In a steady state, $I = \delta K$ and $Q = 1$. The user cost of capital is then a weighted average of the cost of equity and debt, using the debt ratio b^l as a weight,

$$w^K = \left[\frac{\delta}{1-\tau} + \frac{i^k}{1-\tau}\cdot\left(1-b^l\right) + i^l\cdot b^l\right]\left(1-t^z\tau\right)\bar{P}. \tag{18}$$

A unit of capital effectively costs $(1-\tau^z\tau)\,\bar{P}$, to be financed with debt and equity. The tax inflates the cost of equity $i^k/(1-\tau)$, but not the cost of debt i^l, since interest on debt is tax deductible. Replacement investment is fully equity financed, and hence bears a tax adjusted cost of depreciation equal to $\delta^K/(1-\tau)$.

3.2.4 Fiscal Policy

The government inherits debt B^G_{t-1}, raises tax revenue T_t, spends on productive services P_tG_t and on social transfers E_t, and potentially pays subsidies T^b_t to stabilize banks (see below). The fiscal constraint restricts issuing new gross debt B^G_t at a price $1/(1+i^g_t)$,

$$B^G_t/(1+i^g_t) = B^G_{t-1} - S^G_t, \quad S^G_t = T_t - P_tG_t - E_t - T^b_t. \tag{19}$$

Sovereign risk is reflected in an interest premium on sovereign bonds, $i^g_t = \theta^g_t \cdot i_t$. The premium is assumed to follow an autoregressive process $\theta^g_t = 1-\rho^g+\rho^g\theta^g_{t-1}+\varepsilon^g_t$ that converges to $\theta^g = 1$ in the long run. Shocks reflect investor panic (or a safe haven effect if $\theta^g_t < 1$). As a result, the interest rate must rise to induce investors to hold on to stocks, leading to increasing costs of government debt service.

Taxing wages and profits at rate τ_t and consumption at rate τ^c_t yields revenue

$$T_t = \tau_t \cdot w^L_t L_t + \tau_t \cdot T^k_t + \tau^c_t \cdot \bar{P}_t\bar{C}_t - T^l_t, \quad T^l_t = \left(1-\rho^T\right)\bar{t}^l P_tY_t + \rho^T T^l_{t-1} + \varepsilon^T_t. \tag{20}$$

Reflecting the efficiency of tax collection, we allow revenues to shrink due to base erosion, leading to revenue losses T^l_t. The tax yield is reduced by $\bar{t}^l$ percent of GDP in the long run. The larger such tax losses, the higher tax rates must be. This magnifies distortions and slows down growth. To satisfy the fiscal constraint, we scale tax rates $\tau_t = t^s_t\tau_0$ and $\tau^c_t = t^s_t\tau^c_0$ by a common factor t^s_t starting from initial values.

To prevent unstable debt, the government must pursue a consolidation policy. We specify a policy rule for the 'structural' part $\tilde{S}^G_t$ of the primary surplus which excludes any surprise expenditures or windfall gains. Indeed, the Maastricht rules impose restrictions on the structural rather than the actual deficit, and also specify a long-run debt to GDP ratio $\bar{b}^g = B^G/(PY)$. The parameter γ^g determines how fast debt is reduced (or increased) to reach the long-run target. The consolidation rule thus specifies a structural surplus

$$\tilde{S}^G_t = \left(1-\frac{\gamma^g}{1+i^g_t}\right)B^G_{t-1} - \frac{1-\gamma^g}{1+i^g_t}\bar{b}^g P_tY_t. \tag{21}$$

In the absence of fiscal shocks, $B^G_t/(1+i^g_t) = B^G_{t-1} - \tilde{S}^G_t$. Debt is exclusively driven by the target surplus. With $\gamma^g < 1$, debt follows a stable path

$$B_t^G = \gamma^g \cdot B_{t-1}^G + (1-\gamma^g) \cdot \bar{b}^g P_t Y_t. \tag{22}$$

The stabilization rule makes debt converge to $B^G = \bar{b}^g PY$, equal to $\bar{b}^g$ percent of GDP. The actual surplus may deviate from the structural surplus due to unexpected shocks. Spending policies and required tax revenues T_t are

$$\begin{aligned} P_t G_t &= \bar{g} \cdot P_t Y_t - \xi^g \cdot \tilde{S}_t^G + \varepsilon_t^G, \\ E_t &= \bar{e} \cdot w_t^L L_t - \xi^e \cdot \tilde{S}_t^G + \varepsilon_t^E, \\ T_t &= \bar{g} \cdot P_t Y_t + \bar{e} \cdot w_t^L L_t + (1-\xi^g-\xi^e) \cdot \tilde{S}_t^G. \end{aligned} \tag{23}$$

Productive spending consists of a normal level $\bar{g} P_t Y_t$, reduced by spending cuts to finance a share ξ^g of the required surplus. Social spending reflects a replacement rate $\bar{e}$ of wage earnings, and spending cuts must contribute a share ξ^e to fiscal consolidation. The required tax revenue T_t covers the structural part of public spending, $\bar{g} P_t Y_t + \bar{e} w_t^L L_t$, plus tax increases equal to $(1-\xi^g-\xi^e)\,\tilde{S}_t^G$, needed to reduce public debt. Tax rates are set such that revenue (20) matches this target level. Spending shocks ε_t^G and ε_t^E as well as unexpected subsidies to banks T_t^b are not immediately financed with taxes but raise next period's debt and are consolidated only later on. To see how unconsolidated shocks affect fiscal debt dynamics, substitute the policy rules (23) into the primary surplus (19) and get $S_t^G = \tilde{S}_t^G - \varepsilon_t^G - \varepsilon_t^E - T_t^b$. Unexpected spending reduces the actual primary surplus and raises debt before is gets consolidated in future periods. The policy parameters ξ^e and ξ^g determine whether consolidation is tax or expenditure based. If ξ^e and ξ^g are low, budget consolidation is mostly tax based. High values indicate budget consolidation with spending cuts. These parameters thus connect to research on the effectiveness of tax- versus spending-based consolidation (e.g., Alesina et al., 2015). Higher tax rates discourage labor supply and investment and slow down growth. Spending cuts involve their own costs. For example, cuts in social spending might be good for growth but involve unfavorable distributional effects. Cutting productive spending tends to impair private sector productivity. In the spirit of Barro (1990), we assume that a higher stock of infrastructure K_t^G shifts factor productivity by $\bar{z}_t$ in (3),

$$K_t^G = G_t + (1-\delta^g)\,K_{t-1}^G, \quad \bar{z}_t = z_0 \left(K_t^G/\bar{K}^G\right)^{\sigma^z}. \tag{24}$$

3.2.5 Banking Sector

Banks provide credit B_t^l to (investment) firms and B_t^g to the government. The government issues debt B_t^G in total, of which $B_t^g = \bar{s}^b B_t^G$ is acquired by banks, and the rest by investors (private households). In holding a fixed share $\tilde{s}^b$ of bonds, banks receive interest and repayment S_t^G in proportion. The remainder is paid to households, see (10). Outstanding business loans and sovereign bond holdings thus evolve as

$$B_t^l / \left(1 + i_t^l\right) = B_{t-1}^l - S_t^l, \quad B_t^g / \left(1 + i_t^g\right) = B_{t-1}^g - \tilde{s}^b S_t^G. \tag{25}$$

In line with prior literature (e.g., Kollmann et al., 2011), we capture loan risks by private defaults of borrowers that diminish banks' earnings. We introduce a share s_t^l of non-performing loans. When a default occurs, banks extract liquidation values $1 - \ell$ which are available for new lending to other firms.[6] The relationship in (25) lists the liabilities of (surviving) firms, while credit losses $d_t^l B_{t-1}^l$ reflect real costs that diminish bank earnings S_t^l. Losses are proportional to the share of non-performing loans,

$$d_t^l = \ell \cdot s_t^l, \quad T_t^b = t_t^b d_t^l B_{t-1}. \tag{26}$$

To keep up lending in a crisis and to mitigate the bank's losses, the government may provide some support T_t^b. The latter is equal to a fraction t_t^b of total losses.[7]

Banks are funded with deposits and equity. Given repayment S_t^d and interest, the stock of deposits D_t follows

$$D_t / \left(1 + i_t^d\right) = D_{t-1} - S_t^d. \tag{27}$$

Depositors and equity holders require a risk premium compared to the safe benchmark rate such that deposit rate and return on equity satisfy

$$\begin{aligned} i_t^d &= \theta_t^d \cdot i_t, \quad \theta_t^d = 1 - \rho^\theta + \rho^\theta \theta_{t-1}^d + \varepsilon_t^d, \\ i_t^b &= \theta_t^b \cdot i_t, \quad \theta_t^b = \left(1 - \rho^\theta\right) \bar{\theta}^b + \rho^\theta \theta_{t-1}^b + \varepsilon_t^b. \end{aligned} \tag{28}$$

While bank equity requires a permanent premium $\bar{\theta}^b \geq 1$, the deposit rate is normally equal to the safe benchmark rate. During a crisis, however, a loss of confidence may lead to prohibitive interest costs leading to a sudden stop in deposit funding. We capture such panic-driven shocks by including a risk premium on deposits, which is absent in normal times ($\theta_t^d \to 1$ without any shocks).

Relating *net* inflows and outflows of funds, the bank's budget constraint gives dividends to

[6] Keuschnigg and Kogler (2020) provide microfoundations for the process of credit reallocation.

[7] More specifically, public support stems from asset purchases similar to the troubled asset relief program (TARP) of the U.S. during the financial crisis. The government buys a fraction t_t^b of the loan portfolio and pays the face value of one, giving a volume $t_t^b B_{t-1}^l$. After absorbing losses $T_t^b = t_t^b d_t^l B_{t-1}$, it sells back 'cleaned' assets at a depreciated value $\left(1 - d_t^l\right) t_t^b B_{t-1}^l$. The net transfer to banks is T_t^b.

equity holders (households)[8]

$$\chi_t^b = S_t^l + \tilde{s}^b S_t^G - S_t^d - \left(1 - t_t^b\right) d_t^l B_{t-1}^l. \tag{29}$$

The banking sector's balance sheet requires that total assets equal deposits and equity,

$$\frac{B_t^l}{1+i_t^l} + \frac{B_t^g}{1+i_t^g} = \frac{D_t}{1+i_t^d} + \frac{E_t^b}{1+i_t^b}. \tag{30}$$

Banks are subject to capital requirements, which define minimum regulatory capital as a fraction of risk-weighted assets. Banks therefore have to raise total equity equal to κ^B percent of business loans plus κ^G percent of sovereign bonds. In line with the preferential treatment of government debt, which is deemed to be safe in the Basel accords, we assume $\kappa^G < \kappa^B$. Given that equity is much more expensive than deposits, banks tend to economize on the use of equity and raise no more than $\frac{E_t^b}{1+i_t^b} = \kappa^B \frac{B_t^l}{1+i_t^l} + \kappa^G \frac{B_t^g}{1+i_t^g}$. Substituting into the balance sheet determines the volume of deposits

$$\frac{D_t}{1+i_t^d} = \left(1 - \kappa^B\right) \frac{B_t^l}{1+i_t^l} + \left(1 - \kappa^G\right) \frac{B_t^g}{1+i_t^g}. \tag{31}$$

In addition to holding a share of total government debt, banks choose net deposit funding S_t^d and net business lending S_t^l. Referring to the Technical Appendix for details, value maximization subject to financing constraints results in loan pricing

$$1 + i_t^l = \frac{\kappa^B \cdot \left(1 + i_t^b\right) + \left(1 - \kappa^B\right) \cdot \left(1 + i_t^d\right)}{1 - \left(1 - t_{t+1}^b\right) d_{t+1}^l}. \tag{32}$$

The loan rate i_t^l is a mark-up over the cost of capital which is a weighted average of deposit interest and the cost of equity. The mark-up factor reflects default risk and expected depreciation of bad loans as discussed in (26) above. Government support with a subsidy t_t^b reduces the markup, leading to lower loan rates. After all, the program aims at preventing a surge in loan rates that would block investment of firms.

To close the feedback loop between banks and the real economy, we relate the share of bad loans to macroeconomic fundamentals and assume an autoregressive process

$$s_t^l = \left(1 - \rho^{sl}\right) s_0^l \cdot \left(\bar{Y}_t / Y_t\right)^{\sigma^{sl}} + \rho^{sl} s_{t-1}^l + \varepsilon_t^{sl}, \quad t_t^b = \rho^{sl} t_{t-1}^b + \varepsilon_t^{tb}. \tag{33}$$

When output Y_t falls short of potential output $\bar{Y}_t$, the share of bad loans shifts up with elasticity σ^{sl}. The subsidy rate on bad loans follows a policy process as specified in the second equation.

[8]For example, the gross inflow from deposit funding is $D_t / \left(1 + i_t^d\right)$, while the gross outflow is the repayment of the stock D_{t-1}. The *net* outflow is $S_t^d = D_{t-1} - D_t / \left(1 + i_t^d\right)$ and reduces dividends.

The program is activated only if the share of non-performing loans s_t^l is very high. When the program is terminated, the subsidy rate vanishes with speed ρ^{sl}.

