A DSGE Model with Endogenous Bank Risk-Taking

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Abstract

The bank risk-taking channel is the empirical regularity according to which bank risk increases after monetary policy easing. Dell'Ariccia, Laeven and Marquez (2014) provide a theoretical framework that explains the channel's foundations. In their partial equilibrium context, banks' optimal choice of risk is influenced by changes in banks' margins originating from monetary policy decisions. There are three subordinate effects through which monetary policy influences margins. Until now, no DSGE model includes all three channels. For central banks, this deficit is relevant. They desire models with endogenous bank risk-taking.

I provide a DSGE model incorporating all three effects. To do so, I extend the seminal Gerali et al. (2010) model. Subsequently, I study the model's propagation mechanism. I depict its endogenous responses in bank risk-taking to monetary policy and TFP shocks. I contribute narrative VAR evidence as a reference. The results are: First, the DSGE model retains the ability to match stylized responses in output and inflation to the two shocks. Second, in terms of risk-taking, the model's IRFs closely match the patterns and timing of narrative VAR evidence. Banks respond to monetary policy tightening by initially decreasing risk-taking. Subsequently, bank risk shows a temporary hump-shaped increase. In response to a TFP shock, bank risk-taking initially increases and then reverts to its steady state. The model correctly incorporates all three effects into the propagation mechanism. Overall, the model performs well.

Subsequently, I successfully apply the model to provide further insights into the pass-through effect. To achieve this, I refine Dell'Ariccia, Laeven and Marquez's considerations. Banking market competition determines the pass-through effect either through the elasticity of substitution or through interest rate stickiness. Via these two characteristics of competition, competition may exert opposite influences on the pass-through effect and thus on bank risk-taking. From the perspective of the elasticity of substitution, bank risk-taking should decline more in response to monetary policy tightening in markets which are more competitive. From the perspective of interest rate stickiness, bank risk-taking should decline more in response to monetary policy tightening in markets that are less competitive. However, the influences upon bank risk-taking are small. The influence of competition is stronger in entrepreneurial loan markets as compared to household loan markets. One reason for the small influence is this. In a general equilibrium model, banking market competition influences the risk-shifting effect via the optimal leverage effect. The pass-through effect's influence is thus offset.

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Chapter 1

Introduction

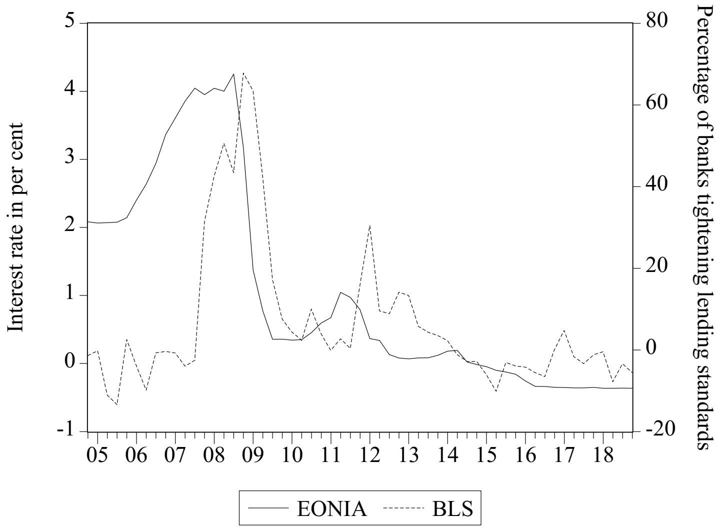
The Financial Crisis of 2007/08 has sparked a debate about monetary policy's influence on financial sector stability. In the academic and popular press, commentators have blamed the prolonged low interest rate environment at mid-decade for having spurred financial sector's risk-taking (Borio & Zhu 2012, Dell'Ariccia, Laeven & Marquez 2011). The story goes as follows. Had central banks raised interest rates earlier and more aggressively, banks would not have engaged in extensive rent seeking. By extension, the banking sector would thus not have accumulated the same amount of risks. Had central banks responded by increasing policy rates earlier, the bubble's burst would have been less severe.

Empirical evidence shows that periods of low interest rate environments cause banks to "search for yield" (Rajan 2005). This results in lower lending standards and an accumulation of risk in the banking system. Figure 1.1 depicts in panel (a) how monetary policy co-moves with the banks' willingness to accept risks in their portfolios. Therein, monetary policy is proxied by the Euro Over Night Index Average (EONIA). The net percentage of banks tightening their bank lending standards (BLS) reflects the banks' willingness to accept risk. Lower policy rates precede higher risks of loans being issued. In panel (b), the same proxy for banks' risk-taking precedes changes in the growth rate of new loans issued by banks. Monetary policy easing not only relaxes lending standards, but also leads to more loans of higher risk. In subsequent research, this monetary policy transmission channel has been coined the "bank risk-taking channel". A stream of empirical research has further documented the observable pattern of the bank risk-taking channel (Dell'Ariccia et al. 2011, Buch, Eickmeier & Prieto 2014, Paligorova & Santos 2017, Altunbas, Gambacorta & Marques-Ibanez 2010, Delis & Kouretas 2011).

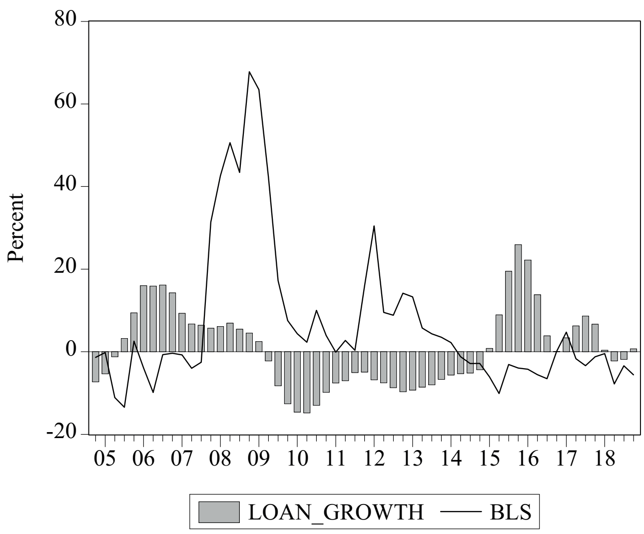
Following Dell'Ariccia, Laeven and Marquez (2014), a bank risk-taking

Figure 1.1: Time Series of EONIA, BLS and Loan Growth

(a)



(b)



Note: Figure 1.1 illustrates the time series of a proxy for monetary policy (EONIA) within the Euro area in panel (a). Monetary policy decisions appear to precede changes in banks' risk-taking as measured by the net percentage of banks tightening lending standards BLS. In panel (b), the percentage of banks tightening their lending standards appears to precede reductions in loan volumes issued (loan growth).
Source: own illustration based on ECB data

channel can be rationalized in a stylized partial equilibrium context as follows. Banks invest into risky loan projects. They finance their investment by bank capital and deposits. Risk manifests in the sense that loans (including interest) will not be repaid if the bank does not monitor them sufficiently. The degree of bank monitoring essentially determines the probability of borrowers repaying. The bank can increase its proceeds through costly monitoring. In this light, the bank manager will choose the level of monitoring which maximizes profits attributable to the bank's owners. In this sense, bank monitoring serves as the measure of banks' risk-taking. The higher the degree of monitoring, the lower the bank's risk-taking.

In the stylized Dell'Ariccia, Laeven and Marquez (2014) world, each bank is assumed to benefit from limited liability protection. A given bank's choice of the monitoring level in combination with limited liability protection exposes depositors to a risk. This assumes that no deposit insurance is in place.[1] If the bank chooses for too little monitoring, it might default on its obligations to its depositors. Due to limited liability, depositors have no recourse to the bank capitalist. Prevailing information asymmetries preclude that depositors directly observe the bank's riskiness. Instead, depositors infer the monitoring effort from the bank's equity ratio. Limited liability and information asymmetries provoke a moral hazard problem between the bank's owner-manager and the depositors. To compensate for the risk of insufficient monitoring, depositors require a spread over the risk-free rate set by the monetary policy maker. Monetary policy is thus intrinsically linked to the interest rate on deposits.

In this environment, bank monitoring (i.e. bank risk-taking) is determined by banks' margins on loans. Higher bank margins incentify banks to monitor more. The bank risk-taking channel emerges as the cumulative result of three effects – a pass-through effect, a risk-shifting effect, and an optimum leverage effect. Each effect reflects the partial influence of a monetary policy decision on the bank's margin. Monetary policy may affect the single bank's margin via its influence (i) on the interest rate on loans (pass-through effect), (ii) on the interest rate on deposits (risk-shifting effect), (iii) on the share of deposit funding of the bank (optimal leverage effect). Each effect will individually be reviewed.

The first effect is the so-called *pass-through effect*.[2] The effect captures

[1] This assumption stands in contrast to a vast amount of the earlier literature, which grounded on the assumption that deposit insurance sufficiently protects depositors. In the current discussion in the literature, however, the term deposits is interpreted to include also repurchase agreements (Repos) and certificate of deposits (CDs), which are not subject to deposit insurance.

[2] Within the literature relevant to this paper, two connotations of the term pass-through

the impact of monetary policy on interest income on bank loans. When the policy rate decreases, interest rates on loans decrease as well. The bank's gross margin[3] decreases conditional on the loans being repaid,[4] which, in turn, reduces banks' monitoring. Thus, banks accept higher risks in times of decreasing policy rates. The strength of the pass-through effect is determined by the extent to which changes in the policy rate trigger changes in retail loan rates. Thus, the pass-through is shaped by banking market competition. More competitive markets will exhibit a stronger pass-through effect.

The second effect is the *risk-shifting effect*. As uninsured deposits are priced over the risk-free policy rate, a monetary policy decision that results in a reduction in the policy rate also reduces the interest burden that the bank must pay on deposits. Since costs to banks decrease, the banks' gross margin increases. The higher gross margin allows for higher bank monitoring. Since the effect is linked to deposits, it only applies to leveraged banks. Compared to a purely equity-financed bank, the interest burden on deposits in the gross margin of a deposit-financed bank reduces the bank's monitoring. As depositors are uninsured, the relatively higher risk-taking of a leveraged bank shifts risk on depositors.

The pass-through effect and the risk-shifting effects point in opposite directions. Hence, they will partly offset each other. In response to expansionary monetary policy, the risk-shifting effect decreases risk-taking. Contrarily, the pass-through effect increases risk-taking. Which effect dominates depends on the degree of limited liability protection, on bank leverage and on the degree of market competition.

The third effect is the *optimal leverage effect*. If banks can choose their leverage ratio, the leverage ratio depends on the policy rate as well. On the

exist. Both are intrinsically linked together. The earlier interest rate channel literature considers the pass-through from policy rates into retail rates, as the latter might affect the marginal rate of substitution of households. Therein the stickiness and completeness with which retail rates in loan and deposit markets respond to a monetary policy shock are considered. This pass-through depends on the competition in banking markets. More competitive markets are expected to exhibit a more complete and faster pass-through. The bank risk-taking channel literature in the sense of Dell'Ariccia, Laeven and Marquez (2014) relates to this notion and considers a pass-through from policy rates into retail loan rates exclusively. Likewise, competition determines the degree to which policy impulses affect the retail rate and, thereby, the bank's revenue.

[3]Within this paper, the gross margin of banks ought to be understood as the intermediation margin obtainable. The intermediation margin is the difference between the retail interest rate on loans, r_L, and the deposit interest rate, r_D, weighted by the deposit ratio in the bank's funding structure, i.e. $r_L - r_D\,(1-k)$, where k is the bank's capital-ratio.

[4]This assumes that everything else is kept constant, i.e. a monetary policy decision would only affect the retail rate on loans, but not the retail rate on deposits and the capital-ratio. These restrictions are subsequently relaxed.

one hand, bank capital serves as a commitment device in the communication with depositors in the presence of information asymmetries. Bank capital mitigates the risk-shifting effect. As depositors infer bank monitoring based on the bank's capital share, higher deposit-ratios increase the marginal costs of deposit funding. On the other hand, bank capital is relatively costly due to an equity premium. Consequently, the bank will choose a leverage ratio such that the marginal costs of both financing options are identical. Expansionary monetary policy will increase banks' leverage, as agency problems decline and the benefit of holding equity shrinks. The change in leverage alters the influences of the risk-shifting effect relative to the influence of the pass-through effect. Lower bank leverage reduces the risk-shifting effect's influence on bank risk-taking. It thereby reinforces the pass-through effect's relative influence.

After the Financial Crisis, most central banks took an active approach towards managing financial sector risks.[5] This entailed buying up troubled assets and lowering policy rates to the zero-lower bound (ZLB). Monetary policy makers extended their mandate from being a lender of last resort towards becoming an active gatekeeper of financial stability. The resulting low-interest rate environment has since then rekindled concerns about bank risk-taking. In this situation, the central bank's understanding of the bank risk-taking channel has become pivotal.

Incorporating bank risk-taking into central banks' decision making poses a considerable challenge. Although the general pattern of bank risk-taking may indeed be well-documented, bank risk-taking has nontheless up until now remained largely unincorporated into the central banks' workhorse models. The considerations of Dell'Ariccia, Laeven and Marquez (2014) have been confined to a partial-equilibrium model. In most Dynamic Stochastic General Equilibrium (DSGE) models a bank risk-taking channel is absent. Prior to the Financial Crisis, the financial sector had not been modeled explicitly

[5]The pre-crisis approach towards monetary policy, however, assigned the task of inflation rate targeting to most central banks, whereas opposition formed against central banks' regular intervention in asset markets (Bernanke & Gertler 2000) or financial markets (Cecchetti 2016). Central banks were only supposed to act as a lender of last resort in individual and exceptional cases, but not on an ongoing basis as a part of monetary policy. On the contrary, the stability of the financial system was assumed to be sufficiently ensured if microprudential banking regulation safeguarded that the individual bank held an adequate capital buffer to absorb idiosyncratic shocks. For instance, the Basel II accord's internal-ratings based (IRB) approach was considered to be a viable approach prior to the subprime crisis. Additionally, financial regulators' forbearance might have contributed to the build up of financial sector risk. When safeguarding the financial stability moves into the spotlight and is tasked to central banks, this obligates central banks to actively monitor banks' risk-taking and include it in their policy functions.

within most DSGE models. Instead, financial intermediation was assumed to function without any frictions. When a financial market was incorporated into the model, the focus rested solely on the quantity rather than on the quality of intermediated credit.[6] Credit risk has been either largely absent or, if present, it has been incorporated in the spirit of a financial accelerator (Bernanke, Gertler & Gilchrist 1996).

Existing models that incorporate financial accelerator type credit risk are not suited to shed light on the bank risk-taking channel. Their predictions will namely differ, since the two types of risks point in opposite directions. When policy rates decrease, bank risk-taking increases. This is central to the bank risk-taking channel. This stands in sharp contrast to the predictions of the financial accelerator. Financial accelerator models predict that when policy rates increase, information asymmetries widen. When information asymmetries between lender and borrower widen, risk increases. The risk eventually provokes a flight-to-quality on the side of lenders.

Until now, there is only one DSGE model (Angeloni & Faia 2013, Angeloni, Faia & Lo Duca 2015) that incorporates a bank risk-taking channel. In this model, the microfoundations of bank risk-taking are solely based on an optimal leverage effect. A complete modeling of Dell'Ariccia, Laeven and Marquez's (2014) rationale in a general equilibrium context is missing. To fully incorporate the bank risk-taking channel a new model is needed.

The main goal of this paper is to incorporate a bank risk-taking channel in the spirit of Dell'Ariccia, Laeven and Marquez (2014) into a medium-scale DSGE model. In modeling the microeconomic foundations of bank risk-taking, the conditions in the banking market underlying the pass-through effect in particular need to be carefully modeled. Therefore, I draw on the advances made in modeling banking markets in extant DSGE models. I use the seminal Gerali et al. (2010) model as a foundation. This particular model already incorporates an elaborate banking market. However, it notably lacks a bank risk-taking channel. I thus extend the model to explicitly include endogenous bank monitoring. Similar to the theoretical foundations, banks weigh off the marginal benefits arising from monitoring with concomitant marginal cost increases. The proposed model will thus encompass all three effects underlying the bank risk-taking channel.