3.2.6 General Equilibrium

We analyze fluctuations around a steady state with constant money supply and zero inflation. To introduce monetary policy, we specify a policy rule as in Ascari and Ropele (2013) and Sargent and Surico (2011),

$$M_t^s = (1-\rho^m)\,\phi^m \bar{Y}_{t-1} \cdot \frac{\left(\bar{Y}_{t-1}/Y_t\right)^{\psi_y}}{(1+\pi_t)^{\psi_\pi}} + \rho^m M_{t-1}^s + \varepsilon_t^m, \quad T_t^M = M_t^s - M_{t-1}^s. \tag{34}$$

Trend output is smoothed over the business cycle according to $\bar{Y}_t = \delta^m Y_t + (1-\delta^m)\,\bar{Y}_{t-1}$. With a smaller rate δ^m, trend output depends less heavily on current output realizations. Money supply consists of a trend and a cyclical component. The trend component $\phi^m \bar{Y}_{t-1}$ accommodates a permanent increase in output. The cyclical part is meant to dampen fluctuations and depends on parameters ψ_y and ψ_π. If current output is below trend, $Y_t < \bar{Y}_{t-1}$, money supply scales up by a factor $\left(\bar{Y}_{t-1}/Y_t\right)^{\psi_y} > 1$, while the opposite happens in a boom. Similarly, if actual inflation exceeds the trend rate ($\pi_t > 0$), money supply is scaled down by $1/\left(1+\pi_t\right)^{\psi_\pi} < 0$.
An autonomous monetary policy regime creates exchange rate risk. If an Eurozone saver invests 1 Euro at home, she earns gross interest $1+i_t^e$. If she invests 1 Euro in the Italian bond, she gets e_t^{ie} Lire at the beginning of period which grow by $1+i_t$ and are converted back at a rate $1/e_{t+1}^{ie}$, giving end of period wealth equal to $(1+i_t)\,e_t^{ie}/e_{t+1}^{ie}$. Standard interest rate parity prevents arbitrage. However, when there is country risk, investors request a premium θ_t. Modified interest rate parity then requires

$$(1+i_t)\,e_t^{ie}/e_{t+1}^{ie} = (1+i_t^e)\,\theta_t. \tag{35}$$

The return of the Italian bond in Euros must exceed the domestic return $1+i_t^e$ by a factor of θ_t. When the country's debt ratio rises, investors start to worry about solvency and ask for a higher premium. The reverse case may be associated with a safe haven effect. Following Schmitt-Grohé and Uribe (2003), we postulate

$$\theta\left(b_t^f\right) = 1 + \gamma\left(e^{b_t^f - \bar{b}^f} - 1\right), \quad b_t^f \equiv B_t^f/\left(P_t Y_t\right). \tag{36}$$

In a steady state, exchange rates are constant and $i = i^e = 1/\beta$, to support stationary consumption. The country premium must disappear, $\theta\left(b^f\right) = 1$ which requires $b_t^f = \bar{b}^f$. The model thus explains fluctuations around a stationary foreign debt to GDP ratio. The debt sensitivity of the country premium assures stability of savings in an open economy.

The trade balance TB_t is equal to the value of exports minus imports. Exports reflect import demand of other regions as specified in the next subsection. In focusing on the interactions within the Euro Area, we assume that foreign debt is exclusively held by Eurozone investors. Foreign debt B_t^f, denominated in domestic currency, grows by

$$B_t^f / (1+i_t) = B_{t-1}^f - TB_t, \quad TB_t = P_t E_t^x - P_t^{ie}\left(C_t^{ie} + Z_t^{ie}\right) - P_t^{io}\left(C_t^{io} + Z_t^{io}\right). \tag{37}$$

Since loans B_t^l are in nominal terms, real credit losses are $d_t^l B_t^l / P_t$. Subtracting from gross output Y_t^g as listed in (3) gives net output or real GDP, $Y_t = Y_t^g - d_t^l B_{t-1}^l / P_t$. Market clearing conditions for output, asset and money markets are,[9]

$$Y_t = C_t + G_t + Z_t + E_t^x, \quad A_t = -B_t^f, \quad \bar{M}_t = M_t^s / \bar{P}_{t+1}. \tag{38}$$

Demand for home goods stems from consumption, public spending, investment and exports. Households own firms and banks and, accordingly, receive dividends as in (10). They also hold deposits, leading to a net income flow S_t^d equal to interest minus savings in new deposits as demanded by banks. Therefore, A_t is the residual stock of savings which must be equal to net foreign assets if B_t^f is negative. Alternatively, the country is a net debtor. Finally, the private sector chooses real money balances which must be equal to money supply, $\bar{M}_t = M_t^s / \bar{P}_{t+1}$. One of the conditions is redundant by Walras' Law.

3.2.7 Eurozone and Rest of the World

Given our focus on Italy, we propose a minimal model of the rest of the Eurozone but rich enough to analyze Italy's policy alternatives in the Euro Area. We therefore entirely abstract from fiscal policy, banking and supply side details, and replace production of final goods by an autoregressive process for Eurozone GDP,

$$Y_t^e = \left(1 - \rho^{Y,e}\right) Y_0^e + \rho^{Y,e} Y_{t-1}^e + \varepsilon_t^{Y,e}. \tag{39}$$

Preferences are similar to (8-9), except for fixed labor supply. Being endowed with an income stream $P_t^e Y_t^e$, households choose intertemporal consumption and money demand. The real interest rate determines consumption growth and savings as in the Euler equation (12), and demand for real money balances is $\bar{M}_t^e = m_t^e \bar{C}_t^e$. By the same principles as in (6), households allocate spending on home goods and imports,

$$\bar{P}_t^e \bar{C}_t^e = P_t^e C_t^e + P_t^{ei} C_t^{ei} + P_t^{eo} C_t^{eo}, \tag{40}$$

[9] There is no separate condition for labor market clearing since each household type j is a 'local' monopolist and serves the entire market.

where $P_t^{ei} = P_t^i/e_t^{ie}$ and $P_t^{eo} = P^o e_t^{eo}$ are local demand prices of final goods from Italy and rest of the world, denominated in Euros. Goods demand is parallel to (6). Given the trade balance $TB_t^e = P_t^e E_t^{x,e} - P_t^{ei} C_t^{ei} - P_t^{eo} C_t^{eo}$, the current account is the mirror image of (37). Net foreign debt of Italy corresponds to net foreign assets of the Eurozone. In parallel to (38), market clearing in the EZ economy requires $Y_t^e = C_t^e + E_t^{x,e}$, $A_t^e = -B_t^e$, and $\bar{M}_t^e = M_t^{s,e}/\bar{P}_{t+1}^e$. Supply stems from the output process above. Demand consists of consumption demand and exports only. In an autonomous regime, the money supply rule is parallel to (34). One of the three conditions is redundant by Walras' Law.

The Rest of the World consists of other countries (indexed by o) and is even simpler. The final good serves as the *numeraire*, i.e., we abstract from monetary policy in RoW and normalize the local price to $P^o = 1$. Income and demand are exogenous. RoW is represented only by import demand functions for Italian and EZ exports to RoW,

$$C_t^{oi} = s^{oi} \cdot \left(e_t^{io}/P_t\right)^{\sigma_r}, \quad C_t^{oe} = s^{oe} \cdot \left(e_t^{eo}/P_t^e\right)^{\sigma_r}. \tag{41}$$

Now all export demands are specified. Italian exports $E_t^x = C_t^{ei} + C_t^{oi}$ reflect import demand from the Eurozone and RoW. Exports of the Eurozone and of RoW to Italy reflect Italian imports for both consumption and investment needs, giving $E_t^{x,e} = C_t^{ie} + Z_t^{ie} + C_t^{oe}$ and $E_t^{x,o} = C_t^{io} + Z_t^{io} + C_t^{eo}$. Since we abstract from capital flows relating to RoW, trade of that region must be balanced, $TB_t^o = P^o E_t^{x,o} - P_t^{oe} C_t^{oe} - P_t^{oi} C_t^{oi} = 0$. Finally, by Walras' Law, $TB_t + e_t^{ie} TB_t^e + e_t^{io} TB_t^o = 0$. In the world economy, the sum of trade balances, after converting them into the same currency (e.g. Lire), must add up to zero.

3.2.8 Currency Union

In a *currency union*, there is only one monetary policy subject to one money market clearing, and the internal exchange rate is fixed at $e^{ie} = 1$. Money supply is based on the state of the whole union which is a weighted average of the two regions. We use weights $s^Y = PY/(PY + P^e Y^e)$ and $1 - s^Y$ equal to the calibrated shares in total Eurozone GDP of Italy and the rest. We define a 'price index' $\bar{P}_t^u$ and get

$$Y_t^u \equiv \left(P_t Y_t + P_t^e Y_t^e\right)/\bar{P}_t^u, \quad \bar{P}_t^u \equiv s^Y \bar{P}_t + \left(1 - s^Y\right) \bar{P}_t^e. \tag{42}$$

Accordingly, the Euro Area wide inflation is $1 + \pi_t^u \equiv \bar{P}_{t+1}^u/\bar{P}_t^u$, while local inflation reflects the changes in local price indices. In money market equilibrium, central money supply must accommodate the sum of money demands in both regions, $M^{s,u} = \bar{P}\bar{M} + \bar{P}^e \bar{M}^e$. The common monetary policy rule includes trend and countercyclical components as before,

$$M_t^{s,u} = (1 - \rho^m)\,\phi^{m,u}\bar{Y}_{t-1}^u \cdot \frac{\left(\bar{Y}_{t-1}^u / Y_t^u\right)^{\psi_y}}{\left(1+\pi_t^u\right)^{\psi_\pi}} + \rho^m M_{t-1}^{s,u} + \varepsilon_t^{m,u}. \quad (43)$$

We allocate total money supply to each region to accommodate local money demand.
We solve the model for two alternative regimes. In the monetary union, the internal exchange rate is fixed ($e^{ie} = 1$), and monetary policy is centralized. Total money supply is governed by the policy rule (43) and must accommodate the sum of regional money demands. For a very small member state with little weight in total Euro Area wide GDP and inflation, monetary policy is effectively exogenous. Common monetary policy serves as our base case. Alternatively, in the autonomous regime, money markets are separate. Monetary policy is decentralized to target local conditions, and the internal exchange rate e_t^{ie} becomes fully flexible. Exit from the Eurozone reflects a regime change from common to separate policies.

3.3 Quantitative Analysis

3.3.1 Model Calibration and Estimation

We calibrate a stationary state and estimate selected parameters and shock processes to track past economic performance. To reflect conditions in the early phase of the Eurozone, we use an average of the period 2001:1-2006:4 of detrended quarterly data. The focus is on Italy. After de-trending, growth and inflation rates are zero. Model solutions are thus interpreted as deviations from long-run rates. We normalize Italian GDP to 100 so that all macro data are conveniently interpreted in percent of GDP. We infer relative country size from Eurostat and Worldbank data. Italy produced 18% of EA's GDP, while EA's GDP amounted to 17% of world GDP.
Table 1 reports key parameters and data. By OECD data, EA sovereign bonds paid an annual rate of roughly 4%, largely the same in all member states. The prototype safe asset is long-term US Treasury bills which paid on average of 2% per anno. We assume that all assets yield the same risk adjusted return equal to 0.75% quarterly, corresponding to 3% per anno. The discount factor β is set to support stationarity in consumption. A typical equity premium from Eurostat data yields a required return on equity capital of 3% (12% p.a.). The loan rate of interest for private credit is a weighted average of bank funding costs and, thus, amounts to 1.45%, or roughly 5.8% p.a.
Based on evidence in Keane and Rogerson (2012) and Chetty et al. (2011), we set $\eta = 2$, corresponding to a Frisch labor supply elasticity of 1/2. The intertemporal substitution elas-

ticity is 2/3, implying $\sigma^c = 1.5$, which is a typical value as in Smets and Wouters (2003, 2005), for example. The interest sensitivity of money demand depends on the substitution elasticity between consumption and real money balances, equal to 3 as in Walsh (2010, p.49-52 and 72). The price sensitivity of trade flows depends on the Armington elasticity of substitution between goods of different country origin. Evidence in Adolfson et al. (2007) and Obstfeld and Rogoff (2000) gives $\sigma^r = 5$. To match mark-up data, we fix the elasticity of variety substitution at $\sigma^v = 6$, implying a mark-up factor of 1.2 (Schmitt-Grohé and Uribe, 2005). Finally, we follow Gali (2015, p.177) and set the substitution elasticity for labor varieties equal to $\sigma_l = 4.5$ and the degree of wage stickiness to $\omega = 0.8$. This is broadly consistent with Schmitt-Grohé and Uribe (2005) who rely on wage stickiness between 0.64 and 0.87 and with Erceg et al. (2000) who use a value of 0.75.

Key Parameters and Data		
Interest rates:		
i	0.75%	risk adjusted interest rate
i^k, i^b	3%	required return on equity
i^l	1.45%	loan rate of interest
Household sector:		
$1/\eta$	0.5	Frisch labor supply elasticity
$1/\sigma^c$	2/3	intertemporal Substitution elasticity
σ^m	3	Substitution elasticity consumption / money
σ^r	5	Substitution elasticity goods by region
σ^v	6	Substitution elasticity differentiated products
σ^l	4.5	Substitution elasticity labor varieties
ω	0.8	rate of wage adjustment
Production and banking sector:		
α	0.25	capital income share
δ	0.03	capital depreciation rate
b^l	0.6	debt asset ratio firms
κ^B	0.11	equity ratio business credits
κ^G	0.03	equity ratio sovereign bonds
s^l	0.06	non performing loan share
$1-\ell$	0.925	recovery rate of liquidated credit
σ^{sl}	13.3	output elasticity of bad loan share
Dynamics:		
b^f	0.22	net foreign debt
γ	0.0124	interest sensitivity w.r.t. foreign debt
ψ	5	adjustment cost to investment
ρ	0.95	persistence of cyclical shocks

Table 1: Key Parameters and Data

Regarding transitional dynamics, a widely used parameter value for adjustment costs to investment is $\psi = 5$, in line with Smets and Wouters (2003) who estimate a confidence interval between 5.1 and 8.9. We set the prior of the autoregressive coefficients of business cycle shocks equal to $\rho = 0.95$, with the estimated values ranging from 0.9 to 0.94 (see Appendix). Estimations for the Euro Area suggest values between 0.85 and 0.95 (Smets and Wouters, 2003, Gerali et al., 2010).

Turning to production, we set the capital share in value added to $\alpha = 0.25$. Adding monopolistic profits then comes close to OECD data on the income share of capital. The depreciation rate is $\delta = 0.03$, or 12% annually. Demand for bank credit follows from a fixed debt asset ratio $b^l = 0.6$, based on Eurostat data of a debt-to-asset ratio of 63% for EA non-financial firms. Italian banks had an equity ratio κ^B of 11%, leaving a buffer of 3% in excess of the minimum regulatory capital ratio of 8% for corporate credit. In line with Basel II accords, we set the regulatory weight for sovereign bonds to zero and set κ^G equal to the voluntary buffer. Already in the early 2000's, Italy's non-performing loan (NPL) share amounted to 6.6%, substantially above the share of 2.5% in the EA, and multiplied by roughly 2.7 since then. The loss rate on non-performing loans amounts to 30% annually, or $l = 7.5\%$ per quarter, reflecting estimates for total recovery rates between 50 and 85%.[10] The NPL share is sensitive to output fluctuations. By (33), the (long-run) semi-elasticity in a steady state is $ds^l = -s^l \sigma^{sl} \cdot dY/Y$. We postulate that a recession with an output loss of 5% ($dY/Y = -.05$) changes the NPL share by 4 percentage points ($ds^l = .04$) which requires $\sigma^{sl} = (.04/.05)/s^l \approx 13.3$.[11]

Finally, net foreign debt amounts to 21.6% of GDP, reflecting liabilities to foreigners. The parameter γ captures how an increase in net foreign indebtedness translates into a higher country premium and raises domestic interest rates. We normalize the country premium to zero at this (steady state) level, requiring $\theta = 1$ in (36). We then calibrate γ such that an increase in the debt to GDP ratio by 20 percentage points raises the interest rate by 25 basis points (1 pc annually).[12] Turning to trade flows, Italy imported 23% of GDP and exported 21%, according to Eurostat data. Of all imports, 47% were sourced from the EA and 53% from RoW. On the export side, 47% of all exports went to the EA and 53% to RoW. Using export data from RoW to all individual EA countries (except Italy), one can determine EA's import share as 19% of GDP, of which 12% stemmed from Italy and 88% from RoW.

Table 2 reports parameter values that govern fiscal and monetary policy as well as transitional

[10] Acharya et al. (2007) report a mean loan recovery rate of 81% from a sample of non-financial US corporations over 1982-1999. Grunert and Weber (2009) find a 73% retrieval rate for German firms while Caselli et al. (2008) estimate a rate of only 48% for Italian SMEs.

[11] Nkusu (2011) finds that a 2.7 percent shock to GDP growth causes NPLs to increase by 1.7 percentage points within 4 years in an advanced economy. His analysis also shows that this relationship is highly non-linear. Larger shocks to GDP growth will lead to substantially larger responses in NPL rates.

[12] Specifically, we define $(1 + i_t)\, e^e_t / e^e_{t+1} \equiv 1 + \tilde{\imath}_t$ in (35) and use (36) to calculate the slope $d\tilde{\imath}_t / db^f_t = (1 + i^e)\,\gamma$ where $e^{b^f - \bar{b}^f} = 1$ in a steady state. Replicating the quantitative response thus requires $d\tilde{\imath}_t / db^f_t = (1 + i^e)\,\gamma = .0025/.2$. Noting $i^e = i = .0075$, we find the parameter $\gamma = .0124$.

Policy Parameters		
Fiscal policy:		
$\bar{b}^g$	105%	fiscal debt to GDP target
γ^g	0.97	fiscal consolidation speed
$\bar{g}$	15%	public consumption spending to GDP
σ^z	0.25	productivity effect public infrastructure
ξ^g	0.2	consolidation share productive spending
ξ^e	0.1	consolidation share social spending
Monetary policy:		
m	1.3	money consumption ratio
ψ_π	2	sensitivity of money supply to inflation
ψ_y	1	sensitivity of money supply to output gap

Table 2: Policy Parameters

dynamics. By OECD data, the Italian debt to GDP ratio was 105% in 2006 ($\bar{b}^g = 1.05$) which compares to a much lower ratio of 61% in EA without Italy in 2006, and has grown since then to about 130% of GDP (see next subsection). Banks (and other financial institutions) hold around 35% of national public debt in Italy, giving $\tilde{s}^b = 0.35$. The parameter γ^g determines the speed of fiscal consolidation and the convergence of public debt towards the target ratio $\bar{b}^g$. The value $\gamma^g = 0.97$ implies a half-life of debt adjustment of 23 quarters, or less than six years. We assume that 70% of consolidation results from tax increases and 30% from spending cuts. One third are cuts in social spending ($\xi^e = 0.1$), and two thirds are cuts in productive spending ($\xi^g = 0.2$). Social spending absorbs 18.5% of GDP which is 30% of gross wage income ($\bar{e} = 0.295$). Public consumption in Italy amounts to 14.6% of GDP ($\bar{g} = .15$). Adding debt service gives a total expenditure share of 44.3% of GDP.

Following Barro (1990), we allow for a positive productivity effect of productive public spending where $\sigma^z = 0.25$ is consistent with typical estimates of the output effect.[13] In calibrating money demand, we set the money consumption ratio to $m = 1.3$. Regarding monetary policy, we postulate a money supply rule, but allow for discretionary intervention in times of crisis. Ascari and Ropele (2013) have estimated the sensitivities of money supply to changes in the price level and the output gap and report values between 1 and 3 for ψ_π and a range of 0 to 1 for ψ_y.

[13] Colombier (2009) finds that an increase in public spending on transport infrastructure, water systems and education by 1 percentage point raises the per capita growth rate of real GDP by 0.5 percentage points. The estimate of Bleaney et al. (2001) is somewhat lower at 0.3 percentage points. In our model, growth relates to long-run level effects. In (24), the long-run effect on factor productivity is $\hat{z} = \sigma^z \hat{G}$, where stationarity implies $z = \bar{z}$ and $G = \delta^g K^G$. Assuming user cost and employment are constant, technology $Y^g = zK^\alpha L^{1-\alpha}$ implies $\hat{Y}^g = \hat{z} + \alpha\hat{K}$ while Y_K^g constant implies $\hat{Y}_K^g = \hat{z} - (1-\alpha)\hat{K} = 0$. Combining, the long-run output effect is $\hat{Y}^g = \frac{1}{1-\alpha}\hat{z} = \frac{\sigma^z}{1-\alpha}\hat{G}$. With $\alpha = .25$ and $\sigma^z = .25$, the output elasticity of productive spending is $.25/.75 = 0.33$, well within the range of typical estimates.

3.3.2 Tracking Past Performance

Calibration results in a deterministic steady state reflecting the conditions at the start of the monetary union in early 2000. We now use the model to track the evolution of the Italian economy since then, and Euro Area GDP. Since the model requires stationary data, we use a Kalman implementation of the one-sided HP filter for detrending output data. The Kalman filter includes a zero constant which allows us to scale the series to fluctuate around a normalized output value. We also remove seasonal trends in wages. Prior to 2014, the share of non-performing loans is reported with annual frequency only. We obtain quarterly data by linear interpolation of annual values.

The most commonly used estimation method adds structural shocks to the model (see Smets and Wouters 2003, 2007, and Rabanal and Rubio-Ramírez, 2005) in order to estimate the parameters influencing model dynamics and to calibrate those affecting the steady state. Starting from this steady state, we use Bayesian estimation procedures and let the model determine the shock processes to replicate key time series from 2000 to 2018. Specifically, we estimate shocks to factor productivity ϕ_t^Y, bad loan share s_t^l, risk premia on sovereign bonds θ_t^g and deposits θ_t^d, as well as government consumption G_t and social spending E_t in Italy. Furthermore, we include a shock process to the Eurozone GDP Y_t^e into our estimation. With seven endogenously determined shocks, the model replicates exactly, without error, seven selected time series as part of the stochastic general equilibrium solution. Motivated by the earlier discussion of past economic performance in Italy, we track the wage index w_t, the GDP share of fiscal debt $B_t^G/(P_tY_t)$ and government consumption $G_t/(P_tY_t)$, the bad loan share s_t^l, interest rates i_t^d and i_t^g on deposits and fiscal debt in Italy, as well as output in the Eurozone Y_t^e.

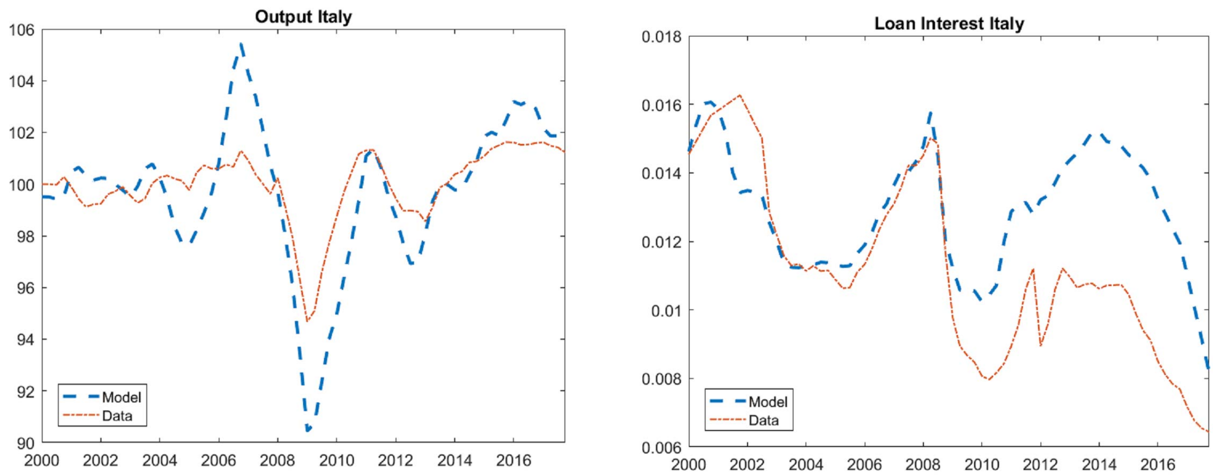

Figure 1: Simulated and Actual Time Series

Given a relatively small selection of 'targeted' variables, the model cannot exactly replicate but only approximate more or less closely the remaining data. Figure 1 compares actual and simulated gross output and the loan rate of interest in Italy since the start of the currency union. As a result of detrending, the Figure shows fluctuations around a trend. The approximation appears reasonable. The relatively favorable performance prior to the crisis led to output substantially moving above trend. The sharp recession starting in 2008 resulted in a large drop in output. The subsequent periods have seen a moderate recovery over the past ten years. By and large, the loan rate of interest followed a downward trend, although with a period of rising rates prior to the start of the crisis.

In addition to the shocks, we have also estimated a number of structural parameters. Appendix B describes the estimation procedure in more detail, including our assumptions on priors and the resulting posterior distributions of estimated parameters in Table A1.

3.3.3 Sustained Reform

Our rich structural model of Italy as part of the Eurozone allows for an analysis of many policy options. Although the model is quite detailed, we can only paint a broad picture. Starting from unfavorable initial conditions, we explore the potential consequences of (i) sustained reform within the Eurozone with a long-term policy commitment; and (ii) exit from the Eurozone, triggered by a severe asymmetric recession. The starting point of the analysis is an unfavorable stationary equilibrium as portrayed in Table 3.

The model is calibrated to reflect the situation at the start of the Eurozone and some key model parameters are estimated to track the development since then. Today, Italy appears to be stuck in a bad equilibrium and confronts a 'trilemma' of excessive government debt, a vulnerable banking sector and stagnant growth. The last column of Table 3 illustrates a constructed steady state that can rationalize the state of the Italian economy today in several key variables (FSS). The numbers partly reflect a cumulative negative causation of the three drivers of the Eurozone crisis that were discussed, for example, by Shambaugh (2012). Public debt is about 130% of GDP, compared to 105% twenty years earlier, with no clear tendency for reversal. Given the growth in government spending resulting from a larger debt burden and an assumed increase in social spending of about 3% of GDP,[14] the effective income tax rate is 3.5 points higher,[15] thereby discouraging employment and investment. To stabilize debt, the government must initiate fiscal consolidation which, by assumption, is based 70% on tax increases, 20% on cuts in productive spending and 10% in social spending (which partly offsets the initial increase). Importantly, the cuts in productive spending imply deteriorating public services and infrastructure which endogenously transmits into stagnant factor productivity.

[14] By Eurostat data, social spending increased from 19% in the early 2000s to more than 22% in 2018.

[15] The OECD tax database reports an all-in average personal income tax rate at the average wage for a single worker without children of 31.4%, up from 28.5% in 2001.

Symbols	Names	ISS	FSS
B_G/PY	Fiscal Debt/GDP Ratio	1.0500	1.3000
s_l	Bad Loan Share Banks	0.0600	0.1500
Y	Real GDP	0.0000	-10%
K	Capital Stock	0.0000	-17%
L	Employment	0.0000	-2%
Cbar	Private Consumption	0.0000	-8%
w/Pbar	Real Wage	0.0000	-6%
z	Factor Productivity	1.0700	1.0428
tau	Income Tax Rate	0.3000	0.3337
i	Ann.Domestic Interest	0.0300	0.0300
B_f/PY	Net Foreign Debt/GDP	0.2200	0.2200

Remark: ISS stationary state at start of Eurozone.
FSS stationary state in bad equilibrium.

Table 3: A bad stationary equilibrium

On top of that, the banking sector remains vulnerable with a high share of bad loans which forces banks to raise the loan rate. A higher cost of credit, a higher tax burden and a deteriorating infrastructure all contribute to a slowdown of investment and growth. In this bad equilibrium, the model implies a capital stock 17% lower than at the start of Eurozone membership. Higher labor taxes and lower real wages on account of declining productivity discourage labor supply and employment as well which is 2% lower. The decline in real wages of about 6% comes close to observed trends (ILO, 2018). Reduced factor inputs and declining productivity imply a 10% reduction of the output level and an 8% loss in private consumption.[16]

These developments render Italy in a vulnerable position. As a member of the Eurozone, it lacks monetary policy instruments that could be targeted to the national economy to dampen the impact of asymmetric shocks. It also lacks important adjustment mechanisms such as exchange rate flexibility. As a consequence of the trilemma discussed above, the ability of fiscal policy, banks and the real sector to absorb shocks and dampen business cycle fluctuations is limited, leading to larger recessions and making it more vulnerable to a loss of confidence on financial markets. We first discuss key reforms that could potentially reverse the unfavorable trends and increase the gains from Eurozone membership. A comprehensive reform agenda for sustained recovery requires to address all three fronts of the economic trilemma. The reform scenario thus involves three separate packages.