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[6] See the vast literature on the bank lending channel starting with, among others, Bernanke and Gertler (1995) and Kiyotaki and Moore (1997). These seminal papers have influenced DSGE modeling. Financial accelerator type banking market frictions were incorporated into DSGE models. An early example is Bernanke, Gertler and Gilchrist's (1998) general equilibrium model. More recent examples advance interest rate stickiness and intermediation margins based on banking market competition (Gerali, Neri, Sessa & Signoretti 2010, Hülsewig, Mayer & Wollmershäuser 2009).

My intent is to achieve the following: First, extend the Gerali et al. (2010) model for a bank risk-taking channel; second, show that the model performs correctly; and third highlight the extended model's potential for further research.

To do so, I follow a four-stage process. First, I collect new, narrative VAR evidence on the bank risk-taking channel. The evidence gathered serves as a reference for the DSGE's impulse-response functions (IRFs). In contrast to previous research of other researchers, I have chosen to incorporate measures of bank profitability into the VAR model. In doing so, I am able to investigate how bank profitability might be influenced by monetary policy and in turn might affect bank risk-taking. The results obtained will help to verify whether the IRFs of bank profitability and bank risk-taking to a monetary policy shock produced by my DSGE model resemble the patterns observed in the data. Thereby, I follow the conventional approach of using VAR evidence as a benchmark for DSGE models (Angeloni & Faia 2013).

In the second stage, I develop the DSGE model's microfoundations. I transfer the underlying rationales of Dell'Ariccia, Laeven and Marquez (2014) to a general equilibrium context. This extends the banking sector of the Gerali et al. (2010) model for an endogenous bank monitoring choice and reflects the major contribution of this paper.

In the third stage, I employ my DSGE model to conduct two stochastic policy experiments. I use a monetary policy and a total factor productivity (TFP) shock. The goal is to study how the adapted model propagates the shocks into output and inflation. I further aim to study the endogenous responses in bank risk-taking to the two shocks. In studying the responses in bank risk-taking, I compare the impulse-response functions produced by my DSGE model to the VAR evidence.

In the fourth stage, I create an exhibit that illustrates how the model can be used to understand the implications of the Dell'Ariccia, Laeven and Marquez's (2014) rationale in a general equilibrium context. More specifically, I use the DSGE model to shed light on a largely unresolved issue within the bank risk-taking channel literature. Due to the lack of sufficient data and models, previous analyses of the individual effects were more limited. I particularly focus on the pass-through effect and its determinant, i.e. banking market competition. Based on insights borrowed from the interest rate channel literature I am able to refine the assessment of the influence of banking market competition on the pass-through effect. I extend the rationale of the pass-through effect along two dimensions. First, banking market competition shapes how easily borrowers can switch between different banks. The elasticity of substitution determines the bank's mark-up on loans over the risk-free rate. Second, banking market conditions might result in interest rate stickiness. Sticky retail interest rates might alter the response in bank profitability in response to monetary policy shocks. By drawing on my DSGE model, it becomes possible to individually conduct policy experiments altering both characteristics of banking market competition. I then analyze the pass-through effect's influence on bank risk-taking after monetary policy shocks under different parameterizations capturing changes in the two characteristics of competition.

In my research, I focus on the Euro area. I do so for three reasons. First and foremost, bank intermediated credit is more important in Europe than in the US (Angeloni, Kashyap & Mojon 2003). A higher dependence on banks increases the dependence on a well-functioning and stable banking sector.[7] Second, focusing on the Euro area allows me to circumvent the additional complexities associated with prepayment risk for banks. Prepayment risk is namely more prominent in the US market. Third, the European Central Bank (ECB) is confronted with a heterogeneous set of banking markets. The heterogeneity necessitates to understand the different determinants of the bank risk-taking channel.

My VAR results confirm the patterns of the bank risk-taking channel suggested by Fig. 1.1. In response to monetary policy tightening, banks reduce their risk appetite for approximately one year. Interestingly, there is a relatively homogeneous picture that emerges from the cross-section of ten Euro Area countries. The responses in bank risk-taking are fairly alike given heterogeneously competitive banking markets in these countries. This calls for a better understanding of the pass-through effect. With an eye on the pivotal role attributed to bank margins in the theoretical considerations, my VAR evidence offers confirming insights. Banks' margins improve temporarily in response to tightening monetary policy. Also an innovation in bank profitability translates into a tightening of bank lending standards. Hence, bank risk-taking declines. Novel is the observation that an improvement in bank margins not only results in an initial reduction in bank risk-taking, but also results in a subsequent increase in bank risk-taking in excess of the initial level for the Euro area as a whole. In the cross-section of ten Euro area countries, not all countries exhibit the subsequent relaxation of bank lending standards in excess of the initial level. New but not unexpected is the following observation. Bank risk-taking is determined to a greater degree by banks' profitability on the average loan and to a lesser degree by banks' profitability on marginal lending activity. The suggestive VAR evidence also indicates that bank risk-taking bears economic consequences for

[7] Simultaneously, there is still observable fragility in the Euro area banking sector with regional heterogeneity (Blinder, Ehrmann, de Haan & Jansen 2017).

bank profitability and aggregate economic output. Bank profitability improves temporarily in response to tightening bank lending standards.[8] Real economic output contracts once bank lending standards tighten.

After developing the microfoundations of the model, I verify whether it matches stylized patterns in output and inflation in response to a monetary policy shock and a TFP shock. In response to a monetary policy shock, the model with an endogenous bank risk-taking channel is able to qualitatively replicate stylized responses in inflation and real output. The predicted response resembles the responses found in most economic models incorporating nominal rigidities. The introduction of a bank risk-taking channel attenuates the influence of the model's financial accelerator effects. Thus, the model correctly reflects the opposing directions of the financial accelerator and the bank risk-taking channel. The response in bank risk-taking reconfirms theoretical considerations as well as patterns observed in the VAR evidence. Monetary policy tightening increases bank monitoring. Thus, monetary policy tightening decreases bank risk-taking. The responses in bank monitoring produced by the DSGE model closely resemble the VAR estimates. My DSGE model exhibits the subsequent reversal of bank risk-taking shared by my VAR evidence. Overall, the model incorporates a well-functioning bank risk-taking channel.

The TFP shock experiment confirms my model's ability to match stylized patterns. Once again, the inclusion of a bank risk-taking channel attenuates financial accelerators already embedded in the model. The model preserves its ability to match stylized responses in real economic quantities. Bank risk-taking increases in response to a positive innovation in TFP.

Overall, the model successfully captures the stylized dynamics in real output, inflation and bank risk-taking. Changes in the propagation mechanism attributable to the introduction of endogenous bank risk-taking are reconcilable with the opposing forces of the bank risk-taking channel and financial accelerator effects. Relative to my VAR evidence, my model matches stylized patterns well. The proposed approach of integrating a bank risk-taking channel in the spirit of Dell'Ariccia, Laeven and Marquez (2014) into a general equilibrium model might be particularly useful for monetary policy makers trying to balance their mandates with financial sector stability.

Upon application, my model provides insights into how banking market competition influences bank risk-taking. The results indicate the following. First, changes in both characteristics of banking market competition (the elasticity of substitution and interest rate stickiness) exert comparably small

[8]This confirms, for instance, previous insights of Paligorova and Santos (2017), who showed that bank profitability responds to bank risk-taking.

influences on bank risk-taking. In a general equilibrium context, this can be explained as follows. Competition does not influence the pass-through effect in isolation. It also exerts compensating effects through the risk-shifting effect and through the optimal leverage effect. The influence of competition is asymmetrically stronger for loan markets to entrepreneurs than for loan markets for impatient households. Second, the two characteristics of competition result in opposing forces. In line with Dell'Ariccia, Laeven and Marquez (2014), higher competition manifesting in a higher elasticity of substitution will reinforce bank risk-taking through the pass through effect. On the other hand, stronger competition might reduce interest rate stickiness, which attenuates bank risk-taking. It is the individual market's environment which defines how competition manifests in the two characteristics. How strongly competition affects the elasticity of substitution relative to interest rate stickiness will thus determine the strength of the pass-through effect. The exhibit not only refines the Dell'Ariccia, Laeven and Marquez rationale of the pass-through effect, but also offers insights into the influence of banking market characteristics.

The insights generated by the application offer two complementary explanations for one of my VAR observations. In the VAR, there was a fairly homogeneous response of bank risk-taking in the cross-section of Euro area markets despite heterogeneously competitive banking markets. First, in a general equilibrium context, differences in competition that affect the pass-through effect will influence banks' retail rates. These changes have an influence on loan demand given a downward-sloping demand function. Changes in demand will shift the relative force of the risk-shifting effect through the optimal leverage effect. This balances the influence of the pass-through effect. Second, banking market competition exerts two influences on the pass-through effect via the elasticity of substitution and interest rate stickiness. Since both point into opposite directions, the cumulative effect on the pass-through effect depends on how differences in competition alter the the elasticity of substitution and interest rate stickiness. This influence will in turn depend on the environment of the banking market. Overall, the new insights provide an explanation for this particular observation.[9]

[9]These insights might also explain why the empirical relationship between monetary policy, bank profitability and bank risk (Martinez-Miera & Repullo 2010) is nonlinear. The extension of Dell'Ariccia, Laeven and Marquez's (2014) rationale is flexible enough to even provide a pass-through effect that might be locally declining around the current level of competition. Whether changes in competition will affect the elasticity of substitution or interest rate stickiness more heavily depends on environmental factors such as credit contracts in place, the legal framework or institutional characteristics of the banking market.

The report at hand is structured as follows. Chapter two provides further insights into previous research. It starts with a discussion of the Dell'Ariccia, Laeven and Marquez (2014) framework. Thereafter, the status quo of empirical research in the bank risk-taking channel and its incorporation in DSGE models is presented. Chapter three provides insights based on Vector Autoregression (VAR) models for the Euro area and ten individual Euro area members. The purpose is to sketch stylized facts that serve as a verification of the DSGE model. Chapter four represents the core of this paper. It develops my medium-scale DSGE model on the basis of Gerali et al.'s (2010) model. Chapter five investigates whether the model's responses to certain shocks qualitatively match stylized responses in real economic quantities and previously observed bank risk-taking behavior. In chapter six, I exhibit how banking market characteristics might affect the bank risk-taking channel through the subordinate pass-through effect. Chapter seven provides conclusions and a critical appraisal.

Chapter 2

Related Literature

The subsequent literature review is subdivided into two sections. In the first section, I provide an overview of the theoretical foundations (Dell'Ariccia, Laeven & Marquez 2014) of the bank risk-taking channel of monetary policy transmission.[1] Core to the bank risk-taking channel is the influence that monetary policy exerts on banks' margins. As monitoring is costly, higher margins incentify banks to increase monitoring. As will be shown, monetary policy transmission through the bank risk-taking channel is supposed to depend strongly on banks' environment in terms of banking market competition, limited liability and information asymmetries. The environment determines three partial effects through which monetary policy might influence bank margins. These three partial effects are the pass-through effect, risk-shifting effect, and optimal leverage effect. This discussion aims at providing a framework for the development of the DSGE model. The framework clarifies the microeconomic foundations of a bank risk-taking channel so that they can be incorporated within a general equilibrium context.

I then provide an overview of the evidence that supports the presence of a bank risk-taking channel in both a reduced form context as well as in a general equilibrium context. From this review, a gap becomes apparent. Although the general pattern of a bank risk-taking channel is indeed well documented in reduced form estimations, it is notably absent within a general equilibrium context. Moreover, evidence on the individual effects underlying the bank risk-taking channel is scarce. Likewise, the relevance of the different market conditions for bank risk-taking remains opaque.

[1] For a complete treatment of Dell'Ariccia, Laeven and Marquez (2014), the reader may refer to the original work. In this chapter, only an excerpt will be provided that replicates the aspects most relevant to the paper at hand.

2.1 A Theoretical Framework of Bank Risk-taking

Until now, various rationales for a bank risk-taking channel have been proposed.[2] Dell'Ariccia, Laeven and Marquez (2014) provide one of the most rigorous theoretical frameworks. This model's stylized banking sector rests on two assumptions. First, banks are granted limited liability protection. Banks invest into risky loan projects and bank entrepreneurs[3] are able to influence the riskiness of the bank's investments. Limited liability exposes uninsured depositors to bank risk. Second, monetary policy directly influences the interest rate on deposits. Depositors price deposits relative to the risk-free rate set by the monetary policy maker. These assumptions are introduced into a stylized partial equilibrium model. I replicate the model in parts below without becoming overly technical.[4]

To understand banks' behavior, the stylized environment will be reviewed first. Subsequently, banks' optimality conditions will be highlighted.

Banking market environment. Within Dell'Ariccia, Laeven and Marquez's (2014) model, banks issue loans to their borrowers. These loans represent the single bank's only asset type. Borrowers' demand for loans decreases in the retail interest rate on loans charged by the bank. The bank acts as a price setter in loan markets.

The loans issued to borrowers are generally risky and require bank monitoring. Otherwise, the borrower will not pay the principal and the interest to the bank. The bank's owner-manager can choose the level of monitoring. The monitoring effort exerted by the bank can be understood as the probability of the single bank's loan portfolio being repaid. The bank is endowed with a monitoring technology, which provokes increasing marginal costs in monitoring.

The bank does not hold sufficient capital to meet its loan demand. In order to service the loan demand, the bank capitalist must raise deposits and will invest all of the bank's capital. Thus, the bank's stylized balance sheet consists of one asset type, risky loans, and two types of liabilities, bank capital and deposits. The capital-ratio is defined as bank capital relative to the loan volume issued. Due to the balance sheet condition, the capital-ratio is the complement to the deposit-ratio. The bank entrepreneur's goal is to

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[2]See, among others, Rajan (2005) who provides an earlier treatment. However, his treatment is not as applicable to banks as it is to other financial intermediaries, such as pension funds. Thus, I focus on the Dell'Ariccia, Laeven and Marquez (2014) framework.

[3]The bank's owner is simultaneously the bank's manager.

[4]The reader interested in a more comprehensive treatment may refer to the original work or for selected formulas to the respective footnotes provided in this chapter.

maximize the bank's profits. In order to do so, the bank's entrepreneur can decide on the capital-ratio, the interest rate on loans, and the monitoring effort.

In the stylized world of Dell'Ariccia, Laeven and Marquez (2014), bank capitalists can choose the amount of bank capital freely. Banks are able to either redeem equity or raise equity without further costs.[5] However, equity requires an equity premium. This renders equity a relatively costly financing option. Since the bank's entrepreneur is simultaneously the bank manager, no information asymmetries occur. The entrepreneur directly observes the monitoring effort. However, the required return on equity will be priced over the risk-free rate.

Next to bank capital, the bank manager can finance the bank's activities by uninsured deposits.[6, 7] Limited liability protection granted to the bank exposes uninsured depositors to a risk. In the case that the bank's monitoring effort is not sufficiently high, the bank will default on its deposits without any recourse to the owner. Bank risk is decreasing in the degree of monitoring. Depositors require a compensation for the expected loss. Thus, the interest rate on deposits includes a risk-premium over the risk-free interest rate. Since the probability with which the bank will repay its deposits depends on the extent of monitoring, the risk-premium will decrease in bank

[5]This freedom to choose the capital-ratio appears to contradict prevailing bank regulation, which imposes minimum capital regulations. Dell'Ariccia, Laeven and Marquez defend their choice by two claims. First, in line with Peek and Rosengren (2005) and Huizinga and Laeven (2012), banks that are in close proximity to the regulatory capital constraint will defer the recognition of losses. This will overstate the capital-ratio. Second, Dell'Ariccia, Laeven and Marquez claim that the prevailing capital requirements (e.g. the Basel Accords) allow for regulatory arbitrage. Banks are allowed to save on capital while simultaneously permitting larger risks. From their perspective, both claims favor the treatment of the bank's capital-ratio as an endogenous choice variable. For the subsequent discussion of the Dell'Ariccia, Laeven and Marquez model, this assumption will be preserved. However, in my later work, I will replace the assumption.

[6]Although Dell'Ariccia, Laeven and Marquez (2014) consider a situation where banks may acquire a mixture of insured and uninsured deposits, I subsequently discuss only the special case where banks may exclusively raise uninsured deposits. The reader interested in a more elaborate treatment may refer to Dell'Ariccia, Laeven and Marquez (2014). However, also in their discussion of the model, they initially abstract from insured deposits for the sake of brevity and comprehendability.