- The first pillar is fiscal reform: We reduce the long-term debt target to the level at the start of Eurozone membership equal to 105% of GDP ($\bar{b}^g = 1.05$) which initiates tax- and expenditure-based consolidation as described in (22-23). Past experience shows that fiscal consolidation is predominantly tax based. To reconcile fiscal consolidation with growth, we instantaneously raise investment tax credits (increasing the expensing rate t^z from .1 to .5) to reduce the effective tax on investment.

- The second pillar aims at reversing stagnant productivity growth. Specifically, we raise the share $\bar{g}$ of productive fiscal spending (e.g., basic research, schools, judicial system, hard infrastructure) by 2% of GDP. This endogenously transmits into slowly accumulating productivity gains, see (24) and (2). To boost competitiveness, we also mimic internal devaluation and reduce the taste parameter $\bar{\phi}$ by 5% which initiates a delayed reduction of ϕ_t as in (9), thereby stimulating employment and inducing households to accept somewhat lower wages.[17]

[16]The last two lines of Table 3 result from a model with international capital flows and infinitely lived agents. In the long-run, domestic interest is tied to foreign interest rates, see (36). The net foreign asset position must thus be a constant fraction of GDP, with possibly large deviations in transitory periods.

[17]A lower ϕ_t directly reduces the marginal rate of substitution between work and consumption which determines the required consumption and wage to compensate for extra work, see (13) and footnote 4. In a more refined labor market model, such reform could reduce the bargaining strength of unions, remove obstacles to

- The third pillar addresses the non-performing loans problem to stimulate lending at lower interest rates, see (32-33). Specifically, we analyze the consequences of banks reducing the share of bad loans to the level at the start of the Eurozone ($s_t^l \rightarrow \bar{s}^l$, from 15% to 6%). This decrease is supported by the recovery of the economy driven by sustained reforms. The government provides some support and subsidizes the currently high credit losses at a rate t^b, starting with 50% and phasing out with the reduction in bad loans.

Comprehensive reform requires long-term commitment and involves a long time-horizon for the gains to become effective. Private and public capital accumulation and fiscal consolidation are slow processes. The figures below show the adjustment process over 400 quarters or 100 years. Table 4 reports key indicators, starting from a bad equilibrium (column ISS) as portrayed in Table 3 and reaching a new final steady state (column FSS). Column 'Col40', for example, lists the changes 40 quarters or 10 years after the start of reform program. The dark shaded rows report absolute numbers, the light shaded rows give percent changes relative to the base case equilibrium.

The reform is designed for the country 'to grow out of high debt levels'. Adjustment is driven by several strong growth stimuli, consisting of a large, instantaneous increase in investment tax credits, a productivity-enhancing program of improving public infrastructure, 'internal devaluation' by inducing households to accept somewhat lower wages, and a bank recovery program to assure lower rates of interest. The total reform plan initiates strong and sustained accumulation of private and public capital stocks and boosts productivity and competitiveness. The early adjustment phase reflects intertemporal substitution in labor supply. Households are willing to work more in the beginning when income and consumption levels are low, while they work less in the future when consumption is expected to be high.[18] Furthermore, the instantaneous increase in employment by more than 4% in the first quarters also reflects the internal devaluation, making households willing to work more even though taxes are higher initially and wages increase only with delay. The initial rise in GDP rests on employment gains and is of roughly equal size. The increase in GDP mainly accommodates a strong investment boom and leaves little room for private consumption and exports. Consumption is only 1% higher after five years or 20 quarters, and exports even decline by 2% in the short-run before export growth sets in. Over time, the GDP expansion increasingly relies on capital accumulation while the initial employment gains fade out. Household incomes increasingly stem from growth in real wages rather than more employment. Private consumption recovers only with considerable delay.

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labor market participation etc. An alternative would be fiscal devaluation by shifting the tax burden from wage to consumption taxes (which are already rather high in Italy).

[18]In other words, low consumption today implies a low marginal rate of substitution (MRS) between leisure and consumption so that households require little compensation for an extra unit of work and are willing to expand labor supply at low wages. As sustained growth increases the MRS in line with rising wages and consumption, households increasingly cut back on labor supply in the future.

Ultimately, GDP is 17% higher than in the bad equilibrium. The long-run income gains exclusively rest on capital accumulation and improved factor productivity as employment remains rather constant and even slightly declines in the long run. Consumption follows the increase in aggregate output only with substantial delay but finally exceeds low initial levels in the bad equilibrium by about 11%. Rising exports, although setting in only after more than two years, reflect improved international competitiveness.

Strong growth is achieved in spite of fiscal consolidation, which requires higher consumption and income taxes. In isolation, the latter would discourage labor supply but the larger investment tax credit more than compensates for the higher tax rates, substantially reduces the cost of capital, and boosts investment. Tax rates almost instantaneously rise by 3 percentage points to generate the revenue needed for sustained debt reduction but they roughly stay constant thereafter. Income and consumption growth swells the tax base and generates more revenue. Furthermore, the sustained reduction in the debt to GDP ratio on account of strong income growth partly reduces the need for further revenue increasing measures. Social entitlements are largely determined by a constant replacement rate of wage earnings as in (23) and contribute relatively little to budget consolidation. The simulation shows a reduction in social spending of less than half a percent of GDP. We conclude that a program of national recovery can be designed to be largely neutral in terms of intra-generational fairness but must involve substantial redistribution across present and future generations.[19]

Table 4 also illustrates a strong decline in interest rates for business loans, down from about 8.6% in the initial situation to about 5.8% annually in the long-term. A major part is due to the fiscal subsidy which temporarily subsidizes credit losses of banks and is priced into lower loan rates. The subsidy is phased out along with the reduction in the share of bad loans. The debt ratio of firms is about 60% of assets. The reduction in bank lending rates therefore substantially reduces the cost of capital and boosts investment, which is the main purpose of the measure in the first place. Finally, the investment-led recovery in the early adjustment phase is financed to a large extent with foreign debt. Net foreign debt is relatively low at the outset, equal to 22% of GDP. Italy is thus in a relatively good position to resort to foreign funding of domestic investment. Within five years, the foreign debt almost doubles to 41% of GDP before again rapidly declining. Within the same period, the national interest rate rises by almost one percentage points as investors require a somewhat higher premium due to the rising debt to GDP ratio. Funding costs of government, banks and firms increase in line and decline thereafter.

Figure 2 illustrates dynamic adjustment and separates the effects of the three pillars of the

[19] A model of infinitely lived families doesn't lend itself to discuss fairness across generations. Future research should use an overlapping generations model to explore intergenerational effects.

Symbols	Names	ISS	Col4	Col8	Col20	Col40	Col80	FSS
B_G/PY	Fiscal Debt/GDP Ratio	1.3000	1.2365	1.2379	1.2079	1.1340	1.0582	1.0500
s_l	Bad Loan Share Banks	0.1500	0.1359	0.1197	0.0849	0.0548	0.0397	0.0600
Y	Real GDP	0.0000	4%	5%	7%	10%	14%	17%
K	Capital Stock	0.0000	4%	9%	15%	20%	30%	39%
L	Employment	0.0000	4%	3%	1%	1%	1%	-1%
Cbar	Private Consumption	0.0000	0%	0%	1%	4%	8%	11%
Ex_e	Exports to Rest of EZ	0.0000	-2%	-1%	3%	6%	8%	9%
Ex_o	Exports to RoW	0.0000	-2%	0%	3%	5%	7%	9%
K_G	Public Capital Stock	0.0000	2%	3%	8%	15%	24%	34%
w/Pbar	Real Wage	0.0000	1%	2%	4%	7%	12%	16%
z	Factor Productivity	1.0428	1.0433	1.0451	1.0539	1.0703	1.0953	1.1216
tau	Income Tax Rate	0.3337	0.3609	0.3615	0.3625	0.3620	0.3606	0.3612
i	Ann.Domestic Interest	0.0300	0.0308	0.0317	0.0353	0.0372	0.0339	0.0300
i_g	Ann.Gov.Debt Interest	0.0300	0.0308	0.0317	0.0353	0.0372	0.0339	0.0300
i_l	Ann.Loan Interest	0.0859	0.0636	0.0646	0.0667	0.0645	0.0570	0.0582
e_io	Euro/Dollar Exch.Rate	0.9943	1.0036	1.0014	0.9970	0.9952	0.9977	1.0062
B_F/PY	Net Foreign Debt/GDP	0.2200	0.2802	0.3485	0.4132	0.3430	0.2619	0.2200

Remarks: ISS stationary state in bad equilibrium. FSS stationary state in reform scenario.

Table 4: Reform within the Eurozone

reform plan. The decomposition is cumulative, that is, the competitiveness program is added to the fiscal package, and bank recovery comes on top of the other parts. Fiscal reform stabilizes the debt to GDP ratio. Consolidation is mostly tax based and immediately raises tax rates across the board (income and consumption taxes) by more than three percentage points. To avoid distortions, a strategy of 'growing out of debt' must thus combine consolidation with powerful investment incentives. Model simulations draw an encouraging picture of growth-friendly fiscal consolidation. The direct effect is a sustained reduction of the debt to GDP ratio after a small decline in the first quarters. This is partly due to strong growth induced by tax incentives. The output gains correspond to about 6 percentage points of GDP,[20] and the index of real producer wages recovers to the level at the start of the Eurozone. As discussed above, labor supply responses shift employment from the future to the present and speed up current recovery.

The program that aims at enhancing competitiveness and growth includes internal devaluation to encourage employment and an increase in productive government spending. The growth effect is powerful, adding another 5 percentage points of GDP in the long run which substantially stems from employment gains. Engineering an internal devaluation realistically takes considerable time. We mimic this by slowly phasing in labor supply incentives with the autoregressive process stated in (9). The employment gains (relative to the fiscal scenario) thus

[20]The effect appears large but studies of fundamental tax reform yield even larger effects. Altig et al. (2001), for example, simulate output gains up to 9% from a comprehensive tax reform in the U.S. that among other measures includes full expensing of new investment.

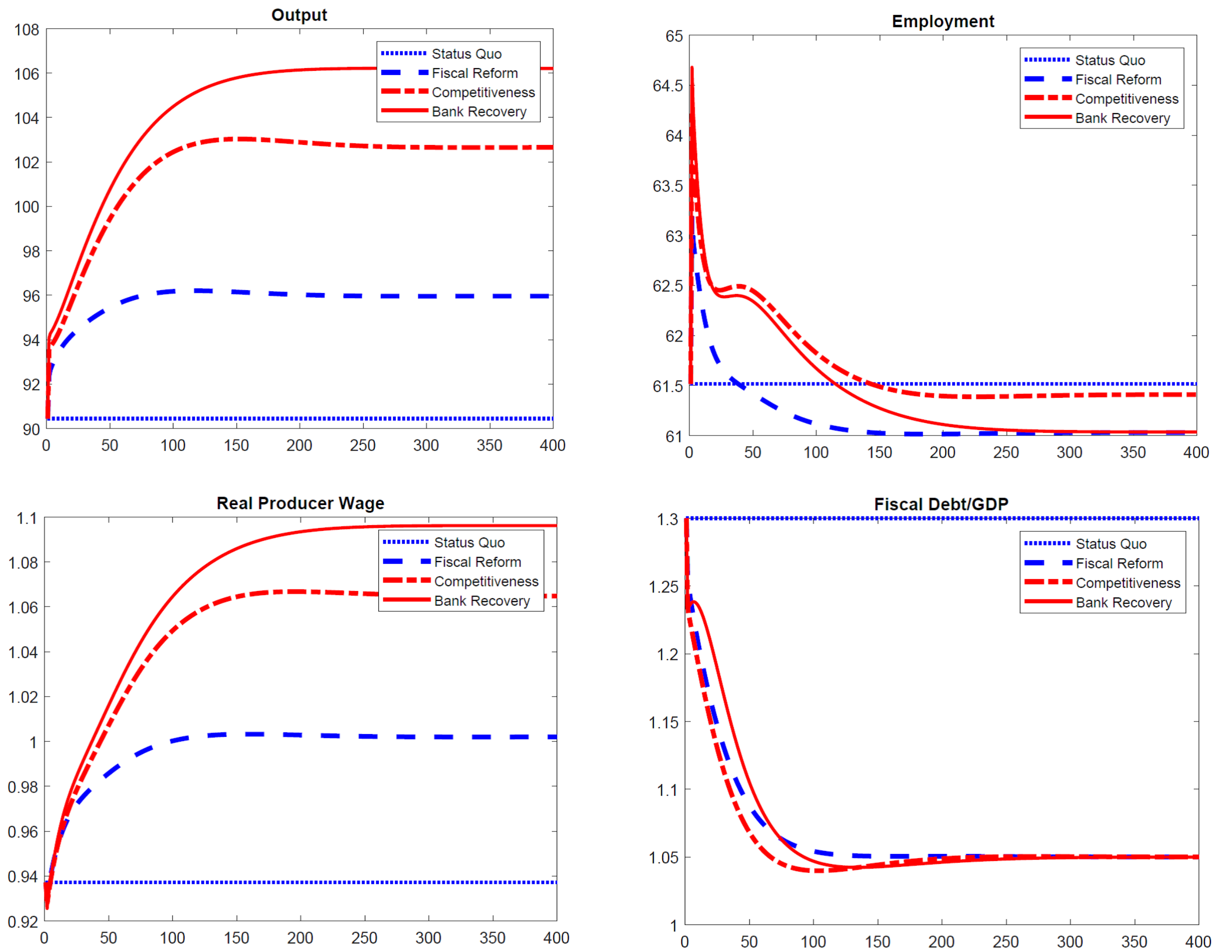

Figure 2: Reform within the Eurozone

The horizontal axis shows the quarters after the start of the policy scenario. The vertical axis denotes the value of the respective variable.

materialize with some delay. The budget cost of productive spending increases tax rates by about 2 percentage points across the board (not shown). Apart from transitional dynamics, the consolidation policy in (22) allows the nominal debt level to increase in proportion to nominal income gains where the proportionality factor corresponds to the new target level of 105% of GDP. For this reason, the effect on the debt to GDP ratio is almost not visible in the early adjustment phase, while induced growth in later periods speeds up the debt reduction.

Finally, the bank recovery program, by reducing the cost of credit and stimulating demand driven bank lending, adds about 2 additional percentage points of GDP in the long run. The effects kick in with some delay, since induced investment takes time to build up productive capacity, and because the reduction in bad loans is a prolonged process as well. Since we treat temporary bank subsidies as not being part of the 'structural deficit' subject to fiscal consolidation, they fully go into additional debt before they are consolidated in later periods. The bank subsidies thus slow down the reduction in the sovereign debt to gdp ratio in the early adjustment phase.

3.3.4 Recession and Exit

Scenarios: The preceding section paints an encouraging picture about how structural reform and fiscal consolidation could help to escape the current stagnation. An uncompromising policy commitment over more than a decade could yield substantial productivity gains, revive growth and achieve a remarkable reduction in the public debt to GDP ratio. However, is political commitment realistic? Could the reform process be interrupted by another severe crisis? Given the difficulties of securing lasting political support and the current economic vulnerabilities, we explore an alternative scenario. How can the country cope with a severe asymmetric recession when exchange rate adjustment is not possible and monetary policy cannot target the specific situation in a single member country? Whether intentional or forced, an exit from the Eurozone and the introduction of an own currency (Lira) might become a possibility. To which extent could the country reduce the costs of a severe recession by pursuing autonomous monetary policy and allowing for exchange rate flexibility? Given the complexity of the problem, our analysis can be no more than a crude approximation of possible developments. We focus on three scenarios.

- Asymmetric recession with continued Eurozone membership: Italy is hit by a combination of severe economic shocks, lasting for six quarters, while other regions are unaffected. Disutility of labor supply is exogenously increased by 10% over the period, implying that workers reduce labor supply and/or request higher wages. In addition, factor productivity is exogenously reduced by -2%, and the share of bad loans rises by 10% (from 15% to 16.5%). Apart from these exogenous changes, the emerging output gap endogenously adds to the share of bad loans as in (33), and factor productivity partly responds to changes in productive fiscal spending.

- Benign exit: Italy is hit by the same recession which instantaneously triggers exit from the Eurozone. The Euro Lira exchange rate is flexible, and monetary policy is autonomously chosen. We assume that the national central bank aggressively responds to the output gap by expanding money supply, and thus raises the sensitivity to the output gap from 1 to 5 (see ψ_y Table 1). The exit is benign in the sense that it does not lead to investor panic and speculative capital flight.

- Escalating exit: Mimicking investor panic, we raise the interest premium on government bonds and bank deposits as well as equity of firms and banks by a factor of 2. The sudden increase in 'risk premia' reflects funding shocks that require high interest to secure at least a reduced level of funding. These shocks last for two quarters and then phase out with the autoregressive process.

We emphasize two implications of the model to prepare intuition for the results. First, we treat the recession with and without Eurozone exit is a purely temporary event which may have quite dramatic short- and medium-run effects but is inconsequential for the long run. After the recession ends, the shock variables revert back to initial values in line with the estimated autoregressive processes. In the same vein, monetary policy may have substantial effects in the short but is neutral in the long run. Since we abstract from any permanent changes in structural parameters, the economy reverts to the same bad stationary equilibrium. Second, whenever the economy is in a steady state and no shock occurs, and whenever national monetary policy fully replicates centralized policy making, an unanticipated exit is completely neutral. Any effect on the exchange rate can only result from asymmetric shocks and from differences in monetary policy between Italy and the Eurozone. We thus expect in our scenarios rather modest changes in exchange rates even after an exit. Figures 3 and 4 decompose the cumulative effects of the three scenarios and illustrate transitional dynamics for key economic indicators. Table 5 reports more detailed information of the total effect (scenario 3, escalating exit).

Recession Within Eurozone: The dashed lines in Figures 3-4 refer to the impact of a deep asymmetric recession in Italy. Neither the internal exchange rate nor monetary policy can adjust. Our assumption is that monetary policy is conditional on average economic performance in the total Euro area and cannot separately address the recession in Italy. Given several large negative shocks, the recession is bound to be very severe and involves an instantaneous output loss of about five percentage points. This loss accumulates to a maximum of six percentage points within eight quarters when shocks start to fade out and economic recovery sets in.

The recession feeds on several sources: The cost of capital is linked to interest rates, which tend to rise rather than fall in the absence of monetary intervention. The output price instantaneously rises due to a negative productivity shock and weakens competitiveness relative to trading partners, thereby eroding exports as well. Given nominal wage stickiness, the price increase somewhat reduces the real producer wage to stabilize employment. However, the negative labor supply shock counteracts this effect so that employment, all in all, drops by 4 percent relative to the bad stationary state. The large emerging output gap substantially raises the share of non-performing loans from already high 15% to 22% within 4 years. This forces banks to raise loan interest rates by about 2.4 percentage points annually, from 8.6 to 11% over the same period such that firm investment substantially falls.

By construction, centralized monetary policy cannot target the specific situation in Italy and remains rather passive. Fiscal policy is constrained by a high level of debt and cannot run into a substantial deficit, thereby preventing automatic fiscal stabilization to a large degree.

The model does not allow for a deviation from the consolidation rule as described in Section 2.4, so that the government must slightly tighten the fiscal stance to prevent a substantial increase in public debt. Our model simulation thus emphasizes that a Eurozone member state with excessive public debt, little competitiveness and a vulnerable banking sector is bound to experience more severe recessions than other member states if they were subject to the same shocks.

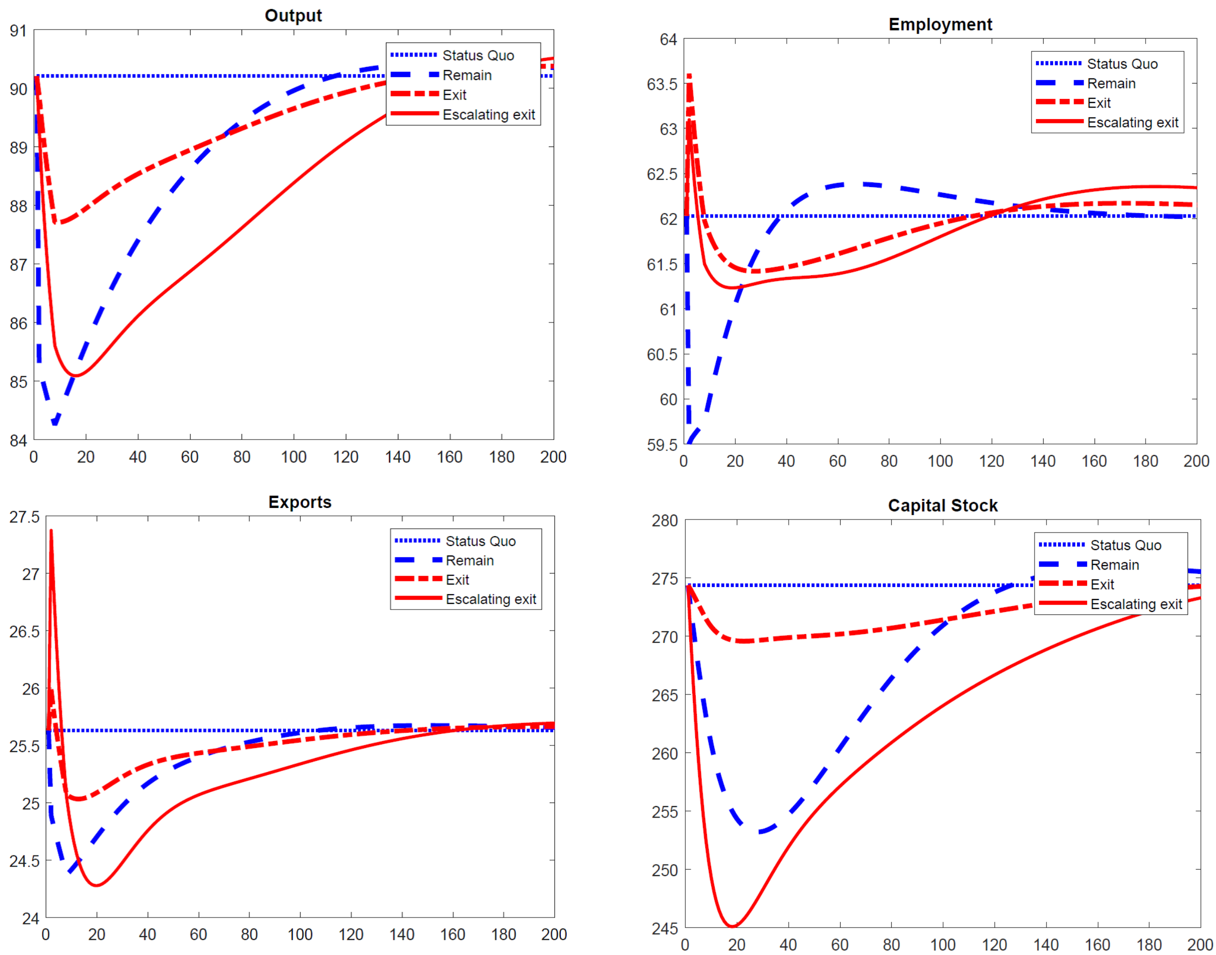

Figure 3: Recession and Exit from Eurozone

The horizontal axis shows the quarters after the start of the policy scenario. The vertical axis denotes the value of the respective variable.

Benign Exit: This scenario mimicks a 'benign exit' without panic driven investor reactions. We consider the same shocks as before but now the internal exchange rate is fully flexible, and monetary policy is autonomous and can help cushion the recession. We assume that the national central bank aggressively expands money supply and liquidity to counter the deep recession. We thus raise the sensitivity of money supply to the output gap from 1 to 5. The aggressive monetary expansion leads to a sudden and unanticipated increase in the price level. The real value of outstanding nominal debt is depreciated.

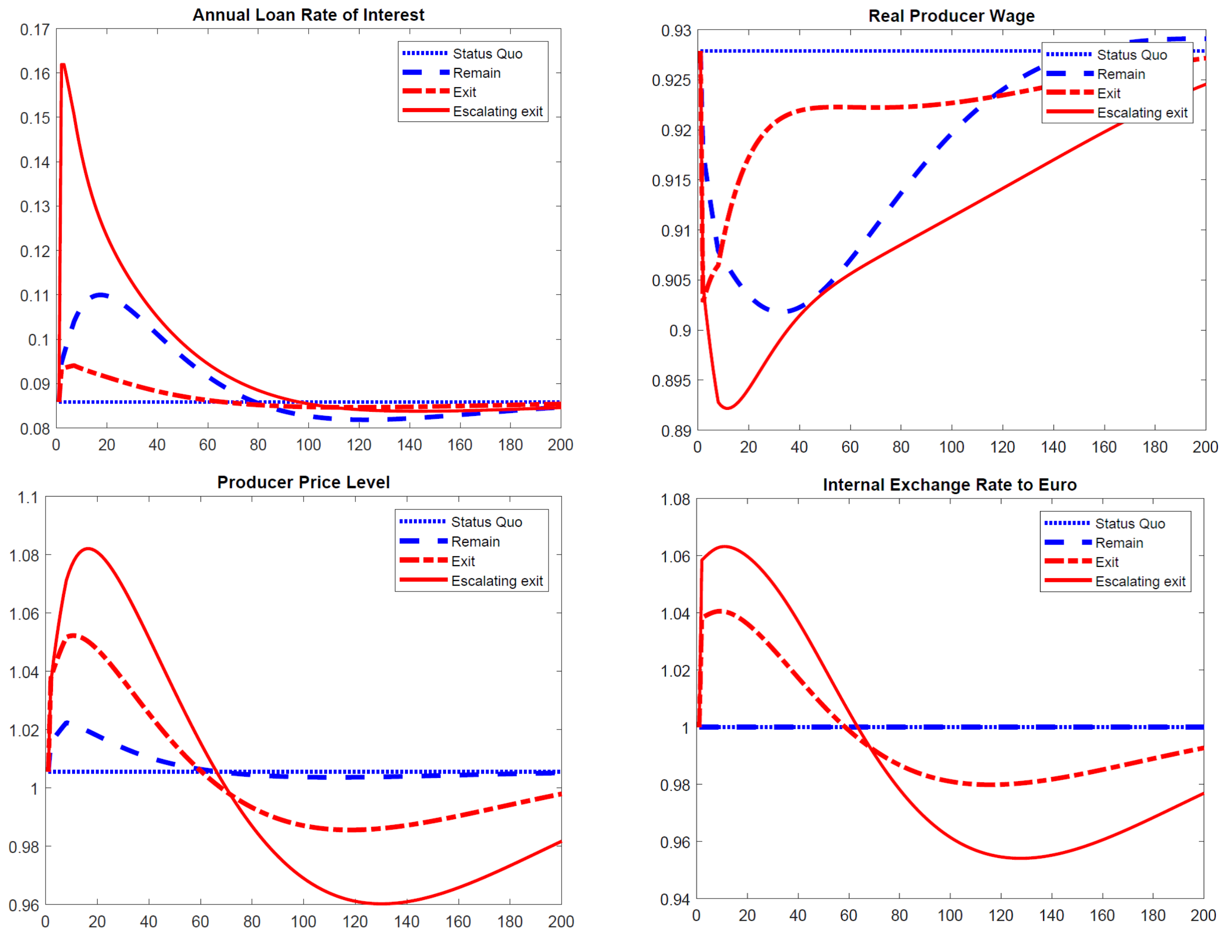

Figure 4: Recession and Exit from Eurozone

The horizontal axis shows the quarters after the start of the policy scenario. The vertical axis denotes the value of the respective variable.

More importantly, given sticky nominal wages, monetary policy is able to engineer an immediate reduction in real wages, much faster than in the first scenario. Real wage cuts lead to substantial employment gains before the recession deepens. Given the immediate losses in real wages and consumption, households respond by expanding labor supply today when consumption is low, and reduce it later on when real wages and consumption recover again. The initial employment response prevents a massive reduction in output. The real wage reduction more than halves the output loss in the early adjustment period. On the demand side, the decline in investment and consumption is much less dramatic, and exports largely keep up as the sudden increase in domestic producer prices goes in line with an immediate depreciation of the Lire. This restores competitiveness in international markets, facilitates a moderate initial increase in exports and contributes to the reduction in output losses. Given the more benign nature of the recession in the exit scenario, the share of bad loans rises much less dramatically, so that banks can abstain from charging much higher loan rates and thereby squeezing credit demand.