[7]It may seem counterfactual to focus on uninsured deposits, since the literature of the preceding decades has taken deposit insurance as given. However, over the recent years the share of Repos and CDs in the banking system's funding mix has increased (Shin & Shin 2011). As these funding sources are not insured, the fraction of uninsured depositors to the banking system has increased as well. This has led to a shift in the emphasis placed on deposit insurance in the literature. In the subsequent treatment, the term deposits shall be interpreted as a synonym for banks' liabilities.

monitoring. Information asymmetries preclude that depositors observe the bank's monitoring choice directly. Instead, depositors render a zero-mean error estimate of banks' equilibrium monitoring behavior. They infer the equilibrium monitoring behavior from the bank's capital-ratio. Since depositors compare the expected return on their investment to the risk-free rate, the interest rate on deposits increases the higher the default probability of the bank is. Put differently, the lower the estimated monitoring effort of the bank, the higher will be the spread between the deposit rate and the risk-free rate.

Optimal bank behavior. Given the assumptions about banks' environment, the single bank's optimal choices can be considered. The bank capitalist will maximize the profit attributable to her. Once the risk-free interest rate has been set by the monetary policy maker, the bank entrepreneur observes the risk-free rate and then chooses the optimal capital-ratio for the bank. Depositors observe the capital-ratio and adjust their deposit rate accordingly. Based on the risk-free rate and the interest rate on deposits, banks then set the interest rate on their loans. Finally, the bank entrepreneur decides on the degree of monitoring effort.

Considering the profit maximization objective,[8] the bank manager chooses monitoring such that marginal benefits of increasing monitoring equals the attributable marginal costs. The bank capitalist decides on the level of monitoring within a conventional marginal cost / marginal benefit context.[9] The marginal benefit of increasing the bank's monitoring activity is reflected by the obtainable unitary gross margin on loans. The unitary gross margin on loans can be understood as the difference between the interest rate on loans

[8]The objective function can be shown to be

$$\Pi = \left[q \left(r_L - r_D \left(1 - k \right) \right) - \left(r^* + \xi \right) k - \frac{1}{2} c q^2 \right] L \left(r_L \right),$$

where Π reflects the bank's profits. The variables q, r_L and r_D reflect the level of monitoring, the interest rate on loans and the interest rate on deposits. The capital share is given by k. ξ represents the equity premium and r^* is the risk-free rate. The quadratic monitoring costs provoked by the monitoring technology are scaled by c. Finally, the loan volume demanded is given by the demand function $L \left(r_L \right)$.

[9]The resulting FOC of the bank in the stylized partial equilibrium context becomes

$$\widehat{q} = \min \left\{ \frac{r_L - r_D \left(1 - k \right)}{c}, 1 \right\},$$

where $\widehat{q}$, r_L, r_D, k, and c are the optimal choice of monitoring, the gross interest rates on loans, the gross interest rate on deposits, the capital-ratio, and the monitoring costs in Dell'Ariccia, Laeven and Marquez's terminology, respectively. The numerator reflects the marginal benefit of monitoring, whereas the denominator shows the marginal costs.

less the interest rate on deposits weighted by the deposit-ratio. The marginal benefit increases in the interest rate on loans, decreases in the interest rate on deposits and decreases in the deposit-ratio. Under constant marginal costs, an increasing gross margin obtainable (i.e. the marginal benefit) will incentify the bank capitalist to increase monitoring. The marginal costs of increasing the monitoring activity arise from the assumptions about banks' monitoring technology. Since the properties of the monitoring technology are exogenous to the bank manager's choice, the gross margin is of primary interest to understanding the bank risk-taking behavior.

The bank manager's choice of monitoring is generally bound. The maximum value for the bank's monitoring will be unity. This arises from two assumptions. First, loans cannot return more than the principal plus the contractually agreed interest rate to the bank. Second, monitoring reflects the probability of loans repaying. In the case of a monitoring choice of one, loans will be repaid with certainty. On the lower end, monitoring cannot fall below zero.

Dell'Ariccia, Laeven and Marquez (2014) reflect further on the determinants of the bank margin. This results in the three subordinate effects – the risk-shifting effect, the pass-through effect, and the optimal leverage effect. Each effect reflects one partial effect of how monetary policy decisions might affect the bank margin, which in turn determines the monitoring effort. The pass-through effect depicts the influence of monetary policy on the margin via its influence on the interest rate on loans. The risk-shifting effect reflects the partial effect that monetary policy decisions exert via the interest rate on deposits. Finally, the relative influence of the former two effects on the margin might be governed by the leverage choice of the bank (i.e. the optimal leverage effect), which is again influenced by monetary policy. Each will be examined in more detail below.

Risk-shifting effect. In order to understand a bank's monitoring decision, the various determinants of which the unitary gross margin is composed need to be individually considered. The unitary gross margin is the bank's revenue less of the costs attached to fractionally financing the dollar lent by deposits. The bank's costs increase as the interest rate on deposits increases. In consequence, the gross margin decreases, which in turn causes monitoring to decrease. In the choice of the bank's monitoring level, the bank entrepreneur takes into account the interest rate on deposits. As previously stated, depositors price deposits over the risk-free rate set by the monetary policy maker. Depositors' assessment of monitoring must be correct in equilibrium. Holding the risk premium constant, refinancing costs for the bank decrease as the risk-free rate decreases. Due to the increasing margin, banks monitor loans more.

Since the return on deposits is weighted by banks' deposit-ratio in the unitary gross margin, the choice of how much a given bank chooses to monitor depends on whether that given bank is leveraged or not leveraged. Leveraged banks aim to maximize the profit after servicing depositors. So the interest rate on deposits is relevant to the bank capitalist's choice of monitoring. In contrast, the interest rate on deposits does not exercise any influence on a purely equity-financed bank. In this case, the profitability attributable to shareholders is purely determined by the interest rate on loans.[10] Thus, monitoring solely depends on the revenue generated by the interest rate on loans. The choice of a purely equity financed bank coincides with the choice of a benevolent social planner. If a given equity-financed bank were now to up its leverage, the increased leverage would drive a wedge between the benevolent social planner's choice of monitoring and the bank manager's choice. As long as the interest rate on deposits is positive, a deposit-funded bank will undermonitor its loan portfolio. Leveraged banks will gamble for success. A risk-shifting effect arises as a second order agency conflict between depositors and bank capitalists. This risk-shifting effect increases in the monitoring costs, decreases in the capital-ratio and/or increases in the risk-free interest rate. In its spirit, the risk-shifting effect is similar to the initially cited financial accelerator (Bernanke et al. 1996, Bernanke & Gertler 1995) and to the risk-shifting effect documented in the literature on banking competition (Repullo 2004, Matutes & Vives 2000, Hellmann, Murdock & Stiglitz 2000). Overall, the risk-shifting effect underlying the bank risk-taking channel predicts that bank risk-taking will decrease if risk-free rates decrease.

Pass-through effect. The bank capitalist chooses the optimal interest rate on retail loans.[11] Dell'Ariccia, Laeven and Marquez (2014) show[12] the

[10]Dell'Ariccia, Laeven and Marquez (2014) show that the bank entrepreneur's optimality condition for monitoring $\hat{q}$ can be solved explicitly. For a leveraged bank, the optimality condition becomes $\hat{q} = \frac{1}{2c}\left(r_L + \sqrt{r_L^2 - 4cr^*(1-k)}\right)$, where c, r_L, k and r^* are the costs attributable to monitoring, the interest rate on loans, the capital ratio and the policy rate, respectively. In the purely equity financed case, where $k = 1$, the solution for optimal monitoring simplifies to $\hat{q}^{FB} = \frac{r_L}{c}$, as the second term under the root vanishes. Since the second term under the root is negative, deposit funding of banks will lead to lower monitoring.

[11]The bank entrepreneur's optimal choice of the interest rate on loans is characterized by $L(r_L)\frac{r_L - r_D(1-k)}{c} + \frac{\partial L(r_L)}{\partial r_L}\frac{(r_L - r_D(1-k))^2}{2c} - (r^* + \xi)\, k \frac{\partial L(r_L)}{\partial r_L} = 0$. Within the bank capitalist's decision how to set the interest rate on loans, the direct effect of an increase in the interest rate (the first term) on the bank's profitability is weight off with the indirect influence working through the elasticity of loan demand. The interest rate elasticity of loan demand influences the bank's profitability through its influence on the margin (second term) and the return on equity (third term).

[12]See their Lemma 1.

following. An increase in the risk-free rate will increase the opportunity costs to the bank attached to granting loans. Hence, an increase in the risk-free rate due to monetary policy tightening will increase the interest rate on loans. Increasing the interest rate on loans widens, ceteris paribus, the bank's gross margin, conditional on the loan portfolio being repaid. The higher margin in turn allows for a higher equilibrium monitoring effort. This marks the so-called pass-through effect subordinate to the bank risk-taking channel. As long as the increase in the interest rate on loans is larger than the increase in the interest rate on deposits, banks will be incentified by increasing margins to increase monitoring.[13] Overall, this effect is similar to the portfolio reallocation effects witnessed in the portfolio choice literature. How banks will be able to pass-through changes in the risk-free rate into loan rates depends on banking market competition.

The influence of the competitive landscape on the pass-through effect can be understood by considering two polar opposite cases. In the first case, a perfectly competitive market with atomic banks is considered. Each bank takes the interest rate on loans as given and generates zero profits. In the second case, a monopolistic bank faces an inelastic loan demand up to the reservation interest rate of its borrowers.

In the first case, any change in the risk-free rate will be passed-through immediately into retail loan rates because banks set the interest rates competitively. In this environment, borrowers can easily switch between different banks offering homogeneous loan products. This translates into a zero-profit condition on the side of banks. Competition will preclude any excess margins in the steady state and any interest rate smoothing on the side of the banks. In response to monetary policy tightening, the pass-through into retail loan interest rates will be instantaneous and perfect. Under perfect competition, the pass-through effect is at its maximum and the pass-through effect will dominate over the risk-shifting effect.

In the second case, the bank is a monopolist. Borrowers cannot switch between different banks. The bank will hold the interest rate on loans at the borrower's reservation loan rate. This shows that banks can reap a relatively larger margin in the steady state. The larger margin warrants higher monitoring independent from any changes in the risk-free rate. Assuming that the borrower's reservation loan rate does not respond to a change in the risk-free rate, the bank will keep the interest rate on loans constant even after an increase in the risk-free rate. In this case, the pass-through effect is at its minimum. Nonetheless, the costs to the bank will increase due to the risk-shifting effect. With constant revenues, margins will shrink in response to an

[13]See the discussion in Dell'Ariccia, Laeven and Marquez (2014) on p. 72.

increase in the risk-free rate. The monitoring effort will be reduced and bank risk-taking will in consequence increases. In this scenario, the risk-shifting effect dominates over the pass-through effect.[14]

The relative strength of the risk-shifting and pass-through effects will govern the bank's monitoring, i.e. bank risk-taking. From the previous discussion, it can be seen that the risk-shifting effect leads to an increase in monitoring in response to decreases in the risk-free rate. In opposite manner, the pass-through effect will result in a decrease in monitoring in response to an easing of monetary policy. The risk-shifting effect emerges from the liability side of banks' balance sheets and is intrinsically linked to assumptions about limited liability protection made at the outset of this section. The pass-through effect originates from the balance sheet's asset side and depends on the competition faced by banks. Consequently, the strength of market competition as well as limited liability protection together determine the relative strength of the two effects. Independent of any leverage choice of the bank, it is primarily the pass-through effect that provokes an increase in bank risk-taking in response to monetary policy easing. For given bank leverage, the pass-through effect must be stronger than the risk-shifting effect to provoke the observable pattern of the bank risk-taking channel. The leverage choice of the bank will tilt the relative influence of the two effects.

Optimal leverage effect. In the Dell'Ariccia, Laeven and Marquez (2014) world, the bank capitalist can choose the capital-ratio of the bank. The bank owner-manager will trade off two effects. On the one side, bank capital is relatively costly due to an equity premium. Holding more deposits will improve the return to shareholders as long as the marginal costs of financing via equity are higher. On the other side, an increase in the deposit ratio will result in an increasing risk-premium on deposits. This arises through depositors' information asymmetries. The bank will choose the deposit-ratio so that the marginal costs of both financing options are identical. Moreover, the following can be shown. Since the interest rate on loans and monitoring are increasing in the risk-free rate, the bank's deposit ratio will decrease in the risk-free rate. When the risk-free interest rate increases, agency problems between the bank and its depositors are exacerbated. This precludes leveraging up on the side of the bank. The optimal leverage effect shifts the influence of the risk-shifting effect.

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[14]However, the influence of banking market competition on banks' margins is likely less linear than suggested by the two polar extremes (Martinez-Miera & Repullo 2010) in reality. Hence, also bank risk-taking might not respond linearly to changes in risk-free rates.

Table 2.1: Expected Influences of Monetary Easing

	Direction of Influence						
	Risk-free rate	Deposit rate	Loan rate	Margin	Leverage	Monitoring	Risk
Pass-through effect	↓		↓	↓		↓	↑
Risk-shifting effect	↓	↓		↑		↑	↓
Optimal leverage effect	↓				↑		

Note: Table 2.1 presents a summary of the expected directions of the three effects constituting the bank risk-taking channel. Within each row, the individual channel's expected responses in the relevant variables to an expansionary monetary policy shock are depicted.

The discussion has shown the following. For a bank risk-taking channel to emerge, banks must be subject to an environment that meets the following conditions. First, banks need to be protected by limited liability. Second, competition determines the banks' ability to forward changes in the policy rate. Third, information asymmetries prevail between the bank and its depositors. Arising from these conditions, the bank risk-taking channel depends on three effects. The risk-shifting effect depends on the degree of limited liability protection. Tightening monetary policy depresses the bank's margin. This results from an increase in the costs attached to deposits. The pass-through effect depends on the degree of market competition. The more perfect the competition in the banking market, the more complete will be the pass-through of changes in the risk-free rate. Likewise, higher competition results in smaller margins that banks reap in the steady state. Focusing on these two effects alone, bank risk-taking arises primarily from the pass-through effect. Monetary policy easing results in declining margins through the pass-through effect, which results in lower bank monitoring. The risk-shifting effect partly compensates the pass-through effect by alleviating the cost burden. The optimal leverage effect determines the relative strength of the pass-through effect and risk-shifting effect at the border. Depending on changing environmental factors, cross-country differences and the competitive position of the individual bank, the influence of an otherwise homogeneous monetary policy impulse might lead to different responses in bank risk-taking. Table 2.1 summarizes these effects and their expected influence on bank risk-taking.

2.2 Evidence on the Risk-Taking Channel

Subsequent to the Financial Crisis and as concerns of banks' risk-taking behavior emerged, several studies have attempted to provide empirical insights into the bank risk-taking channel. Most of the reduced-form evidence gathered simply documents how risk-taking tends to increase when policy rates decrease. A considerably smaller fraction of the research has tried to identify cross-sectional differences in bank risk-taking behavior. Likewise, general equilibrium applications of a bank risk-taking channel are seldom. I will review the reduced form evidence and its inherent problems first. Subsequently, I will briefly highlight the progress made in terms of general equilibrium applications.

From an empirical perspective, translating the concepts presented in Dell'Ariccia, Laeven and Marquez (2014) poses challenges. These might arise for two reasons. First, even though the previously used notion of bank monitoring has some intuitive appeal, the literature on banks as delegate monitors[15] reveals that monitoring can be interpreted in at least three distinct ways (Hellwig 1991). Monitoring by banks is characterized by:

- a *screening function* prior to the allocation of loans to mitigate adverse selection problems (Broecker 1990),
- a *preventing function* to limit borrowers' opportunistic behavior after the allocation of the loan to the individual borrower and to limit moral hazard problems between the bank and the borrower (Holmstrom & Tirole 1997), and
- an either *punishing* (Diamond 1984) or *auditing role* (Gale & Hellwig 1985, Krasa & Villamil 1992), which becomes relevant once a borrower defaults on the loan in an environment of costly state verification (CSV) (Townsend 1979).

This multiplicity of interpretations complicates the choice of suitable proxies to measure the latent variable "bank monitoring". This applies especially to reduced form estimation. In most cases, the latter two connotations are more opaque and cannot be observed by an outsider to the bank.[16] Consequently,

[15] For a detailed review, see Freixas and Rochet (2008).

[16] The opaqueness and multiplicity of interpretations attached to bank monitoring will become relevant in the context of the approach towards simulating the DSGE model.

most of the evidence has relied on the screening function. Researchers have primarily drawn on survey-based proxies of banks' lending standards in the spirit of Lown and Morgan (2006).[17] Drawing on bank lending standards as a proxy for banks' monitoring activities assumes that the other two latent variables are positively correlated with the proxy for monitoring. However, lagging or leading effects might arise between the different interpretations of monitoring.[18]

Besides the inherent problem of identifying a reliable proxy for bank risk-taking, empirical studies are confronted with a second challenge. In most cases, data is scarce.[19] This especially applies to disaggregate data for individual banks or borrowers, but also holds for aggregate data. By now, there are some papers drawing on disaggregate data on banks (Delis & Kouretas 2011, Dell'Ariccia, Laeven & Suarez 2017, Maddaloni & Peydro 2011) or loans (Ioannidou, Ongena & Peydro 2009, Jiménez, Ongena, Peydro & Saurina 2014). The data originates either from confidential filings with the central bank or from credit registries. However, most of the evidence remained on an aggregate level.

In reduced form estimation, a large fraction of the effort has been devoted to quantifying the negative relationship between the central bank's policy instrument and bank risk-taking. Overall, the evidence for the US (Dell'Ariccia et al. 2014, Buch et al. 2014, Paligorova & Santos 2017) speaks in favor of a significant influence of monetary policy on bank risk-taking. Supporting evidence has been found for the Euro area as well (Altunbas et al. 2010, Delis & Kouretas 2011, Jiménez et al. 2014, Maddaloni & Peydro 2011). This can be interpreted in the light of the Dell'Ariccia, Laeven and Marquez (2014) framework as a dominant pass-through effect (potentially supported by the optimum leverage effect). Overall, the bank risk-taking channel's pattern as sketched in the introduction is well-documented in the literature. However, Dell'Ariccia, Laeven and Marquez (2014) document a break-down of this negative relationship during the US banking crisis (2007 Q3 to 2009 Q3) for the US banking market.

Dedicated evidence on the effects subordinate to the bank risk-taking

[17]Only to a lesser extent, banks' default probabilities provided by rating agencies (Altunbas et al. 2010) have been used.

[18]It is perceivable that bank lending-standards react more instantaneously to a monetary policy shock than, for instance, measures of banks' auditing role, as the latter are generally considered to be ex-post monitoring functions, which require a previous default of the borrower. Since the default in itself might be delayed, the necessary auditing is also delayed.

[19]Central banks have started to collect data on bank risk-taking only several years ago (e.g. the ECB has started to publish the BLSS in 2003).

channel is scarce. This arises primarily from the aforementioned scarcity of data. With regards to the pass-through effect, bank size, industry concentration and more indirectly bank margins have been used in the bank risk-taking literature. Buch, Eickmeier and Pietro (2014) show that larger banks in the US do not exhibit a risk-taking pattern. Contrarily, small banks do. This observation may be interpreted in favor of a dominant pass-through effect and as an indication that the competitive position of the bank might influence risk-taking.[20] In most studies, proxies for industry concentration (Delis & Kouretas 2011, Ioannidou et al. 2009) play a subordinate role as a control variable. They are largely unable to offer conclusive insights into the functioning of the pass-through effect. An explicit incorporation of banks' margins into econometric models is mostly absent. An exemption is the paper of Paligorova and Santos (2017). They show that banks that are generally more lenient in granting loans lower spreads in response to expansionary monetary policy and offer loans at generally lower spreads than their peers do. Even though the paper contains a measure of spreads, the underlying causality is inverted. Bank lending standards are expected to cause spreads in this paper and not vice versa.

Turning to the risk-shifting and optimum leverage effects, additional empirical evidence has been gathered. Focusing on bank's leverage, conflicting evidence on the cross-sectional role of the influence of leverage on bank risk-taking is contributed by Dell'Ariccia, Laeven and Suarez (2017) in the US and Jimenez et al. (2014) for the Euro area. Jimenez et al.'s results support the claim of the Dell'Ariccia, Laeven and Marquez (2014) framework in so far as increasing bank deposit-ratios reinforce risk-taking. Dell'Ariccia, Laeven and Suarez find that especially well-capitalized banks increase their risk-taking once policy rates decrease.

To conclude, the risk-taking channel with its predicted increase in bank risk-taking under expansionary monetary policy appears to be a well established regularity for most periods in the reduced form literature. How the subordinate effects and different characteristics of banking markets contribute to the bank risk-taking channel is less understood from an empirical

[20]Under the assumption that market power increases with bank size, smaller banks will be exposed more heavily to the need of shifting more towards risky portfolios after the policy rate has been decreased. Thus, the larger the bank, the more it can insulate the loan portfolio against the influence of the pass-through effect and the more the risk-shifting effect dominates. There is a potentially rivaling explanation. Multinational banks might also be able to insulate their portfolios by a more diversified refinancing structure against monetary policy decisions. However, due to the fact that also foreign banks exhibit a risk-taking pattern, this is less likely. But, the ceteris paribus influence of the pass-through effect remains opaque.

perspective. Table 2.2 provides further insights into the different econometric approaches, variables and time frames analyzed by the various authors discussed above.

Most of the evidence gathered so far remains purely reduced form evidence. There is, to my best knowledge, only one general equilibrium model that entails a notion of bank risk-taking to date (Angeloni & Faia 2013, Angeloni et al. 2015). However, the model takes a different approach towards modeling bank risk-taking than the theoretical framework presented before.

By critically reviewing Angeloni and Faia's (2013) and Angeloni, Faia and Lo Duca's (2015) microeconomic foundations of the model, it can be shown that the responses in banks' risk-taking exclusively work through an increase in bank leverage (i.e. the optimal leverage effect). Two assumptions preclude the presence of a pass-through effect and a risk-shifting effect. First, Angeloni and Faia (2013) and Angeloni, Faia and Lo Duca (2015) assume that the bank manager maximizes the combined return to bank capitalists and depositors. This stands in stark contrast to the profit maximization objective of Dell'Ariccia, Laeven and Marquez (2014). The assumption precludes an agency conflict between bank capitalists and depositors. The choice resembles the one of a benevolent social planner. Thus, the risk-shifting effect does not exist in the model. Likewise, the bank is expected to issue loans at the borrowers' reservation loan rate.[21] The resulting change in the interest rate on loans originates purely from the borrowers' side (i.e. via a change in the reservation loan rate). An explicit treatment of banking market competition, as it has been integrated in other models (Gerali et al. 2010, Hristov, Hülsewig & Wollmershäuser 2014, Hülsewig et al. 2009), is not given. So, the model does not allow for an adequate treatment of the bank risk-taking channel in the spirit of Dell'Ariccia, Laeven and Marquez (2014).

As a result, the current stance of DSGE models does not provide a direct transfer of the theoretical considerations of Dell'Ariccia, Laeven and Marquez (2014). Only an optimal leverage effect is incorporated, as of yet. This, in turn, does not allow for a dedicated review of the individual effect's influence on the bank risk-taking channel. The pure reliance on the optimal leverage effect might distort the responses to various shocks predicted by the model.

[21]In this context, the real gross return on capital of a fully leveraged capital producer.

Table 2.2: Approaches Used in the Empirical Risk-Taking Channel Literature

Author	**Data**	**Timeframe**	**Econometric Approach**	**Bank risk measure**	**Monetrary policy proxy**	**Control variables**				
						Bank-specific	**Regulatory**	**Socio-economic**	**Borrower-specific**	**Loan-specific**
Altunbas, Gambacorta and Marques-Ibanez (2010)	Euro area bank data	1999-2005	Panel regression	Loan loss provisions over loan volume, 1-year expected default frequency	3M EURIBOR	Residential lending volume, log of total assets, liquid assets to total assets, capital-ratio	None	nominal GDP growth rate	None	None
Buch, Eickmeier and Pietro (2014)	US aggregate bank data	1997 - 2008	FAVAR	US Terms of Business Lending Survey	Effective Federal Funds rate	Gross new loan volume, 4 bank size categories	None	GDP growth rate, GDP deflator	None	4 Loan risk categories
Delis and Kouretas (2011)	Euro area disaggregate bank data	2001 - 2008	Panel regression	Risk assets to total assets, non-performing loans to total loan volume	Various interest rates (3M average interbank rate, 10y T-Bond yield, ECB policy rate)	Time-trend, equity ratio, pre-tax profits to total assets, log of total assets, total revenue to total expenses, off-balance sheet items to total assets	Capital stringency index, bank regulator's power index, disclosure enforcement index	GDP growth rate, importance of banking sector, bank industry concentration	None	None

Author	**Data**	**Timeframe**	**Econometric Approach**	**Bank risk measure**	**Monetrary policy proxy**	**Control variables**				
						Bank-specific	**Regulatory**	**Socio-economic**	**Borrower-specific**	**Loan-specific**
Dell'Ariccia, Laeven and Marquez (2014)	US aggregate bank data	1997Q2 - 2009Q3	Simple correlations	US Terms of Business Lending Survey	3M average effective Federal Funds rate adjusted for 3M average consumer price inflation (CPI)	None	None	None	None	None
Dell'Ariccia, Laeven and Suarez (2017)	US disaggregate bank data	1997Q2 - 2011Q4	Panel regression	Terms of Business Lending Survey	3M ave. Federal Funds rate, 1Y Treasury yield, term spread, Taylor rule residuals	Tier-1 capital-ratio, equity-to-asset, total assets, net income-to-assets, liquid assets to assets, short-term deposits to deposits, non-retail deposits to deposits, loans to assets, C&I loans to loans	None	State-level: income growth, change in CPI, state unemployment rate, change in housing prices, National: Federal funds rate, real GDP, NBER cycles	None	Risk-rating, loan size, loan spread, collateralization, loan maturity

Author	Data	Timeframe	Econometric Approach	Bank risk measure	Monetrary policy proxy	Control variables				
						Bank-specific	Regulatory	Socio-economic	Borrower-specific	Loan-specific
English, van den Heuvel and Zakrajsek (2018)	High-frequency US bank stock market data	1997Q3 - 2007 Q3	Regression analysis	High-frequency stock market data of US BHC in a 2h window surrounding FOMC decisions	Bernanke and Kuttner's (2005) monetary policy surprise measure, term spread surprise in slope and levels	Asset-liability maturity mismatch, core deposits, loans to total assets, log of total assets, market leverage, usage of interest rate derivatives	None	None	None	None
Ioannidou, Ongena and Peydro (2009)	Bolivian banks	1999-2003	Regression analysis	Time to default of loan	Federal Funds rate	Log of total assets, liquidity ratio, foreign funding ratio, equity ratio, loan volume to total assets, non-performing loans ratio	None	Concentration of banking market (HHI), GDP growth rate in Bolivia, CPI in Bolivia, CPI in US, country risk rating of Bolivia	Legal form, industry sector, volume of outstanding bank debt, multiple-bank relations, main-bank relation, previous business relations	Amount, interest rate, collateral, maturity and loan type

Author	**Data**	**Timeframe**	**Econometric Approach**	**Bank risk measure**	**Monetrary policy proxy**	**Control variables**				
						Bank-specific	**Regulatory**	**Socio-economic**	**Borrower-specific**	**Loan-specific**
Jimenez et al. (2014)	Spanish credit registry data	2002-2008	Panel type-2 Tobit model	Probability of receiving a loan, loan volume granted, future default probability, percentage of uncollateralized debt	Overnight rate	Bank capital-ratio, log of bank capital, log of total assets, liquidity ratio, return on assets, non-performing loans ratio, commercial and savings bank dummies	None	GDP growth rate, CPI	Firm credit risk at horizons between 1 to 5 years	cf. Bank risk measures
Maddaloni and Peydro (2011)	Disaggregate Euro area BLS data and aggregate US SLOOS data	BLS: 2002Q4 - 2008Q3 SLOOS: 1991Q2 - 2008Q3	Panel regression	BLS and SLOOS	EONIA, Federal Funds Overnight Rate, Taylor-rule residuals, periods low monetary policy	None	Capital stringency index, securitization regulation	Inflation, GDP growth, 10Y Treasury rate	None	None

Author	Data	Timeframe	Econometric Approach	Bank risk measure	Monetrary policy proxy	Control variables				
						Bank-specific	Regulatory	Socio-economic	Borrower-specific	Loan-specific
Paligorova and Santos (2017)	US disaggregate bank data	1990 - 2008	Two-step Probit	Senior Loan Officer Opinion Survey	Change in the level of Federal Funds target rate, Romer and Romer (2004) narrative proxy	Bank's size (log of total assets), return on assets, volatility of return on assets, net loan charge-offs, capital-to-asset ratio, liquidity, subordinated debt to total assets	None	Quarterly GDP growth rate, VIX, yield spread, slope of yield curve	Structural distance to default, financial distress proxy, Z-score, log of sales revenue, interest coverage, tangible assets to total assets, advertising expenses to sales, R&D expenses to sales, market-to-book value	Dividend payout restriction, strength of collateralization, loan maturity, size, purpose, syndication, and retained share with the bank in case of syndication

Note: Table 2.2 presents an overview over the main papers contributing to the risk-taking channel. Next to the basic bibliographic information, it also sheds light on the economic approach, the proxies for bank risk-taking, monetary policy and potential control variables used for bank specifics, regulatory, soco-economic, borrower and loan specific circumstances.

2.3 Interim Conclusions and Theoretical Implications

Starting from the stylized evidence on banks' risk-taking behavior provided in the introduction, this chapter has explored the rationale of Dell'Ariccia, Laeven and Marquez's (2014) partial equilibrium model. The model illustrates the microeconomic foundations necessary for a bank risk-taking channel. Subsequently, the current stance of empirical research concerning the bank risk-taking channel has been reviewed and contrasted with the rationales of the theory. This has been done in terms of reduced form evidence and general equilibrium modeling.

More precisely, it has been shown that there are strong theoretical arguments in favor of a bank risk-taking channel (Dell'Ariccia et al. 2014), which are grounded on three intertwined effects, a risk-shifting effect, a pass-through effect, and an optimum leverage effect. Each of the effects subordinate to the bank risk-taking channel captures one partial influence that monetary policy exerts on the bank margin. Since banks are incentified by the margin to monitor, higher margins lower bank risk-taking. Bank margins are determined by the interest rate on loans, the interest rate on deposits and the deposit ratio in the bank's financing mix. The pass-through effect predicts that monetary policy easing results in a decrease of the retail rates on loans. This decreases the banks' margins obtainable through reduced revenues. The strength of the pass-through effect depends on banking market competition. In the original work, two polar opposite cases are considered to illustrate that the pass-through effect becomes stronger in more competitive markets. The risk-shifting effect is a compensating effect. A decrease in the policy instrument reduces the interest rate payable on deposits. The reduction in banks' fractional funding costs through deposits increases the intermediation margin. The risk-shifting effect depends on the degree of limited liability protection granted to banks. Banks are endowed with a monitoring technology, which provokes increasing marginal costs. Higher degrees of monitoring reduces bank risk. If banks' margins increase, a higher monitoring level can be afforded and bank risk is decreased. Among the two aforementioned effects, it is the pass-through effect that introduces the increase in risk-taking in response to monetary policy easing in the absence of an endogenous leverage choice of the bank. The optimal leverage effect is an accelerator that shifts the relative strength of the two other effects. In the original work, the optimal leverage effect is defended on the grounds of an equity premium in combination with information asymmetries between the bank and its uninsured depositors. The information asymmetries preclude a direct assessment of bank risk by depositors. Instead, depositors infer the monitoring effort from the bank's deposit ratio. As the risk-shifting effect dictates a divergence of the monitoring choice of a leveraged bank from an unleveraged counterpart, depositors' risk increases if the share of deposits increases. This will increase the risk-premium. Eventually, the bank manager knows that lower than optimal leverage will increase funding costs due to relatively costly bank capital. Likewise, higher than optimal leverage will exacerbate funding costs due to an increase in the risk-premium. Were this not so, the bank would tend to leverage up more excessively.[22] This eventually curbs the strength of the risk-shifting effect.