Symbols	Names	ISS	Per_2	Per_4	Per_8	Per_20	Per_40	Per_80	FSS
B_G/PY	Fiscal Debt/GDP Ratio	1.3000	1.2754	1.2827	1.2895	1.2891	1.3108	1.3364	1.3000
s_l	Bad Loan Share Banks	0.1500	0.1659	0.1702	0.1859	0.2154	0.2040	0.1569	0.1500
Y	Real GDP	0.0000	-1%	-3%	-5%	-6%	-5%	-3%	0%
K	Capital Stock	0.0000	-2%	-4%	-8%	-11%	-8%	-5%	0%
L	Employment	0.0000	2%	1%	-1%	-1%	-1%	-1%	0%
Cbar	Private Consumption	0.0000	-1%	-1%	-2%	-3%	-4%	-3%	0%
Ex_e	Exports to Rest of EZ	0.0000	7%	3%	-2%	-5%	-3%	-2%	0%
Ex_o	Exports to RoW	0.0000	6%	3%	-2%	-5%	-3%	-2%	0%
K_G	Public Capital Stock	0.0000	0%	0%	-1%	-3%	-4%	-4%	0%
w/P	Producer Real Wage	0.0000	-1%	-1%	-3%	-4%	-3%	-2%	0%
w/Pbar	Consumer Real Wage	0.0000	-1%	-2%	-3%	-3%	-3%	-2%	0%
z	Factor Productivity	1.0237	1.0023	1.0022	1.0016	1.0115	1.0135	1.0134	1.0237
tau	Income Tax Rate	0.2935	0.3071	0.3055	0.3012	0.2954	0.2954	0.2958	0.2935
P	Producer Prices	1.0055	1.0361	1.0499	1.0710	1.0803	1.0510	0.9870	1.0055
Pbar	Consumer Price Index	1.0016	1.0363	1.0477	1.0651	1.0721	1.0444	0.9820	1.0016
gi	Ann.Inflation Rate	0.0000	0.0218	0.0166	0.0063	-0.0030	-0.0066	-0.0046	0.0000
i	Ann.Domestic Interest	0.0300	0.0329	0.0322	0.0293	0.0232	0.0229	0.0280	0.0300
i_d	Ann.Deposit Interest	0.0300	0.0986	0.0943	0.0782	0.0483	0.0349	0.0315	0.0300
i_g	Ann.Gov.Debt Interest	0.0300	0.0986	0.0943	0.0782	0.0483	0.0349	0.0315	0.0300
i_k	Ann.Return on Equity	0.1200	0.1973	0.1910	0.1662	0.1180	0.1037	0.1155	0.1200
i_l	Ann.Loan Interest	0.0859	0.1618	0.1591	0.1469	0.1228	0.1048	0.0885	0.0859
e_ie	Lire/Euro Exch.Rate	1.0000	1.0582	1.0599	1.0624	1.0593	1.0366	0.9783	1.0000
e_eo	Euro/Dollar Exch.Rate	0.9942	1.0369	1.0437	1.0541	1.0572	1.0322	0.9727	0.9942
B_f/PY	Net Foreign Debt/GDP	0.2200	0.1707	0.1035	0.0431	0.1160	0.2705	0.2713	0.2200

Remarks: ISS stationary state in bad equilibrium. FSS steady state in exit scenario.

Table 5: Recession and Exit from Eurozone

The recession becomes increasingly worse as soon as employment gains disappear and investment cuts erode the capital stock. Although the negative shocks fade out after eight quarters, their detrimental effects persist and make the recovery slower. A striking feature of the adjustment is that the same recession within the currency union is much more devastating in the early phase compared to a benign exit, but recovery is faster thereafter. The pattern is most dramatic in the time paths of real wages and employment. The monetary expansion shifts forward in time the real wage reduction so that real wages are lower today but higher thereafter. In consequence, employment first rises but is subsequently lower over a long time span which delays the recovery in employment, capital stock and output. The ability of monetary policy to stabilize the economy may thus reduce output and income losses over a prolonged early period but not uniformly so.

Escalating Exit: Since the economy starts from a vulnerable position, an exit could trigger a general loss of confidence and even panic-driven capital flight. An unanticipated inflation shock and a corresponding devaluation of the Lira implies a one-time reduction of wealth. We picture the loss of confidence by a sudden increase in risk-premia on government bonds and bank deposits as well as equity of banks and firms. Interest rates on fiscal bonds and deposits essentially triple in the first two quarters of the recession and then revert back to normal levels with some delay. The solid lines in Figures 3-4 and Table 5 illustrate the dynamic adjustment. Banks pass the increased cost of deposit as well as equity funding onto firms. The resulting increase in the loan rates of interest reflects a weighted average of deposit and equity funding costs and leads to a severe credit crunch. Compared to a benign exit, the funding stop caused by the sudden jump in capital costs severely impairs investment and leads to a much larger decline in the capital stock. The escalating scenario thus magnifies the recession in the early adjustment phase. The decline in economic activity endogenously swells the share of non-performing loans that reaches a maximum of almost 22% after 25 quarters, up from 15% in the bad initial equilibrium. The resulting credit losses endogenously force banks to raise loan rates even more which substantially delays the decline of credit costs and prolongs the recession.

The aggressive monetary policy response to the emerging output gap implies a substantially larger increase in the domestic price level and magnifies the depreciation of the Lira. With sticky nominal wages, the resulting real wage reduction is not only much larger but also persists over a long time span. The real wage cuts still result in a moderate employment gain in the very first quarters but smaller than before. Exports initially rise even more on account of a larger depreciation. However, export demand cannot make up for reduced investment and consumer demand. The sudden increase in sovereign funding costs constrains fiscal policy, which can thus not contribute to the stabilization of the economy. Overall, an escalating exit with a general loss of confidence and rising funding costs not only leads to a much sharper recession in the early adjustment period, but also substantially delays the economic recovery.

3.4 Conclusions

In a currency union, the internal exchange rate is fixed. Monetary policy is no longer available to stabilize the business cycle in a single member country but focuses on the average state of the entire union. Important adjustment mechanisms are missing. To compensate for the loss of monetary autonomy as a tool of macroeconomic stabilization, an individual member country must instead rely on fiscal policy and on automatic fiscal stabilizers. These instruments require low public debt, however. Banks can only help absorb shocks if endowed with sufficient equity and if lending activity rests on a low share of non-performing loans. Finally, a competitive and innovative economy is also more resilient and can better absorb macroeconomic fluctuations without creating large employment losses. In contrast, a recession can set off a vicious cycle if these conditions are not met, driven by mutual contagion between an overly indebted sovereign, a vulnerable banking sector, and an uncompetitive real economy.

Today, the Italian economy appears to be in a vulnerable position with respect to all three focal points. Using a New Keynesian DSGE model with nominal wage rigidity that pictures Italy and the rest of the Eurozone, this paper analyzed two broad alternatives for economic policy. The first scenario considered the possibility of sustained reform within the Eurozone, involving strong policy commitment over several decades. The results indicate the possibility of 'growing out of currently unfavorable initial conditions', provided that sustained fiscal consolidation is combined with bank recovery and a program for competitiveness and growth. On the other hand, a strong asymmetric recession could interrupt any attempt at reform and move the economy 'off track'. In a second scenario, we considered the possible developments in a severe asymmetric recession. We report three main insights. First, an asymmetric recession within the Eurozone is likely to be very severe, given the absence of typical shock absorbers. Second, a benign exit from the Eurozone with stable investor expectations could substantially dampen the negative short-run impact of a recession. On the negative side, the economy takes significantly longer to recover. Stabilization is achieved by an aggressive monetary expansion, combined with exchange rate depreciation to restore international competitiveness. However, 'stable investor expectations' after an exit might be rather unrealistic, given the large vulnerabilities. Third, investor panic may lead to an escalating exit with funding stops due to sudden jumps in risk premia, which magnify private and public borrowing costs, thereby further depressing investment and constraining fiscal policy. Unfavorable capital market reactions tend to offset the advantages of monetary autonomy. Such an exit scenario makes the recession as deep as under continued membership, while considerably delaying the full recovery.

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3.A Appendix

3.A.1 Estimation

Following standard procedures in DSGE research, we add shocks to the model and apply Bayesian estimation techniques. Table A1 provides an overview of estimated shocks together with some structural parameters and reports our prior assumptions together with the resulting posterior distributions.

We have harmonized the priors for the standard deviation of the shock processes by assuming an inverse-gamma distribution (e.g. Gerali et al. 2010) with mean 0.1 and standard deviation of 2. An exception is the shock process for total income in the Eurozone for which we set a mean of 2 and a standard deviation of 0.5. Since persistence of the AR(1) processes is restricted in the 0-1 range, the parameters are assumed to be beta distributed with mean 0.95 and standard deviation 0.01. For other parameters, we use calibrated values as the mean, see Table 2. We estimate σ^{sl} with a mean of 13.33, a value that associates an output loss of 5% with an increase in the NPL share by 4 percentage points. For the elasticity between productivity and government spending, σ^{z}, we consider a mean of 0.2. This implies a 2 percentage point increase in factor productivity after a 10% increase in government spending. The shares of government budget consolidation attributed to productive government spending and social spending ξ_g and ξ_e, are set to a prior of 0.2 and 0.1, respectively. The prior for the parameter of investment adjustment costs, ψ is set to 5, while the prior for the fiscal adjustment speed γ_g is set at 0.97.

Table A1: Prior and Posterior Distributions

Parameter		Prior distribution			Posterior distribution		
		Density	Mean	St.dev	10%	Mean	90%
Autocor. risk premia	ρ^{th}	Beta	0.95	0.01	0.9559	0.9643	0.9723
Autocor. NPL shock	ρ^{sl}	Beta	0.95	0.01	0.9472	0.9578	0.9723
Autocor. revenue losses	ρ^{T}	Beta	0.95	0.01	0.9359	0.9495	0.9621
Autocor. business cycle	ρ	Beta	0.95	0.01	0.9086	0.9246	0.9399
Sensitivity NPL rate	σ^{sl}	Normal	13.33	1	11.8759	13.1615	14.4511
Sensitivity Productivity	σ^{z}	Inv.Gamma	0.25	0.001	0.2487	0.2500	0.2513
Fiscal adjustment speed	γ^{g}	Normal	0.97	0.001	0.9693	0.9705	0.9718
Investment adj. costs	ψ	Normal	5	0.01	4.9877	5.0010	5.0143
Consolidation share G	ξ^{g}	Normal	0.2	0.001	0.1987	0.2000	0.2014
Consolidation share E	ξ^{e}	Normal	0.1	0.001	0.0987	0.1000	0.1013
SD productivity shock IT	$\tilde{\sigma^{z}}$	Inv.Gamma	0.1	2	0.0113	0.0126	0.0141
SD income shock EZ	$\tilde{\sigma^{ye}}$	Inv.Gamma	0.1	2	1.9722	2.2017	2.4494
SD deposit shock	$\tilde{\sigma^{d}}$	Inv.Gamma	0.1	2	0.0803	0.0826	0.0920
SD gov. interest shock	$\tilde{\sigma^{g}}$	Inv.Gamma	0.1	2	0.0739	0.0826	0.0920
SD gov. spending shock	$\tilde{\sigma^{G}}$	Inv.Gamma	0.1	2	0.4648	0.5178	0.5746
SD social spending shock	$\tilde{\sigma^{E}}$	Inv.Gamma	0.1	2	1.1067	1.2374	1.3739
SD NPL shock	$\tilde{\sigma^{sl}}$	Inv.Gamma	0.1	2	0.0095	0.0106	0.0118

The last three columns of Table A1 show the means and confidence intervals of the posterior distributions as obtained by the Metropolis Hastings algorithm. We used 5 chains, each with 25,000 draws which ensures convergence of the sampling algorithm. Shock persistence is estimated to be quite high. Autocorrelation coefficients range from 0.93 (for the business cycle) to 0.97 for the risk premia. All other parameters are estimated to a value close to our prior assumptions. Figure 5 shows prior (gray curves) and posterior distributions (black curves) of the estimated parameters. The vertical dashed lines indicate the estimated posterior mode.[21] The smaller variance of the posterior indicates that the data appear to be informative of the persistence of shock processes. Figure 6 plots estimated standard deviations. They are relatively large for the shocks to Eurozone income, deposits, government interest rate, and both types of government expenditures. By contrast, the estimated standard deviations of the productivity shock and the non-performing loans shock are rather small. The model seemingly does not rely

[21] The mode is the most frequently computed value. It does not coincide with the mean for non-normal (non-symmetric) distributions and not necessarily with the peak of the posterior distribution.