From an empirical perspective, most of the attention has been devoted to documenting the overall relationship between monetary policy easing and bank risk-taking. Consensus holds that bank risk is negatively correlated to the level of the monetary policy instrument. The individual effects underlying the bank risk-taking channel have been analyzed to a lesser extent. Even though some researchers have conducted analyses of cross-sectional differences in bank risk-taking behaviors, the methodological approaches or data availability preclude further insights. Most of the evidence so far is purely of reduced form. A complete incorporation of the bank risk-taking channel in the spirit of Dell'Ariccia, Laeven and Marquez (2014) in a general equilibrium context is missing.

The only DSGE model (Angeloni & Faia 2013, Angeloni et al. 2015) that incorporates endogenous bank risk draws on the optimal leverage effect. It is silent about the the risk-shifting and pass-through effects due to its microeconomic foundations. The exclusive focus on the optimal leverage effect may eventually distort the assessment of bank risk-taking. Ultimately, the adequacy of monetary policy makers' responses to shocks might be distorted. This highlights that further DSGE modeling is necessary for central banks. But also from an academic perspective, these models can help to shed light on the determinants and relevance of the effects subordinate to the bank risk-taking channel.

[22] A similar optimality condition can be reached if the bank is subject to an equity premium and a regulator, who will impose a punishment if an exogenous capital-ratio target is violated. A change of the capital-ratio above the exogenous capital-ratio target (i.e. too low leverage) would increase funding costs if equity were more costly than deposits. An decrease of the capital-ratio below the capital-ratio target would also result in an increase in financing costs through the regulator's intervention.

Chapter 3

Stylized Facts and VAR Evidence

Within the subsequent chapter, I provide novel, however, suggestive evidence that serves as a preliminary analysis for the DSGE model developed in chapter four. As the previous chapter has pointed out, core to the bank risk-taking channel is the response of banks' margins to an innovation in the policy rate. The change in the bank margin triggered by the monetary policy decision is the cumulative result of the pass-through effect, risk-shifting effect, and optimal leverage effect. If bank margins decrease in response to monetary policy easing, banks will reduce costly monitoring and will, thus, increase risk-taking. However, the previous literature has largely neglected bank margins in reduced form estimation. As a consequence, there is little empirical guidance for the assessment whether the DSGE model's dynamics in the responses of bank profitability and risk-taking match stylized patterns observable in the data given the chosen microeconomic foundations and parameter values of the model.

This chapter sets out to close this gap by providing the necessary stylized evidence in the form of VAR IRFs. The IRFs produced by the VAR estimation will serve as a comparable to the IRFs of the DSGE model.[1] In drawing on the VAR IRFs as a comparison, I follow one of the most widely used

[1]While reduced form estimation and especially VARs can provide better forecasting performance (Greene 2017) than large scale Keynesian type models in the tradition of Klein (1950), they are atheoretical. Thus, they are subject to the Lucas (1976) critique and not suited for policy analysis. On the contrary, micoreconomically founded DSGE models are well suited for policy analysis, but DSGE models require a benchmark against which their results (primarily in the form of impulse-response function (IRF)) can be assessed. One way of creating means of comparison is by drawing on VAR models. These models are particularly suited for this task since they provide comparable IRFs.

approach (Angeloni & Faia 2013, Angeloni et al. 2015, Hülsewig et al. 2009) in DSGE model development.[2] Due to the purpose of the exercise, I focus primarily on the IRFs of the VAR.[3]

Relative to previous reduced form evidence, my contribution focuses on proxies for bank margins in the context of VAR estimation. The existing reduced form evidence documents the regularity of increasing risk in response to monetary policy easing. However, it fails to provide richer insights into the transmission of monetary policy impulses through the bank risk-taking channel. The role of bank margins in the bank risk-taking channel remains opaque. This is noteworthy as bank margins play a determining role in the theoretical underpinnings. In previous studies, banks' profitability is either excluded from the analysis or is expected to be explained by bank risk-taking. Dell'Ariccia, Laeven and Marquez (2014) suggests the opposite. Thus, the existing reduced form evidence offers only indirect evidence of the theoretical considerations. By putting emphasis on the margins, I can provide additional insights in how far bank margins react to monetary policy decisions and in how far bank risk-taking responds to changes in banks' margins as suggested by the theoretical considerations. These insights are also relevant in the context of assessing whether the DSGE model is able to replicate these stylized patterns.

Unfortunately, a challenge rests in operationalizing the two latent variables bank profitability and bank monitoring. On top of that, limited data availability imposes restrictions on the estimation of reduced form models. This is especially important for the transmission from policy rates into bank margins. Ideally, one would disentangle the margin into its individual con-

[2]There are generally different approaches towards parameterizing a DSGE model. One approach uses Bayesian inference to estimate the model's parameters based on underlying data. In order to use Bayesian inference for model parameterization, data on bank monitoring would be necessary. As the discussion of chapter two has already indicated, bank monitoring is a multilayered concept (Hellwig 1991). While data on the screening function (Broecker 1990) is available in the form of BLS, data on the preventing (Holmstrom & Tirole 1997), punishing (Diamond 1984) and auditing (Gale & Hellwig 1985, Krasa & Villamil 1992) functions are not readily available. This data scarcity does not allow for a conversion into a comparable variable capturing the probability of loan repayment that could serve as data on which a Bayesian DSGE estimation could be conducted. The other popular approach towards parameterizing the model is that the parameter values are chosen in such a way that the resulting characteristics of the model resemble characteristics observed in the economy (e.g. parameters governing price stickiness are chosen in such a way that the expected duration for which a price holds is similar to the estimates in the data). Subsequently, the resulting IRFs of the DSGE are compared to a VAR comparable. In the later parameterization (cf. ch. 4.3), I follow the second approach.

[3]I disregard further analyses focusing on, for instance, variance decomposition, shock identification or tests of Granger causality.

stituents to shed further light on the three subordinate effects. However, this is impossible for two reasons. First, data on individual retail rates are largely unavailable. Second, even if data on individual retail rates were available, bank risk proxies are available only for a short time frame. This would severely limit the number of variables that can be included into a model.

Overall, I segregate the analysis into two parts. One part focuses on aggregate Euro area data. A second part depicts potentially heterogeneous reactions in the cross-section of ten Euro area countries. This latter part may shed light on the influence of different market conditions in terms of competition.

To shed light on the role of bank margins, I employ different proxies. For the aggregate Euro area, I employ three different proxies for bank margins. Each proxy is intended to capture a different effect in the margin. One distinction that can be drawn is by considering the influence of monetary policy decisions on banks' margin on the portfolio of all loans in contrast to the margin obtainable on the marginal loan. A second distinction concerns the degree to which banks' cost structure responds instantaneously to changes in the policy rate. The theoretical considerations implicitly assumed that interest rates on deposits react instantaneously and fully to policy rate changes. This assumption might be violated. For instance, banks may issue deposits with agreed maturity and fixed interest rates longer than the stylized one-period deposit. Alternatively, adjustment costs for interest rates on deposits may exist. As a result, the banks' costs might not react immediately to policy rate changes.

Thus, the following two distinctions are obtained. First, the influence of monetary policy decisions on banks' margin on the portfolio of all loans is in contradistinction to the margin obtainable on the marginal loan. Second, one must distinguish the degree to which banks' cost structure responds instantaneously to changes in the policy rate.

In the second part, I use ten Euro area countries as exhibits for varying degrees of market competition. I embed my evidence within the extant evidence brought forth from the interest rate channel literature (Leroy & Lucotte 2015, van Leuvensteijn, Kok Sørensen, Bikker & van Rixtel 2013).[4]

[4]The interest rate channel literature has been developed in isolation to the bank risk-taking channel. The interest rate channel literature considers the pass-through from policy rates into retail rates, as the latter might affect the marginal rate of substitution of households. In this stream of the literature, the stickiness and completeness with which retail rates in loan and deposit markets respond to a monetary policy shock are considered. Moreover, imperfect competition has been considered as an amplification mechanism. Overall, the pass-through in the interest rate channel literature depends on the competition in banking markets. More competitive markets are expected to exhibit a

I do so to factor in the degree of competition in the cross-section of banking markets.

Before discussing the VAR evidence in greater detail, I provide a short overview concerning methodology applied and data sources used. I conclude this chapter by identifying patterns which serve as a benchmark for the subsequent policy experiments of chapters 5 and 6.

3.1 Methodology and Data

Within the subsequent analysis, I draw on a standard, orthogonalized vector autoregression approach, which was popularized in economics by Sims (1980) and is similar to the applications in Christiano et al. (1999) and Faust et al. (2004). The lag length included in the respective VAR is set in compliance with the Akaike (1974) and Schwarz Bayesian (1978) information criteria. On the one side, the Akaike Information Criterion (AIC) is not consistent but more efficient (Brooks 2008). On the other side, the Schwarz Bayesian Information Criterion (SBIC) is consistent but not efficient. I follow the SBIC in the case that the two information criteria yield conflicting indications of the optimal lag length. Overall, I attempt to formulate parsimonious specifications preserving degrees of freedom given the limited sample size available.

The respective VAR models are estimated on quarterly Euro area data. For aggregate Euro area data, they are of changing composition. As most of the time-series are only available from 2003 onward, I restrict the number of endogenous variables to four. The choice of the variables reflects the desire to capture primarily the dynamics of bank risk-taking in dependence on the banks' margins.

Subsequently, I will first delineate the variables used on an aggregate Euro area level and thereafter those on an individual country basis.

Aggregate Euro Area Data. The variables included for the Euro area as a whole consist of a measure of seasonally adjusted real economic output growth (LOG_REAL_GDP), which is obtained for the Euro area from Eurostat.[5] My proxy for the monetary policy instrument is represented by the quarterly average of the Euro Over Night Index Average (EONIA) obtained

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more complete and faster pass-through as well as smaller mark-ups over the risk-free rate. The bank risk-taking channel literature in the sense of Dell'Ariccia, Laeven and Marquez (2014) primarily relates to the notion of mark-ups. In parallel, competition determines the degree to which policy impulses affect the retail rate and, thereby, the bank's revenue. In the interest rate channel literature, the influence of monetary policy decisions on banks' revenue is ignored as only the influence on the retail loan rates is considered.

[5]Appendix A depicts the data sources and codes used to retrieve the data.

from the ECB. This is similar to Maddaloni and Peydro (2011) and Jimenez et al. (2014). In line with, among others, Maddaloni and Peydro (2011), I measure the banks' risk-taking behavior by the net-percentage of banks tightening their lending standards originating from the ECB's bank lending standards survey (BLSS).[6]

In order to capture the influence of monetary policy on banks' profitability and in turn the influence of banks' profitability on risk-taking as indicated by Dell'Ariccia, Laeven and Marquez (2014), I employ three novel[7] measures. These are: (i) the spread between banks' average interest rate on their loan portfolio holdings and EONIA (hereafter, spread over EONIA, the variable nomenclature is SPREAD_EONIA), (ii) the spread between banks' average interest rate on their loan portfolio holdings and the average interest rate paid on deposits either with an agreed maturity or callable on notice (hereafter, spread over deposits, the variable nomenclature is SPREAD_DEP), and (iii) the banks' self-reported margin on their newly issued loans (hereafter, new loan margin, the variable nomenclature is BANK_MARGIN). These proxies can all be reliably calculated on an aggregate Euro area basis.

The first two proxies intend to provide an insight into the pass-through effect exerted by banks' overall profitability of their portfolio of assets and liabilities. In the formulation of the first proxy (spread over EONIA), I use the spread between banks' weighted-average annualized interest rate on loans and EONIA. In the calculation, the weighting is attributed to the respective interest rate by the total loan volumes outstanding at the end of the period to households and non-financial institutions relative to the total loan volume outstanding. The data on interest rates on loans and loan volumes are retrieved from the Monetary Financial Institutions (MFI) dataset of the ECB and are transformed to quarterly averages.

The second measure (spread over deposits) uses the same proxy of banks' returns but considers banks' liability structure in greater detail in the calculation of the spread. The former measure follows the considerations of Dell'Ariccia, Laeven and Marquez (2014) closely by assuming that policy rate changes (EONIA) transmit fully and instantaneously into banks' cost of

[6]Note that the questionnaire used for the BLSS has been revised in 2014. Data on credit standards applicable to households became effectively available from 2015 onward. Since my data set covers to a large extent a time frame before 2015, I impose the assumption that the banks' lending standards for loans to enterprises adequately reflect overall bank risk-taking. Thus, I use the bank lending standards for loans to enterprises, which are available for the whole time frame, as a measure of bank risk-taking. This is an assumption that is also shared by the studies drawing on the BLS cited in chapter two.

[7]Novel shall be understood in the sense that the respective variables are newly constructed and have not been used in this context before.

deposits. The existence of deposits with longer maturities and fixed interest rates might lead to a wedge in banks' costs relative to Dell'Ariccia, Laeven and Marquez. Thus, I attempt to reflect the influence of banks' liabilities composition in the calculation of the second profitability proxy. In this case, I calculate the spread over a weighted average reflecting the interest burden on callable deposits and deposits with agreed maturity. For callable deposits, I assume that EONIA will be paid. For deposits with an agreed maturity, the weighted average of annualized agreed rates is used. The weights assigned to the two components are given by the amounts of deposits callable on notice and the amount of deposits with agreed maturities outstanding at the end of the quarter. Each series is once again averaged over the quarter to match the frequencies obtainable from the BLSS and macroeconomic data. The data on the volumes and interest rates applicable on the banks' liability side originate from the ECB's Balance Sheet Items (BSI) data set.

As a third measure (new loan margin) and in order to measure the banks' profitability at the margin, I create a weighted average of the bank lending margin on new loans to non-financial firms and households.[8] The data are available only as disaggregate, national data for monetary union member countries from the ECB's MFI Interest Rate Statistics (MIR) dataset at a monthly basis. I transform the data first on a national level to obtain quarterly averages. Subsequently, I create a weighted average to reflect the lending margin for the Euro area. The weight attributed to the individual national time series is based on the respective banking market's size. The market size is proxied by the total loan volume outstanding at the end of the respective quarter. Data are obtained from the ECB's Risk Assessment Indicators (RAI) data set.

When comparing the different definitions used for bank profitability several differences become apparent. First, the former two proxies spread over EONIA and spread over deposits intend to shed light on the role of banks' intermediation margin based on their overall portfolio of loans and deposits. Contrarily, the new loan margin focuses on banks' marginal lending activity. While the latter is closer to banks' behavior in a theoretical world, where only one-period loans will be issued (Dell'Ariccia et al. 2014), it can be assumed that bank risk-taking will be determined only partially by the lending behavior at the margin. Instead, it should be the average portfolio profitability that incentifies banks to monitor.[9]

[8]This does not control for whether the loan has been granted under a previous commitment of the bank or not.

[9]However, it should be acknowledged that the bank risk proxy also focuses primarily on the screening function of bank monitoring (cf. chapter 2.2) and, thereby, on marginal lending activity.

Second, the difference between the two measures drawing on the average loan's spread in the portfolio of banks reflects the degree to which incomplete pass-through or portfolio effects on the liability side of banks' balance sheets may impact the intermediation margin obtainable. The case of spread over EONIA reflects a polar extreme, as the pass-through is assumed to be perfect. This resembles the case highlighted in Dell'Ariccia, Laeven and Marquez (2014). The pass-through into deposit markets may be incomplete due to portfolio effects, adjustment costs or imperfect banking markets. This is depicted in the spread over deposits case. Therefore, the spread over EONIA helps me to isolate the influence on the banks' portfolio of loans held more clearly.[10] This difference in definitions may become especially important for periods of pronounced monetary policy actions. Monetary policy easing, which leads to sizable cuts in EONIA, might overstate banks' profitability if a complete and instantaneous pass-through into deposit rates were assumed. The risk-shifting effect's relative strength is maximized if the assumption holds that banks finance themselves exclusively with one period deposits with fully flexible interest rates. This then translates into a more pronounced response in the bank profitability proxy. Considering figure 3.1 shows the supposedly stronger response of the spread over EONIA to monetary policy decisions. This becomes visible from the levels of the margins depicted in panel (a) and the absolute changes in the margin observable from panel (b).[11] This holds for periods of monetary policy tightening (2005 to 2007) and episodes of monetary policy easing (2007 to 2009). Over the period, where the policy rate has been kept at the ZLB and especially from 2012 onward, the spread over EONIA reflects a stronger draining of banks intermediation margins than the spread over deposits. This speaks in favor of an interest rate smoothing behavior for banks' retail rates on deposits relative to EONIA. Considering that banks finance themselves by a mixture of callable deposits and deposits with agreed maturities,[12] figure 3.1 also indicates that the inclusion of deposits with longer maturities leads to a slight lag in the time series of bank profitability relative to the spread over EONIA reference. Taken together, this also explains the higher volatility of the spread over

[10]Although the spread over EONIA might appear to reflect a polar case, I will show that it bears some relevance when formulating the DSGE model. When banks might default on their obligations to depositors, but the central bank may enforce repayment at the lending window, EONIA will become an applicable hurdle rate by arbitrage.

[11]I present the actual changes in the margin proxies here since disaggregate data for the individual Euro Area countries are only available as actual changes. The VAR will be calculated based on log changes, which present similar patterns.

[12]Although the average agreed maturity on deposits is longer than one-period, it is still shorter than the average maturity on loans. Thus, the conventional ideas concerning maturity transformation of banks still hold.

EONIA observable from table 3.1. Given that the spread over the weighted average interest rate on callable deposits and deposits with agreed maturities contains also interest rates with longer maturities, it is not surprising that the mean is lower than its counterpart for the spread over EONIA.

Interestingly, new loan margins appear to be consistently below the two other measures of average portfolio spread. Over time, this difference cannot persist. Moreover, new loan margins exhibit an idiosyncratic increase in the years 2013 to 2015, which is not shared by the other two series.

Nonetheless, it becomes apparent that there is some considerable degree of correlation between the three bank profitability proxies. The correlation coefficients between the spread over EONIA and the spread over deposits, between the spread over EONIA and new loan margins, and between the spread over deposits and new loan margins are equal to 0.9586, 0.7489, and 0.7837, respectively.

The data set used for the Euro area covers the time frame from Q4 2003 to Q4 2018. Table 3.1 provides further descriptive statistics of the respective variables. The variables enter in the following order into the VAR: proxy of banks' profitability, bank lending standards, real GDP growth, EONIA.[13, 14]

The identification scheme applied grounds on a lower triangular Cholesky decomposition with the following order: proxy for bank profitability, bank lending standards, real GDP growth and finally EONIA. A variable entering earlier in the order influences the subsequent ones contemporaneously and with a lag. A variable that is placed later in the order may only exert a lagged effect on the preceding ones. It may, however, contemporaneously respond to all other variables. In my order, I follow the conventional assumption that monetary policy may respond contemporaneously to all other variables, but all other variables may respond to monetary policy only with a lag. Due to the theoretical considerations laid out before (Dell'Ariccia et al. 2014), the bank profitability proxy enters first to ensure that bank lending standards can contemporaneously respond to changes in the margin obtainable. Bank lending standards may influence bank profitability only with a lag, as it may take time until borrowers default. Since the bank risk-taking channel suggests that banks' risk appetite determines loan supply and thereby influences

[13] I use natural returns for the profitability proxy and the real GDP because I am primarily interested in the elasticities. For BLS, which is already expressed as a change, i.e. the net percentage of banks tightening their lending standards, logs are not warranted. Likewise, the EONIA is already expressed as a percentage.

[14] The variable names for EONIA, the change in the spread over EONIA, the change in the spread over deposits, the change in the new loan margin, the net tightening of bank lending standards and the growth of real GDP are EONIA, LOG_SPREAD_EONIA, LOG_SPREAD_DEP, LOG_BANK_MARGIN, BLS, LOG_REAL_GDP, respectively.

real economic growth, real GDP growth enters third and may respond endogeneously to changes in bank lending standards. Real GDP growth may also respond contemporaneously to bank profitability but may impact bank profitability and bank lending standards only with a lag.

Table 3.1: Descriptive Statistics of the Endogenous Variables

Summary Statistics of Endogenous Variables						
	EONIA	LOG _SPREAD _EONIA	LOG _SPREAD _DEP	BANK _Margin	BLS	LOG_REAL _GDP
Mean	1.015	0.001	−0.002	−0.004	6.785	0.003
Median	0.350	−0.014	−0.009	−0.007	−0.100	0.004
Maximum	4.250	0.501	0.239	0.168	67.790	0.012
Minimum	−0.364	−0.151	−0.082	−0.142	−13.460	−0.032
Standard Deviation	1.492	0.098	0.059	0.211	18.021	0.007
Skewness	0.972	3.454	2.988	0.441	1.886	−2.976
Kurtosis	2.503	17.078	1.408	4.355	5.914	14.909

Note: Table 3.1 presents descriptive statistics for the variables used in the analysis on a Euro area level.

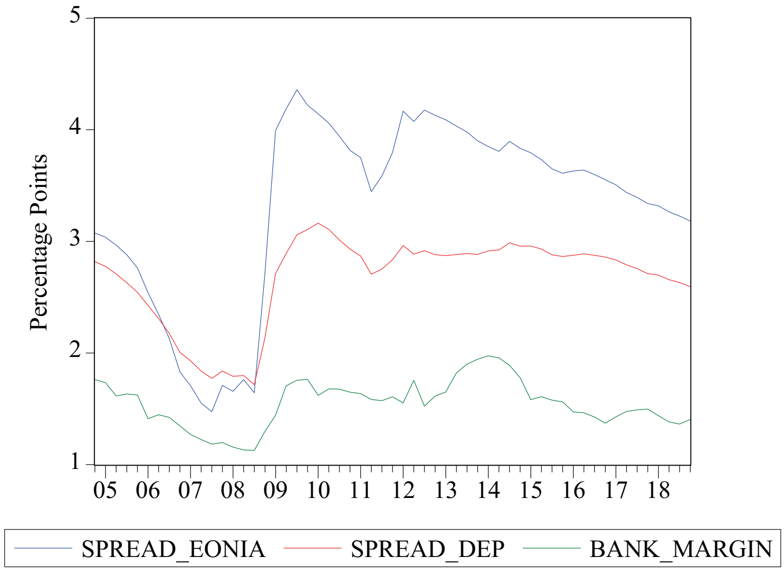
Individual Euro Area Country Data. The Euro area presents a unique case for analyzing cross-country differences in bank risk-taking, as a shared monetary policy impulse transmits into potentially heterogeneous national banking markets. This connects to the research conducted by Leroy and Lucotte (2015) and van Leuvensteijn et al. (2013). Their research into the interest rate channel has shown that the different Euro area countries exhibit different pass-through[15] and margin patterns in dependence on the degree of banking market competition. Once the rationale of the pass-through effect (Dell'Ariccia et al. 2014) holds, varying responses in bank margins to an otherwise homogeneous monetary policy shock should be observable in the cross-section of countries.

In order to analyze differences across banking markets, national measures for bank profitability, risk-taking and economic growth are in order. As will be shown below, aggregate Euro area data indicates that it is the banks' average spread on their portfolio holdings that drives their lending standards. Therefore, I focus on a measure of banks' margin on the average loan, when it comes to the review of country-specific bank risk-taking behavior. The proxy for banks' profitability is the change in the margin on the average loan (MAL) as reported by banks to the ECB as part of the BLSS at a quarterly frequency. More specifically, it is expressed as basis point changes. Data is available for 15 Euro Area countries. Unfortunately, this already excludes some Euro area

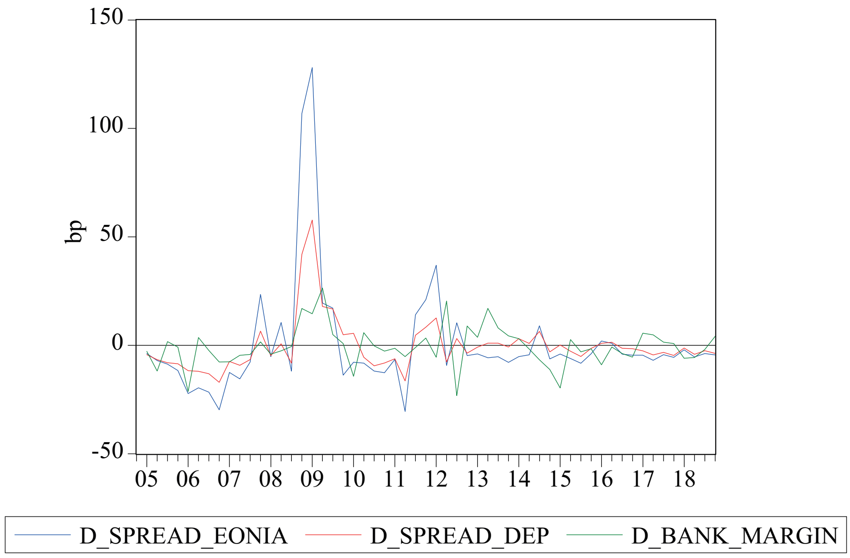
[15]In the context of the interest rate channel, the pass-through describes in how far retail rates completely and instantaneously react to changes in the policy rate.

Figure 3.1: Time Series of Bank Profitability Proxies

(a) Levels of Bank Margins



(b) Actual Changes in Bank Margins



Note: Figure 3.1 illustrates how the three proxies for bank profitability have developed over the timeframe 2004 Q4 to 2018 Q4. Panel (a) reflects the margins in the levels expressed as percentage points. Panel (b) depicts the absolute changes in the respective margin proxy. Although log returns are used in the VAR estimation, I present panel (b) in terms of actual changes to ensure comparability to the measures of bank profitability available in the cross-section of Euro Area countries. A considerable degree of comovement becomes visible, whereby the spread over EONIA exhibits the strongest response in response to the monetary policy easing in 2008. I interpret this as a clear indication of an incomplete pass-through on impact into deposit rates.
Source: own illustration

countries.[16] Out of the 15 countries available, I exclude Cyprus, the Baltic countries and Slovenia, since the time frame covered is considerably shorter. Figure 3.2 shows that there is a considerable comovement among margins on average loans in the cross-section of Euro area countries. However, there are times (e.g. from 2009 to 2012), during which the comovement breaks down. Comparing the cross-country changes to the changes in the aggregate Euro Area (cf. Fig. 3.1 panel (b)) exhibits also a strong correlation among aggregate and disaggregate data. The bp differences depicted in Figure 3.2 are comparable in size to the changes shown for aggregate Euro Area data (cf. Figure 3.1 Panel (b)). They range between the changes in spread over EONIA and spread over deposits in size.[17]

Similar to before, I collect the bank lending survey's net percentage of banks tightening lending standards (BLS) from the ECB and use the log growth rate in real GDP obtainable from Eurostat.

The resulting data set covers the same period as before.[18] Table 3.2 presents the summary statistics for the margin on the average loan (MAL) obtainable in the cross-section of different countries. It becomes apparent that there is some heterogeneity within the margins reported by banks on their mean loans in the cross-section of countries.[19] The heterogeneity appears to widen especially during the Euro crisis (cf. Figure 3.2). Among others, van Leuvensteijn et al. (2013) and Leroy and Lucotte (2015) have assessed the banking market competition in the Euro area. They found that less competitive banking markets exhibit higher mean margins and amplified response patterns. My sample also depicts higher mean margins changes on loan portfolios of banks for those countries characterized as less competitive. With the exception of Portugal, the different countries also exhibit comparably similar standard deviations varying in a band between 15 and 28. It is also interesting to note that there are differences in the variability of BLS across the different countries. Countries that are deemed to be less competitive exhibit a higher standard deviation in BLS (cf. appendix B4).

Each sample covers to a sizable extent the post-subprime crisis and the aftermath of the currency crisis. During this time the monetary policy instrument has been at or even below the ZLB. Thus, I treat the results with

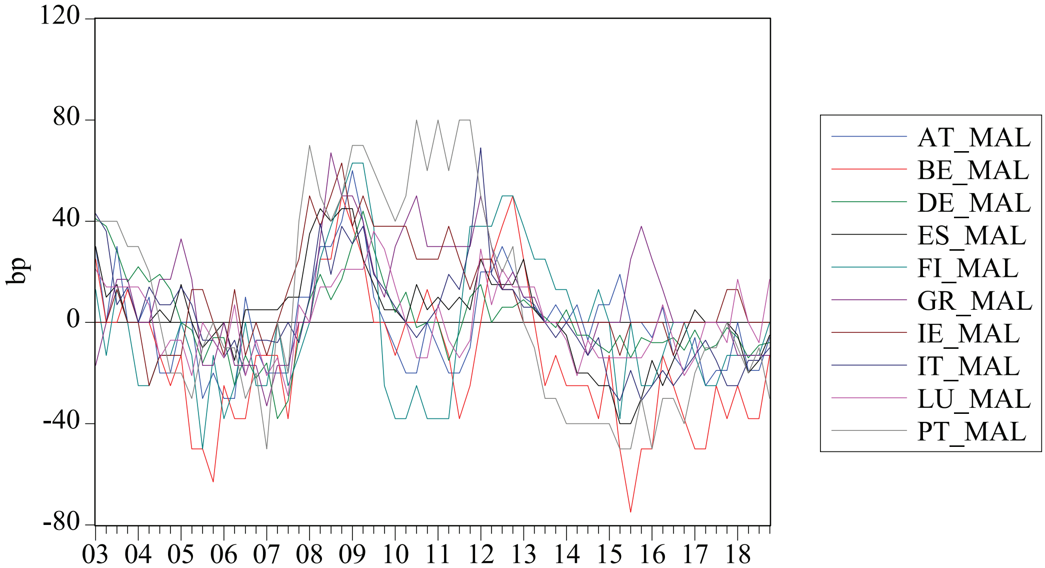
[16]The countries missing are France, Malta, the Netherlands, and Slovakia.

[17]Due to the fact that the ECB reports only absolute changes without any indication of the original level, the disaggregate VARs use absolute difference changes as the endogenous variable of bank profitability responses.

[18]Only the data set for Ireland is shorter as data availability on real GDP was limited to 2015 at the time, when I collected it from Eurostat.

[19]The Kruskal-Wallis test statistic is 29.335 and significantly rejects the null. An ANOVA for autocorrelated data leads to the same conclusion.

Figure 3.2: Time Series of Margins on Average Loan per Country



Note: Figure 3.2 illustrates how margins on average loans have changed in basis points. The data is self-reported over the time frame 2004 Q4 to 2018 Q4. A considerable degree of comovement among individual Euro Area countries becomes visible for most of the time, although it appears to break down from 2009 to 2012. Relative to the aggregate Euro Area data, there is also a visible comovement and the changes in the disaggregate data appear to be between the absolute changes for the spread over EONIA and spread over deposits.
Source: own illustration

utmost caution.[20]

From an econometric perspective, I am primarily interested in the impulse-response functions produced by my VAR models, as they provide guidance for the latter assessment in how far my microeconomically founded DSGE approach can replicate the responses observed. I also plot approximate, asymptotic 95% (± 2 S.E.) confidence bands around the impulse-response functions.

Table 3.2: Summary Statistics of Margins on Average Loans per Euro Area Country

	Austria	Belgium	Germany	Finland	Greece
Mean	−0.281	−13.609	1.313	−2.000	10.281
Median	0.000	−13.000	−2.000	−6.500	0.000
Maximum	60.000	50.000	44.000	63.000	67.000
Minimum	−30.000	−75.000	−38.000	−50.000	−33.000
Std. Dev.	19.352	27.695	16.311	27.804	21.538
Skewness	0.706	0.279	0.483	0.619	0.427
Kurtosis	3.255	2.672	3.406	2.575	2.532

	Ireland	Italy	Luxembourg	Portugal	Spain
Mean	10.234	1.797	0.422	7.500	2.969
Median	0.000	0.000	0.000	−5.000	5.000
Maximum	63.000	69.000	36.000	80.000	45.000
Minimum	−25.000	−31.000	−29.000	−50.000	−40.000
Std. Dev.	19.072	20.168	14.918	40.627	18.596
Skewness	0.773	0.786	0.266	0.314	0.118
Kurtosis	2.915	3.719	2.181	1.760	3.348

Note: Table 3.2 presents descriptive statistics for margin on average loans in the ten Euro area countries analyzed individually.

3.2 Estimation Results

3.2.1 Aggregate Euro Area Evidence

As aforementioned, I am primarily interested in the IRFs produced by my VAR models.[21] Each IRF will be displayed over a 40 period (10 year) horizon

[20] Ideally, I would create a split sample and would replicate the results for the period ending in Q4 2008, when the EONIA approached the ZLB. However, the sample size does not warrant such a stability test.