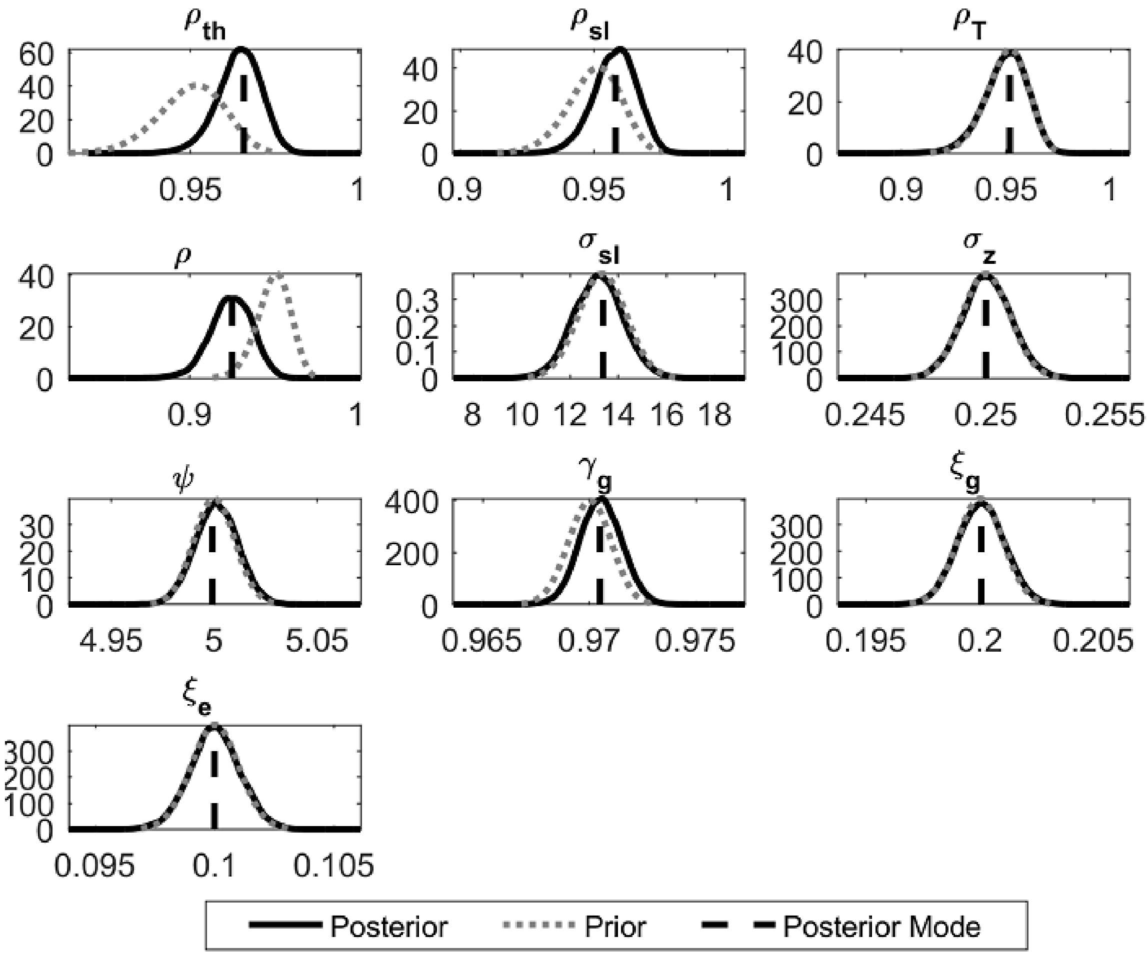

Figure 5: Standard Deviations of Priors and Posteriors

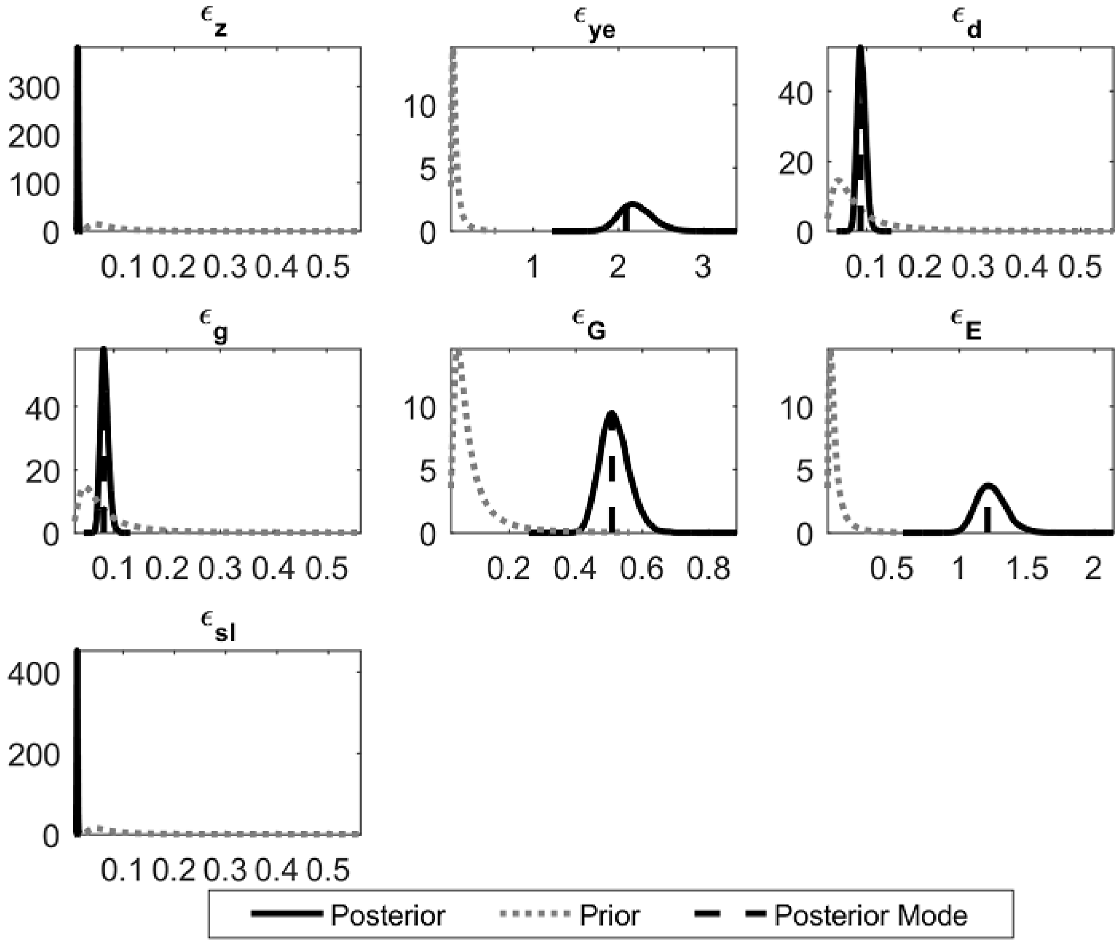

Figure 6: Standard Deviations of Priors and Posteriors

much on these shocks to explain fluctuations.

3.A.2 Model Representation in Dynare

1. $z_t = (1-\rho)\,\bar{z}\left(K_t^G/\bar{K}^G\right)^{\sigma^z} + \rho z_{t-1} + \varepsilon_t^z$, productivity shocks, **ITALY**
2. $\tau_t = t_t^s \tau_0$, tax rate scaling for budged balance
3. $\tau_t^c = t_t^s \tau_0^c$,
4. $P_t^{ie} = e_t^{ie} P_t^e$, import prices
5. $P_t^{io} = e_t^{io} P^o$,
6. $\bar{P}_t = \left[s^{ii}\left(P_t\right)^{1-\sigma_r} + s^{ie}\left(P_t^{ie}\right)^{1-\sigma_r} + s^{io}\left(P_t^{io}\right)^{1-\sigma_r}\right]^{1/(1-\sigma_r)}$, price index
7. $b_t^f = B_t^f / \left(P_t Y_t\right)$, foreign debt to GDP ratio
8. $\theta_t = \left(1-\rho^f\right)\left[1+\gamma\left(e^{b_t^f - \bar{b}^f} - 1\right)\right] + \rho^f \theta_{t-1} + \varepsilon_t^\theta$, country risk premium
9. $1 + i_t = \left(1 + i_t^e\right)\theta_t e_{t+1}^{ie} / e_t^{ie}$, interest parity
10. $1 + \pi_t = \left(1 + \tau_{t+1}^c\right)\bar{P}_{t+1} / \left(\left(1 + \tau_t^c\right)\bar{P}_t\right)$,
11. $1 + r_t = \left(1 + i_t\right) / \left(1 + \pi_t\right)$,
12. $\theta_t^g = 1 - \rho^\theta + \rho^\theta \theta_{t-1}^g + \varepsilon_t^g$, government interest shock
13. $\theta_t^d = 1 - \rho^\theta + \rho^\theta \theta_{t-1}^d + \varepsilon_t^d$, deposit shock
14. $\theta_t^b = \left(1-\rho^\theta\right)\bar{\theta}^b + \rho^\theta \theta_{t-1}^b + \varepsilon_t^b$, equity premium shocks
15. $\theta_t^k = \left(1-\rho^\theta\right)\bar{\theta}^k + \rho^\theta \theta_{t-1}^k + \varepsilon_t^k$,
16. $i_t^g = \theta_t^g i_t$, interest premium
17. $i_t^d = \theta_t^d i_t$,
18. $i_t^b = \theta_t^b i_t$,
19. $i_t^k = \theta_t^k i_t$,
20. $u_{C,t} = \beta\left(1 + r_t\right)\cdot u_{C,t+1}$, Euler equation
21. $m_t = \left[\left(1-s_c\right)\left(1+\tau_{t+1}^c\right)\left(1+r_t\right)/\left(s_c i_t\right)\right]^{1/\sigma_m}$, money consumption ratio
22. $x_t = \left[s_c + \left(1-s_c\right) m_t{}^{1-\sigma_m}\right]^{1/(1-\sigma_m)}$,
23. $\bar{C}_t = \left(s_c x_t^{\sigma_m - \sigma_c} / u_{C,t}\right)^{1/\sigma_c}$,
24. $\bar{M}_t = m_t \cdot \bar{C}_t$, money demand
25. $\left(w_t^L\right)^{1-\sigma_l} = \left(1-\omega\right)\left(w_t^*\right)^{1-\sigma_l} + \omega\left(w_{t-1}^L\right)^{1-\sigma_l}$, wage index
26. $N_{t,t} = \left(w_t^L / w_t^*\right)^{\sigma_l} L_t / H$, per capita

27. $N_{t-1,t} = \left(w_t^L/w_{t-1}^*\right)^{\sigma_l} L_t/H$, vintage $t-1$ at date t

28. $\phi_t = (1-\rho)\,\bar{\phi} + \rho\phi_{t-1} + \varepsilon_t^{\phi}$,

29. $MRS_{t,t} = \phi_t N_{t,t}^{\eta} \bar{C}_t^{\sigma_c} / \left(s_c x_t^{\sigma_m - \sigma_c}\right)$,

30. $\frac{1-\tau_t}{1+\tau_t^c}\frac{w_t^*}{\bar{P}_t} = \frac{\sigma_l}{\sigma_l - 1} MRS_{t,t} + \left(w_t^*/N_{t,t}\right)\omega\mu_{t+1}^w/\left(1+r_t\right)$, new wage setting

31. $\mu_t^w = -\left[\frac{1-\tau_t}{1+\tau_t^c}\frac{w_{t-1}^*}{\bar{P}_t} - \frac{\sigma_l}{\sigma_l-1}\left(w_t^*/w_{t-1}^*\right)^{\eta\sigma_l} MRS_{t,t}\right] N_{t-1,t}/w_{t-1}^* + \omega\mu_{t+1}^w/\left(1+r_t\right)$,

32. $m_t^c = P_t \cdot \left(\sigma_v - 1\right)/\sigma_v$, markup pricing

33. $\tilde{k}_t = K_{t-1}/L_t$,

34. $w_t^L = (1-\alpha)\, m_t^c z_t \tilde{k}_t^{\alpha}$, factor prices

35. $w_t^K = \alpha m_t^c z_t / \tilde{k}_t^{1-\alpha}$,

36. $Q_t = \left(\lambda_{t+1}^K / \left(1+i_t^k\right)\right) / \left(\left(1 - t^z\tau_t\right)\bar{P}_t\right)$, INVESTMENT

37. $K_t = \left(1 + \left(Q_t - 1\right)/\psi\right) K_{t-1}$,

38. $I_t = K_t - (1-\delta)\, K_{t-1}$,

39. $\bar{Z}_t = I_t + \frac{\psi}{2} K_{t-1}\left(I_t/K_{t-1} - \delta\right)^2$, adjustment costs

40. $\bar{Z}_{K,t} = -\frac{\psi}{2}\left(I_t/K_{t-1} + \delta\right)\left(I_t/K_{t-1} - \delta\right)$,

41. $s_t^l = \left(1 - \rho^{sl}\right)\bar{s}^l\left(\bar{Y}_t/Y_t\right)^{\sigma^{sl}} + \rho^{sl} s_{t-1}^l + \varepsilon_t^{sl}$, NPL share

42. $d_t^l = l s_t^l$,

43. $t_t^b = \rho^{sl} t_{t-1}^b + \varepsilon_t^{tb}$, subsidy rate bank rescue

44. $1 + i_t^l = \left(\kappa^B\left(1+i_t^b\right) + \left(1-\kappa^B\right)\left(1+i_t^d\right)\right) / \left(1 - \left(1 - t_{t+1}^b\right) d_{t+1}^l\right)$,

45. $\lambda_t^K = \left(1-\tau_t\right) w_t^K + \left[\left(i_t^k - \left(1-\tau_t\right) i_t^l\right) b^l - \bar{Z}_{K,t}\right]\left(1 - t^z\tau_t\right)\bar{P}_t + (1-\delta)\,\lambda_{t+1}^K/\left(1+i_t^k\right)$,

46. $B_t^l/\left(1+i_t^l\right) = b^l\left(1+i_t^k\right)\left(1 - t^z\tau_t\right)\bar{P}_t K_{t-1}$, debt capacity

47. $S_t^l = B_{t-1}^l - B_t^l/\left(1+i_t^l\right)$,

48. $Y_t^g = z_t \tilde{k}_t^{\alpha} L_t$, gross output

49. $Y_t = Y_t^g - d_t^l B_{t-1}^l/P_t$, GDP

50. $\bar{Y}_t = \delta^m Y_t + \left(1-\delta^m\right)\bar{Y}_{t-1}$, potential output

51. $\chi_t^m = \left(P_t - m_t^c\right) Y_t^g$,

52. $T_t^k = P_t Y_t^g - w_t^L L_t - t^z \bar{P}_t \bar{Z}_t - i_t^l\left(B_{t-1}^l - S_t^l\right)/\left(1+i_t^k\right)$,

53. $\chi_t = P_t Y_t^g - w_t^L L_t - \bar{P}_t \bar{Z}_t - S_t^l - \tau_t T_t^k$,

54. $V_t = \chi_t + V_{t+1}/\left(1+i_t^k\right)$,

55. $\tilde{S}_t^G = \left(1-\gamma^g/\left(1+i_t^g\right)\right)B_{t-1}^G - \left(\left(1-\gamma^g\right)/\left(1+i_t^g\right)\right)\bar{b}^g P_t Y_t$, FISCAL POLICY

56. $P_t G_t = \bar{g}\cdot P_t Y_t - \xi^g \cdot \tilde{S}_t^G + \varepsilon_t^G$,