[21] The coefficient estimates for the VAR(1) models including LOG_SPREAD_EONIA, LOG_SPREAD_DEP and LOG_BANK_MARGIN can be obtained from appendix B.1.1, B.2.1 and B.3.1, respectively. The counterparts for a VAR(2) specification can be found in appendices B.1.2, B.2.2. and B.3.2, respectively.

in response to a one-standard deviation innovation in the respective endogenous variable. For the sake of brevity, I provide only the results of interest to the bank risk-taking channel.[22] To ease comparability, I will discuss the comparable IRFs originating from the three model specifications simultaneously.

In the case of the spread over EONIA, the lag length of the VAR is chosen to be 2.[23] In the model formulation, where the spread over deposits serves as a proxy for bank profitability, both information criteria indicate that a VAR(1) should be chosen.[24] In the specification, where new loan margins are used, both information criteria indicate that a VAR(2) is applicable.[25]

The bank risk-taking channel suggests a general tightening of bank lending standards (i.e. a reduction of bank risk-taking) in response to monetary policy tightening. Therefore, I first of all investigate the response of bank lending standards to an innovation in EONIA.

All three model specifications exhibit a tightening in bank lending standards in response to an innovation in EONIA. This provoked tightening in lending standards is comparably similar in its size for the specifications drawing on the spread over EONIA (cf. Figure 3.3 panel (a)) and new loan margins (panel (c)). In both specifications, a response equal to approximately one-ninth of a standard deviation in bank lending standards is observable. This means that the net percentage of banks tightening their lending standards increases by 2.5 to 3 percentage points. In both cases, the maximum response is reached after two to three quarters. Also the duration for which the innovation in the policy rate results in a significant response is fairly similar with four and five quarters. For the specification including the spread over deposits (panel (b)), the direct response in BLS to an innovation in EONIA is smaller (approximately one-thirtieth of a standard deviation). In this case,

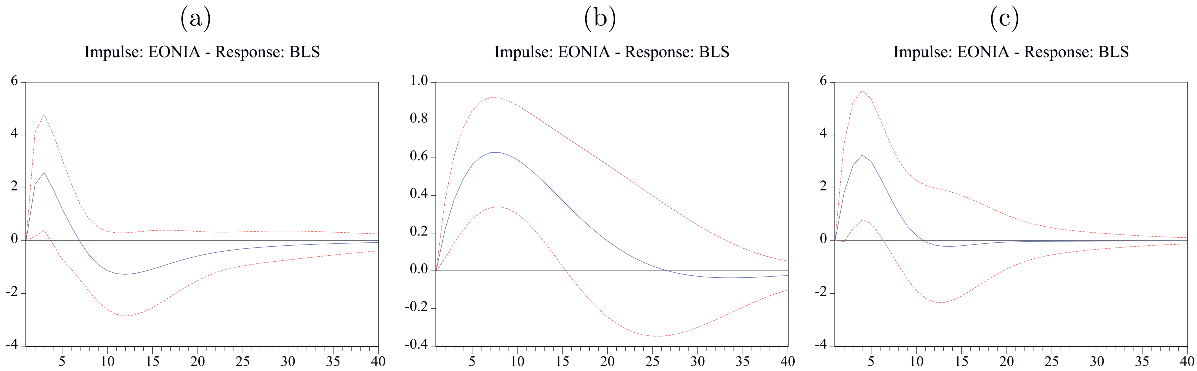
[22]The full set of IRFs per model specification is obtainable from appendices B.1.3, B.2.3 and B.3.3 for the spread over EONIA, the spread over the weighted average interest rate on the deposit structure and on self-reported bank margins on new loans, respectively.

[23]In general, a general-to-simple approach as suggested by Greene (2017) has been followed, where the maximum lag length has been set to 4 and then reduced stepwise. Only the two best fitting lag-lengths are depicted in the appendix. In the spread over EONIA case, the two information criteria point into opposite directions. While the AIC indicates that a VAR(1) will be optimal relative to a VAR(2) with values of -6.019 and -5.502, the SBIC indicates otherwise as the respective values are -4.839 and -4.918. Since the SBIC is consistent, I provide the results for a VAR(2) specification. The unreported results of a VAR(1), however, confirm the results and are available on request.

[24]The AIC values are -7.451 and -6.600, whereas the SBIC values are -6.272 and -6.016 for the VAR(1) and VAR(2) specifications, respectively.

[25]For the VAR(1) and VAR(2), the AIC values are -3.871 and -3.959 and the SBIC values are -3.287 and -2.780, respectively.

Figure 3.3: IRFs of BLS to EONIA Impulses



Note: Figure 3.3 depicts the impulse-response functions of banks' lending standards to a one-standard deviation innovation in EONIA. Panels (a), (b) and (c) represent the responses for specifications, where the spread over EONIA, the spread over deposits, and banks' margins on new loans have been used, respectively. In all three cases, bank lending standards tighten subsequent to monetary policy tightening.
Source: own illustration

the maximum response is reached in quarter five after the shock. The time for which bank lending standards remain significantly tighter is longer with 15 quarters.[26] While the responses in the specifications including the spreads of average loan portfolios turn out significant immediately after the innovation in the policy rate, the response estimated based on new loan margins is only significant from the second quarter onward. Overall, all specifications exhibit a stationary, hump-shaped pattern in the IRFs. The specification, which includes the spread over EONIA as a proxy for banks' intermediation margin, shows that there is a relaxation of banks' lending standards after the initial tightening, but it remains insignificant.

The results obtained generally reconfirm the previously gathered evidence on the bank risk-taking channel. They share the basic pattern exhibited in the introduction. Banks reduce their risk-taking in response to monetary policy tightening.[27]

[26]For a VAR(2) specification, a shorter (7 quarters), but insignificant tightening of lending standards can be observed. This is closer to the estimated responses of the other two proxies.

[27]In the variance decomposition, an innovation to EONIA explains the least in the variance of BLS (approximately one percent) in the VAR(1) specification using the spread over deposits. In the two VAR(2) specifications using the either spreads over EONIA or banks' margins, the innovation to the policy rate can explain up to 10 and 20 percent of the variance in BLS, respectively.

Subsequently, I turn to the transmission of monetary policy into banks' profitability. As the bank risk-taking channel in accordance to Dell'Ariccia, Laeven and Marquez (2014) suggests expanding margins in response to an innovation in EONIA,[28] it is also interesting to investigate the responses in the margin proxies to monetary policy tightening. This exercise can serve to not only further the understanding of the dynamics in bank margins, but also provides a comparable for the DSGE's responses in bank margins. In this context, two questions are of greater interest. First, how do banks' average margins and the margins on new loans respond to monetary policy impulses. The latter margin is expected to respond quicker and more completely. Second, since banks also refinance their loan activities via deposits with agreed maturities longer than the stylized one-period deposit of the Dell'Ariccia, Laeven and Marquez world, the question also arises whether the liability structure influences the response.

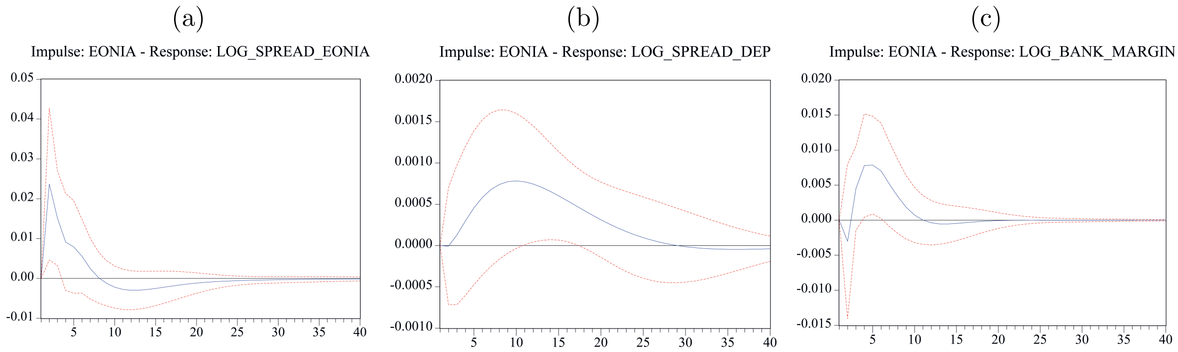
As expected, the three profitability proxies show more heterogeneous responses to an innovation in EONIA, although all proxies exhibit the expected improvement in profitability. The innovation to EONIA results in a significantly positive response in the log return of banks' spreads over EONIA. It lasts for four quarters (Figure 3.4 panel (a)) and reaches a maximum response equal to one-fifth of a standard deviation in the spread. The duration matches the increase in net income of banks observed in response to monetary policy tightening by, for instance, English, van den Heuvel and Zakrajsek (2018) for US banks. After the temporary increase, banks' profitability returns to its mean.

In response to monetary policy tightening, the spread over deposits responds significantly positive for approximately six periods (cf. panel (b)). However, the response turns out to be later (and becomes significant from quarter eleven after the shock onward). This marks a sizable delay. It is also noteworthy that the response in panel (b) of one-eighth of a standard deviation is smaller than in panel (a). While a delayed response generally confirms the expectations towards the distinction between the two proxies, the smaller immediate response is contrary to the expectations. Under the assumption that interest rates on deposits with agreed maturities introduce interest rate stickiness into the cost structure of banks, but banks' returns on loans are calculated identically, monetary policy changes should result in a more pronounced increase in banks' costs. This is not observed. Nonetheless, also the spread over deposits returns to its mean.

Likewise, banks' self-reported new loan margins (panel (c)) respond with a temporary increase to an innovation in EONIA. The increase in margins

[28] This is the case if the pass-through effect dominates.

Figure 3.4: IRFs of Bank Margins to EONIA Impulses



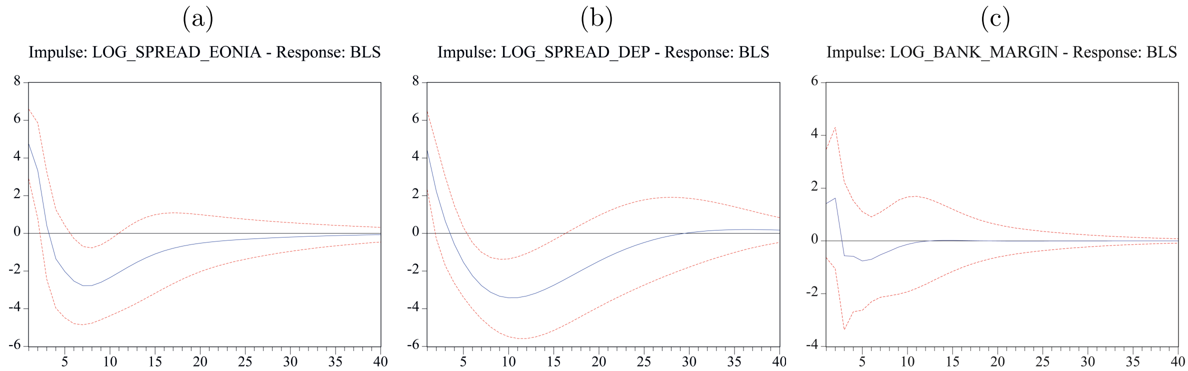
Note: Figure 3.4 depicts the impulse-response functions of banks' profitability measures to a one-standard deviation innovation in EONIA. Panels (a), (b) and (c) represent the responses of the spread over EONIA, the spread over deposits, and banks' self-reported new loan margins, respectively. In all three cases, monetary policy results in the expected improvement in margins.
Source: own illustration

becomes significant from quarter three after the shock onward. The largest response of one-third of a standard deviation is observed after four quarters. The relatively large size of the response is in line with expectations since primarily new loans should respond to innovations in policy rates. Already existing loans with fixed interest rates should not respond. The lagging response in margins on banks' marginal lending activity is contrary to the expectations. It might be reconcilable given that, for instance, non-financial corporate borrowers draw on previously negotiated credit lines with predetermined interest rates. Unfortunately, the data collected by the ECB does not discriminate between loans made under a previous commitment and those freely negotiated.

Considering the observable patterns across the three different proxies, the positive responses to an innovation in EONIA confirm the expectations based on the partial equilibrium considerations of Dell'Ariccia, Laeven and Marquez (2014). The lagging responses observable speak in favor of an incomplete pass-through. However, when comparing panels (a) to (c) to other research (English, van den Heuvel & Zakrajšek 2018, van Leuvensteijn et al. 2013, Leroy & Lucotte 2015, Gropp, Kok & Lichtenberger 2014) on how banks' net income responds to monetary policy tightening, the closest fit becomes apparent for panel (a).[29]

[29]The variance decomposition indicates that in the two VAR(2) specifications drawing on the spread over EONIA and banks' margins, an innovation to EONIA accounts for

Figure 3.5: IRFs of BLS to Bank Margin Impulses



Note: Figure 3.5 depicts the impulse-response functions of banks' lending standards to a one-standard deviation innovation in banks' profitability measures. Panels (a), (b) and (c) represent the responses to innovations in the spread over EONIA, the spread over deposits, and banks' self-reported margins on new loans, respectively. Only in the cases where measures of average loan's profitability are used, the patterns show significant responses. Bank risk-taking initially decreases and subsequently increases before it returns to its mean.
Source: own illustration

Next, the theoretical considerations of the bank risk-taking channel indicate that in response to an improvement of banks' obtainable margins, banks should monitor more. This increase in monitoring should be reflected in the ex-ante screening of borrowers, i.e. in bank lending standards. In the case of my suggestive VAR evidence, an innovation in one of the three bank profitability proxies should result in a positive response in bank lending standards.[30]

An improvement in banks' profitability equal to an innovation to the log return of the spread over EONIA leads to a significant tightening of banks' lending standards over a horizon of approximately one quarter (Figure 3.5

approximately 10 percent of the variance in the respective bank profitability proxy. This is not the case for VAR(1) specification including the spread over deposits. The percentage of the variance in the spread over deposits due to EONIA innovations is negligible.

[30]The variance decomposition indicates that the two specifications using bank profitability proxies capturing the profitability of the average loan help to explain a large percentage of the variance in BLS. In both cases, approximately 40 percent can be explained by innovations to the respective proxy. Innovations to banks' margins on new loans only account for less than 5 percent of the variance in BLS. I interpret this finding as supporting the claim that it is the average loan's profitability that determines banks' risk-taking. Moreover, it speaks in favor of the rationale that bank risk-taking is explained by bank profitability as highlighted in the Dell'Ariccia, Laeven and Marquez (2014) framework.

panel (a)). This result is in line with the predictions of the risk-taking channel as formulated by Dell'Ariccia, Laeven and Marquez (2014). Higher profitability, therefore, warrants a more prudent banking system. Subsequent to the initial tightening, a reversal in banks' lending standards is observable. Banks ease their lending standards again for five quarters beginning with the sixth quarter after the initial impulse. The innovation to the spread triggers a short-lived initial tightening in BLS equal to two-ninth of a standard deviation in size. The subsequent reversal is approximately 50% smaller in size.

The results obtained based on an innovation to the spread over deposits share some remarkable similarity. I observe a confirming short-term increase in banks' lending standards (of approximately two-ninth of a standard deviation) over approximately one quarter. Thereafter, the effect falls insignificant (panel (b)). The tightening of lending standards is in line with the risk-taking channel. The subsequent reversal of bank lending standards observed for the previous profitability proxy is also shared in this specification. The size of the reversal is larger than in the previous specification (approximately one-sixth of a standard deviation). Despite the different definitions of the profitability proxies, the response pattern of bank lending standards to improvements in banks' margins is robust.