57. $E_t = \bar{e}\cdot w_t^L L_t - \xi^e \cdot \tilde{S}_t^G + \varepsilon_t^E$,

58. $T_t = \bar{g}\cdot P_t Y_t + \bar{e}\cdot w_t^L L_t + \left(1-\xi^g-\xi^e\right)\tilde{S}_t^G$, required tax revenue

59. $T_t^l = \left(1-\rho^T\right)\bar{t}^l P_t Y_t + \rho^T T_{t-1}^l + \varepsilon_t^T$, tax base erosion

60. $T_t = \tau_t \cdot w_t^L L_t + \tau_t \cdot T_t^k + \tau_t^c \cdot \bar{P}_t \bar{C}_t - T_t^l$, budget balance

61. $K_t^G = G_t + \left(1-\delta^g\right)K_{t-1}^G$,

62. $d_t^g = \rho^{dg} d_{t-1}^g + \varepsilon_t^{dg}$, unexpected default

63. $S_t^G = \tilde{S}_t^G - \varepsilon_t^G - \varepsilon_t^E - t_t^b d_t^l B_{t-1}^l + d_t^g B_{t-1}^G$,

64. $B_t^G/\left(1+i_t^g\right) = B_{t-1}^G - S_t^G$,

65. $E_t^b/\left(1+i_t^b\right) = \kappa^B B_t^l/\left(1+i_t^l\right) + \kappa^G \tilde{s}^b B_t^G/\left(1+i_t^g\right)$, bank equity

66. $D_t/\left(1+i_t^d\right) = \left(1-\kappa^B\right)B_t^l/\left(1+i_t^l\right) + \left(1-\kappa^G\right)\tilde{s}^b B_t^G/\left(1+i_t^g\right)$, deposits

67. $S_t^d = D_{t-1} - D_t/\left(1+i_t^d\right)$,

68. $\chi_t^b = S_t^l + \tilde{s}^b S_t^G - S_t^d - \left(1-t_t^b\right)d_t^l B_{t-1}^l$,

69. $Y_t^e = \left(1-\rho\right)Y_0^e + \rho Y_{t-1}^e + \varepsilon_t^{Y,e}$, **EUROZONE**

70. $\bar{Y}_t^e = \delta^m Y_t^e + \left(1-\delta^m\right)\bar{Y}_{t-1}^e$, potential output

71. $e_t^{eo} = e_t^{io}/e_t^{ie}$,

72. $P_t^{ei} = P_t/e_t^{ie}$, import prices

73. $P_t^{eo} = P^o e_t^{eo}$,

74. $\bar{P}_t^e = \left[s^{ee}\left(P_t^e\right)^{1-\sigma_r} + s^{ei}\left(P_t^{ei}\right)^{1-\sigma_r} + s^{eo}\left(P_t^{eo}\right)^{1-\sigma_r}\right]^{1/(1-\sigma_r)}$, price index

75. $1+\pi_t^e = \bar{P}_{t+1}^e/\bar{P}_t^e$,

76. $1+r_t^e = \left(1+i_t^e\right)/\left(1+\pi_t^e\right)$,

77. $u_{C,t}^e = \beta\left(1+r_t^e\right)\cdot u_{C,t+1}^e$, Euler equation

78. $m_t^e = \left[\left(1-s_c\right)\left(1+r_t^e\right)/\left(s_c i_t^e\right)\right]^{1/\sigma_m}$, money consumption ratio

79. $x_t^e = \left[s_c + \left(1-s_c\right)\left(m_t^e\right)^{1-\sigma_m}\right]^{1/(1-\sigma_m)}$,

80. $\bar{C}_t^e = \left(s_c\left(x_t^e\right)^{\sigma_m-\sigma_c}/u_{C,t}^e\right)^{1/\sigma_c}$,

81. $\bar{M}_t^e = m_t^e \cdot \bar{C}_t^e$, money demand
82. $C_t^{oi} = s^{oi} \left(e_t^{io}/P_t\right)^{\sigma_r}$, **TRADE FLOWS**
83. $C_t^{oe} = s^{oe} \left(e_t^{eo}/P_t^e\right)^{\sigma_r}$, export demand functions
84. $C_t = s^{ii} \left(\bar{P}_t/P_t\right)^{\sigma_r} \bar{C}_t$, demand structure
85. $C_t^{ie} = s^{ie} \left(\bar{P}_t/P_t^{ie}\right)^{\sigma_r} \bar{C}_t$,
86. $C_t^{io} = s^{io} \left(\bar{P}_t/P_t^{io}\right)^{\sigma_r} \bar{C}_t$,
87. $Z_t = s^{ii} \left(\bar{P}_t/P_t\right)^{\sigma_r} \bar{Z}_t$,
88. $Z_t^{ie} = s^{ie} \left(\bar{P}_t/P_t^{ie}\right)^{\sigma_r} \bar{Z}_t$,
89. $Z_t^{io} = s^{io} \left(\bar{P}_t/P_t^{io}\right)^{\sigma_r} \bar{Z}_t$,
90. $C_t^e = s^{ee} \left(\bar{P}_t^e/P_t^e\right)^{\sigma_r} \bar{C}_t^e$,
91. $C_t^{ei} = s^{ei} \left(\bar{P}_t/P_t^{ei}\right)^{\sigma_r} \bar{C}_t^e$,
92. $C_t^{eo} = s^{eo} \left(\bar{P}_t/P_t^{eo}\right)^{\sigma_r} \bar{C}_t^e$,
93. $E_t^x = C_t^{ei} + C_t^{oi}$, exports
94. $E_t^{x,e} = C_t^{ie} + Z_t^{ie} + C_t^{oe}$,
95. $E_t^{x,o} = C_t^{io} + Z_t^{io} + C_t^{eo}$,
96. $TB_t = P_t E_t^x - P_t^{ie} \left(C_t^{ie} + Z_t^{ie}\right) - P_t^{io} \left(C_t^{io} + Z_t^{io}\right)$, trade balance
97. $TB_t^e = P_t^e E_t^{x,e} - P_t^{ei} C_t^{ei} - P_t^{eo} C_t^{eo}$,
98. $TB_t^o = P^o E_t^{x,o} - C_t^{oi} P_t/e_t^{io} - C_t^{oe} P_t^e/e_t^{eo}$,
99. $Y_t = C_t + Z_t + G_t + E_t^x$, output market clearing
100. $B_t^f = (1+i_t)\left(B_{t-1}^f - TB_t\right)$,
101. $B_t^e = -B_t^f/e_t^{ie}$,
102. $\zeta_t = (1-\tau_t)\, w_t^L L_t + E_t + T_t^l + \chi_t + \chi_t^b + S_t^d + \left(1-\tilde{s}^b\right) S_t^G - (1+\tau_t^c)\, \bar{P}_t \bar{C}_t - TB_t$,
103. $Y_t^e = C_t^e + E_t^{x,e}$,
104. $\zeta_t^e = P_t^e Y_t^e - \bar{P}_t^e \bar{C}_t^e - TB_t^e$,
105. $TB_t^o = 0$,
106. $\bar{P}_t^u \equiv s^Y \bar{P}_t + \left(1-s^Y\right) \bar{P}_t^e$, **MONETARY POLICY**
107. $1 + \pi_t^u \equiv \bar{P}_{t+1}^u/\bar{P}_t^u$, EZ inflation
108. $Y_t^u \equiv \left(P_t Y_t + P_t^e Y_t^e\right)/\bar{P}_t^u$, EZ output

109. $\bar{Y}_t^u = \delta^m Y_t^u + (1-\delta^m)\,\bar{Y}_{t-1}^u$,

110. $M_t^{s,u} = (1-\rho^m)\,\phi^{m,u}\bar{Y}_{t-1}^u \frac{\left(\bar{Y}_{t-1}^u/Y_t^u\right)^{\psi_y}}{(1+\pi_t^u)^{\psi_\pi}} + \rho^m M_{t-1}^{s,u} + \varepsilon_t^{m,u}$,

111. $M_t^s = EZ \cdot \bar{P}_{t+1}\bar{M}_t + (1-EZ)\cdot\left((1-\rho^m)\,\phi^m\bar{Y}_{t-1}\frac{\left(\bar{Y}_{t-1}/Y_t\right)^{\psi_y}}{(1+\pi_t)^{\psi_\pi}} + \rho^m M_{t-1}^s + \varepsilon_t^m\right)$,

112. $M_t^{s,e} = EZ \cdot \bar{P}_{t+1}^e\bar{M}_t^e + (1-EZ)\cdot\left((1-\rho^m)\,\phi^{m,e}\bar{Y}_{t-1}^e \cdot \frac{\left(\bar{Y}_{t-1}^e/Y_t^e\right)^{\psi_y}}{(1+\pi_t^e)^{\psi_\pi}} + \rho^m M_{t-1}^{s,e} + \varepsilon_t^{m,e}\right)$,

113. $0 = EZ\cdot\left(\bar{P}_{t+1}\bar{M}_t + \bar{P}_{t+1}^e\bar{M}_t^e - M_t^{s,u}\right) + (1-EZ)\cdot\left(\bar{P}_{t+1}\bar{M}_t - M_t^s\right)$, market clearing

114. $0 = EZ\cdot(e_t^{ie}-1) + (1-EZ)\cdot\left(\bar{P}_{t+1}^e\bar{M}_t^e - M_t^{s,e}\right)$.

Model Statistics: Expected variables are indexed by $t+1$, predetermined ones by $t-1$.

- 114 equations for 114 endogenous variables: z, K^G, t^s, τ, τ^c, e^{ie}, e^{io}, P, P^e, P^{ie},[10] P^{io}, $\bar{P}$, B^f, Y, b^f, θ, i, i^e, π, r,[20] θ^g, θ^d, θ^b, θ^k, i^d, i^g, i^k, i^b, u_C, m,[30] x, $\bar{C}$, $\bar{M}$, w^L, w^*, N, N_1, L, ϕ, MRS,[40] μ^w, m^c, K, $\tilde{k}$, w^K, Q, λ^K, I, $\bar{Z}$, $\bar{Z}_K$,[50] $\bar{Y}$, s^l, d^l, t^b, i^l, B^l, S^l, Y^g, χ^m, T^k,[60] χ, V, $\tilde{S}^G$, B^G, G, E, T, T^l, d^g, S^G,[70] E^b, D, S^d, χ^b, Y^e, $\bar{Y}^e$, e^{eo}, P^{ei}, P^{eo}, $\bar{P}^e$,[80] π^e, r^e, u_C^e, m^e, x^e, $\bar{C}^e$, $\bar{M}^e$, C^{oi}, C^{oe}, C,[90] C^{ie}, C^{io}, Z, Z^{ie}, Z^{io}, C^e, C^{ei}, C^{eo}, E^x, $E^{x,e}$,[100] $E^{x,o}$, TB, TB^e, TB^o, B^e, ζ, ζ^e, $\bar{P}^u$, π^u, Y^u,[110] $\bar{Y}^u$, $M^{s,u}$, M^s, $M^{s,e}$.[114]
- 17 exogenous variables: ε^z, ε^θ, ε^g, ε^d, ε^b, ε^k, ε^ϕ, ε^{sl}, ε^{tb}, ε^G,[10] ε^E, ε^T, ε^{dg}, $\varepsilon^{Y,e}$, ε^m, $\varepsilon^{m,e}$, $\varepsilon^{m,u}$.[17]
- 64 parameters: ρ, $\bar{z}$, $\bar{K}^G$, σ^z, τ_0, τ_0^c, P^o, s^{ii}, s^{ie}, s^{io},[10] σ_r, γ, $\bar{b}^f$, ρ^f, ρ^θ, $\bar{\theta}^k$, $\bar{\theta}^b$, β, s_c, σ_m,[20] σ_c, σ_l, ω, H, $\bar{\phi}$, η, σ_v, α, t^z, ψ,[30] δ, $\bar{s}^l$, ρ^{sl}, σ^{sl}, l, κ^B, κ^G, b^l, δ^m, γ^g,[40] $\bar{b}^g$, $\bar{g}$, $\bar{e}$, ξ^g, ξ^e, ρ^T, $\bar{t}^l$, δ^g, ρ^{dg}, $\tilde{s}^b$,[50] Y_0^e, s^{ee}, s^{ei}, s^{eo}, s^{oi}, s^{oe}, s^Y, ρ^m, $\phi^{m,u}$, ψ_y,[60] ψ_π, EZ, ϕ^m, $\phi^{m,e}$.[64]
- 26 predetermined variables: z_{t-1}, θ_{t-1}, θ_{t-1}^g, θ_{t-1}^d, θ_{t-1}^b, θ_{t-1}^b, w_{t-1}^L, w_{t-1}^*, ϕ_{t-1}, K_{t-1},[10] s_{t-1}^l, t_{t-1}^b, B_{t-1}^l, $\bar{Y}_{t-1}$, B_{t-1}^G, T_{t-1}^l, K_{t-1}^G, d_{t-1}^g, D_{t-1}, Y_{t-1}^e,[20] $\bar{Y}_{t-1}^e$, B_{t-1}^f, $\bar{Y}_{t-1}^u$, $M_{t-1}^{s,u}$, M_{t-1}^s, $M_{t-1}^{s,e}$.[26]
- 12 expected variables: e_{t+1}^{ie}, $\bar{P}_{t+1}$, τ_{t+1}^c, $u_{C,t+1}$, μ_{t+1}^w, λ_{t+1}^K, t_{t+1}^b, d_{t+1}^l, V_{t+1}, $\bar{P}_{t+1}^e$,[10] $u_{C,t+1}^e$, $\bar{P}_{t+1}^u$.

Curriculum Vitae

Born on April 17, 1985 in Frankfurt/ Main, Germany

EDUCATION

Ph.D. in Economics and Finance, University of St. Gallen, 09/2020

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Analyst, Foreign Exchange and Trading, Swiss National Bank (SNB), since 07/2019

Research Assistant, Institute of Economics (FGN), University of St. Gallen, 02/2016 - 07/2019

Teaching Assistant, School of Economics and Political Science (SEPS), University of St. Gallen, 08/2013 - 12/2018

Assistant Vice President, Structured Transactions Group, Deutsche Bank, 02/2011 - 07/2013

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