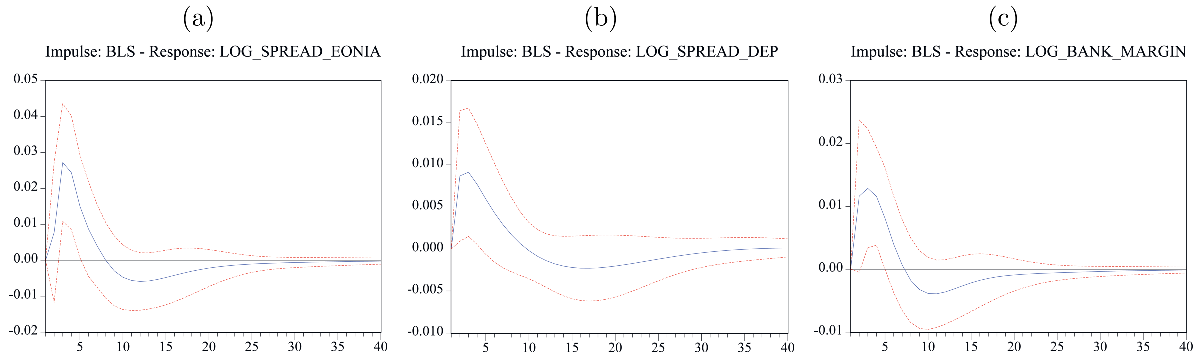
For the self-reported new loan margins, the general shape of the response (cf. panel (c)) is also comparable. However, the response is never significant. I interpret this as a clear indication in favor of the previously stated hypothesis that it should be the average profitability on banks' portfolios that determines bank monitoring and not the profitability of marginal lending activity. Although the results point in the direction of an effect of average profitability, the results are indicative only, as no explicit tests were performed.

Overall, the conclusions resulting from Figures 3.4 and 3.5 support the theoretical considerations of Dell'Ariccia, Laeven and Marquez (2014) with regards to the internal functioning of a bank risk-taking channel. Bank margins positively respond to changes in monetary policy decisions and bank risk-taking decreases as bank margins improve.

Turning to the question in how far banks' risk-taking is economically relevant, two aspects are of major interest. First, the question arises whether bank risk-taking has an influence on bank profitability. The previous evidence by Paligorova and Santos (2017) has pointed in this direction. Second, whether the bank risk-taking channel is relevant for real economic quantities. If so, an increase in bank lending standards should reduce access to loans for borrowers and should therefore reduce real economic activity.

In response to an innovation to bank lending standards, I observe a con-

Figure 3.6: IRFs of Bank Margins to BLS Impulses



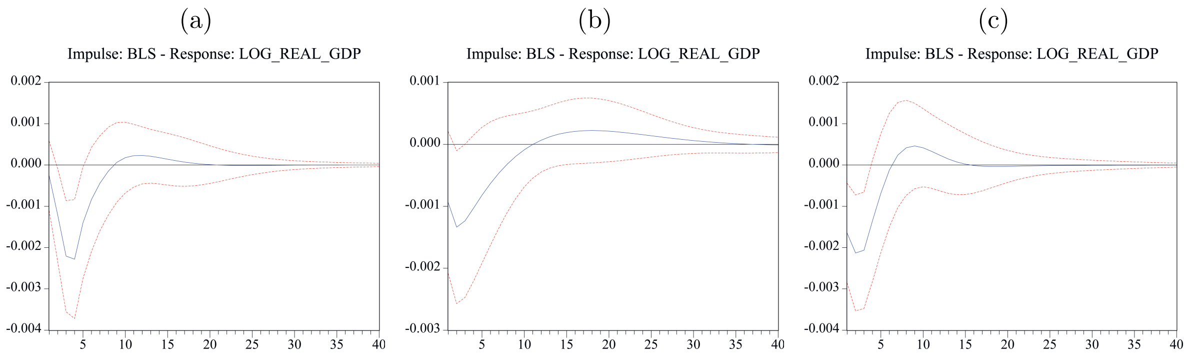
Note: Figure 3.6 depicts the impulse-response functions of banks' profitability measures to a one-standard deviation tightening in bank lending standards. Panels (a), (b) and (c) represent the responses of the spread over EONIA, the spread over deposits, and banks' self-reported margins on new loans, respectively. In all three cases, bank profitability increases temporarily subsequent to tightening bank lending standards.
Source: own illustration

sistent pattern across all three specifications. Banks' profitability measures increase significantly for three to eight quarters depending on the proxy. The longest duration of a significant influence is observed for margins on new loans and the shortest one is visible for the spread over EONIA. The sizes of the response range between one-quarter and one-fifth of a standard deviation in the respective profitability proxies.

Turning to the influence of bank risk-taking on real GDP growth, a reduction in bank risk-taking (i.e. a one-standard deviation innovation in BLS) results in a reduction in real economic activity in all three specification. This confirms the expectations and can be interpreted – with all necessary caution – as an indication in favor of the meaningfulness of the bank risk-taking channel for real economic activity. The maximum responses are relatively robust against the respective bank profitability proxy variables included. The responses range between one fifth (cf. Figure 3.7 panel (b)) and one-third of a standard deviation (panels (a) and (c)) in real economic activity. While the response turns out significant immediately after the innovation in bank lending standards in panel (c) and lasts for four quarters, the response observable in panel (a) is of similar length but turns out to be significant with one-quarter delay. The results obtained from panel (b), the specification including the spread over deposits, share the lagged significant response, but bank lending standards affect real economic activity only for one-quarter.

The results can be summarized as follows. All VAR specifications doc-

Figure 3.7: IRFs of Real Output Growth to BLS Impulses



Note: Figure 3.7 depicts the impulse-response functions for real economic growth (log real GDP) to a one-standard deviation tightening in bank lending standards (BLS). In all three model specifications, a contraction in real economic activity can be observed that differs in size and duration.
Source: own illustration

ument the expected effect of monetary policy on bank risk-taking. Bank risk-taking decreases after monetary policy tightening for approximately one year depending on the proxy for bank profitability included. Novel to the literature is the focus on the response of bank profitability to monetary policy decisions and on the response in bank lending standards to innovations in bank profitability. The responses of banks' margins to monetary policy tightening exhibit the expected increase. The patterns observed show a hump-shaped behavior and only temporary profitability improvements for all three proxies. For the spread over EONIA, the increases are closely reconcilable in terms of length with the previous evidence originating from the interest rate channel literature. This offers reassurance for the suitability of the proxy. The results, however, also indicate that there could be relevant effects of interest rate stickiness in both deposit and loan markets. The insights concerning potential interest rate stickiness in deposit markets arise primarily from a comparison with the weighted average interest rate on deposits being callable on notice and having an agreed maturity. Nonetheless, the spread over EONIA appears most consistent with theory and previous evidence, especially with an eye on its influence on bank risk-taking.

The bank risk-taking pattern resulting from an innovation in bank profitability depicts a strong initial reduction in bank risk followed by a smaller, but still significant reversal. Taken together the responses of bank margins to monetary policy decisions and of bank risk-taking to innovations in bank margins speak in favor of the theoretical considerations of the internal functioning of the bank risk-taking channel. An important new element added is the subsequent increase in bank risk-taking to an improvement in bank profitability. The results obtained also support the claim that the average bank portfolio's profitability is relevant to banks' decision how much risk to accept. Finally, bank risk-taking is relevant to monetary policy makers as tighter lending standards improve bank profitability[31] and contract real economic output.

For the subsequent DSGE model, these results bear implications. I will primarily use the estimated IRFs of the spread over EONIA specification as a reference. In particular, the estimates of the response of bank profitability to innovations in EONIA and of bank lending standards to the spread over EONIA will serve as a benchmark. Likewise, I will primarily draw on the average loan's profitability in the subsequent analysis across different Euro area countries.

3.2.2 Individual Country Evidence

Turning to the results for the Impulse-Response-Functions obtained from the individual banking markets in the Euro area, a VAR(1) specification is favored for virtually all markets.[32] To ensure comparability, I focus on a uniform model lag-length.

For the sake of brevity, I subsequently provide only the three most relevant IRFs for each country in Fig. 3.8. These are the responses of bank lending standards to innovations in the policy rate in the first column, the responses of bank margins to an innovation in EONIA in the second column, and the responses of bank lending standards to innovations in bank margins in the third column.

First, I focus on the IRFs depicting the responses of BLS to innovations in EONIA in the cross-section of countries. These IRFs speak a shared language. BLS unanimously increase after monetary policy tightening. The sizes of the maximum responses in BLS are relatively comparable across countries and range between approximately one-tenth and one-twentieth of a standard deviation. Only Greece exhibits a somewhat higher response with one seventh of a standard deviation. Relative to the evidence gathered on the aggregate Euro area, the duration for which BLS tighten is longer. Most

[31] The evidence documented in appendices B.1.3, B.2.3 and B.3.3 also shows that monetary policy eases in response to a one-standard deviation innovation in bank profitability. This supports the claim that central banks (or the ECB in this case) have started to include bank risk in their policy decisions and acted as a gatekeeper of banking market stability.

[32] See appendix B.4 for the estimates on the VAR(1) specifications.

countries exhibit a significant tightening of lending standards in response to an innovation in EONIA over a timeframe between 15 and 25 quarters. Only Belgium depicts a response that is shorter (5 quarters) and comparable to the aggregate Euro Area responses. Overall, the responses of BLS to EONIA innovations are remarkable given the heterogeneously competitive conditions in the different banking markets.

From the second column, it becomes apparent that there is heterogeneity in the response of the banks' margin on the average loan to an innovation in EONIA across the Euro area. Virtually all countries exhibit a hump-shaped response in the profitability proxy. The maximum responses in the MAL proxies are reached after three to ten quarters after the innovation to EONIA. The maximum response is two to nine quarters later than the previous estimates for the aggregate Euro area's spread over EONIA specification. The largest responses are observable for Greece, Ireland and Portugal (though insignificant), while the smallest are exhibited by Germany and Luxembourg. This reflects responses between 2.5% of a standard deviation for Germany and 10% for Ireland. The responses in margins are only significantly positive for Austria, Germany, Greece, Ireland, Italy and Spain. On the contrary, Belgium, Finland, Luxembourg, and Portugal do not exhibit any significant responses in banks' profitability.[33] The duration and the lag with which EONIA exerts its influence on banks' margins diverges for the countries considered. For most of the countries that exhibit significant responses in bank margins, the duration for which the individual margin remains higher appears to be propagated. Only Germany exhibits a duration that is comparable to the response for the aggregate Euro Area documented before in the spread over EONIA specification.

Considering the timing of the expected maximum responses of margin changes depicts that more competitive banking markets adjust quicker to innovations in EONIA. This finding concurs with the results of Leuvensteijn et al. (2013) and Leroy and Lucotte (2015). Overall, the conclusion can be drawn that the responses in banks' margins in the cross section of Euro Area countries appear to be consistent with the predictions of the bank risk-taking channel.

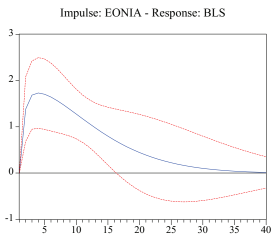
This leads over to the response of banks' lending standards to innovations in the margin on the average loan in the portfolio. The IRFs produced by the respective VARs are generally consistent with the theory and with the patterns observed for the Euro area as a whole, i.e. one standard deviation innovations boosting bank profitability will lead to higher lending standards

[33]This does, however, not imply that the responses are significantly different from each other.

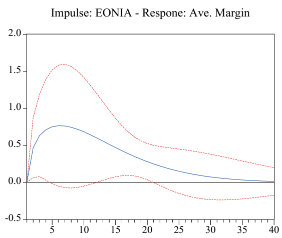
Figure 3.8: IRFs Produced by VARs(1) for the Individual Euro Area Countries

Austria

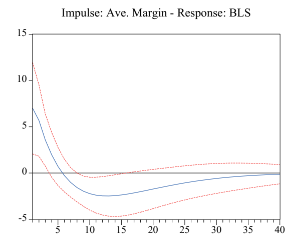
(a)



(b)

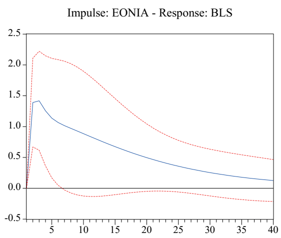


(c)

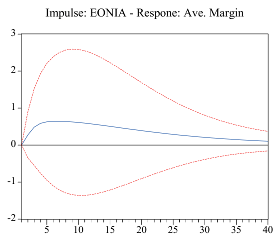


Belgium

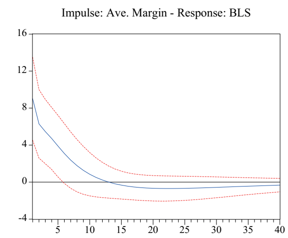
(d)



(e)



(f)



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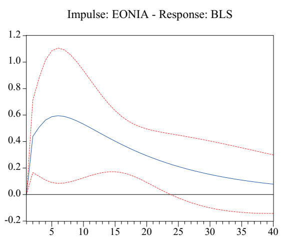

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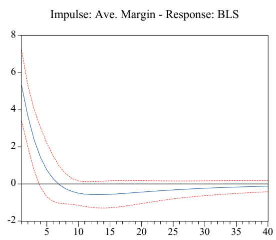

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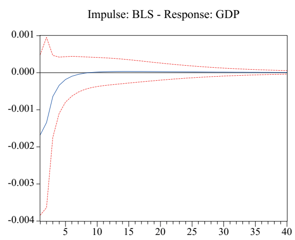

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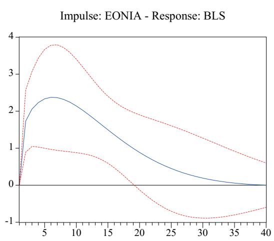

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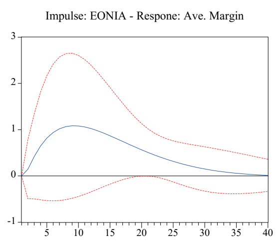

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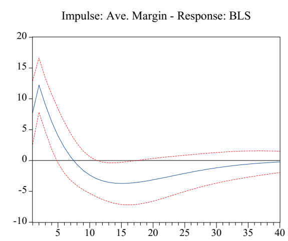

Greece

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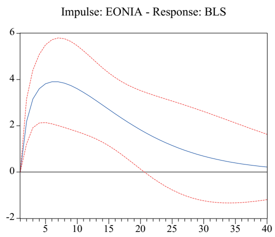

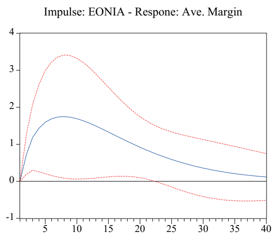

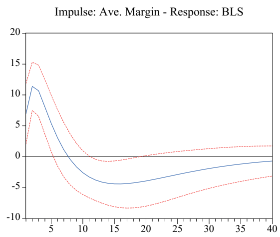

Ireland

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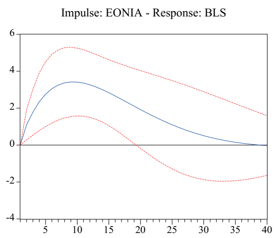
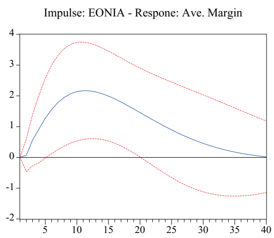
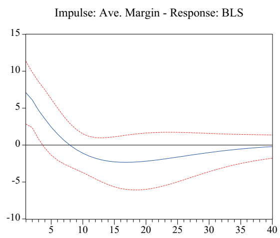
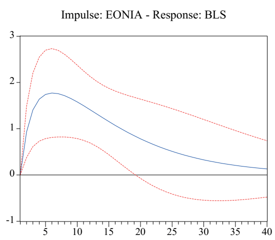


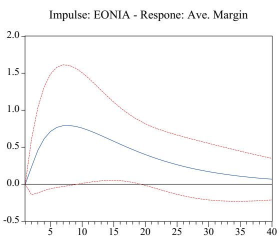


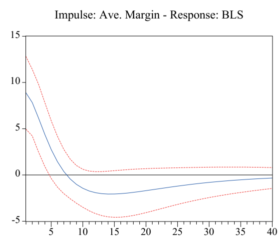


Italy

(g) (h) (i)







Luxembourg

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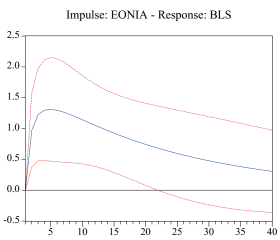
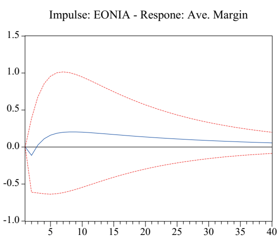
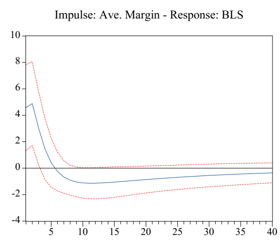
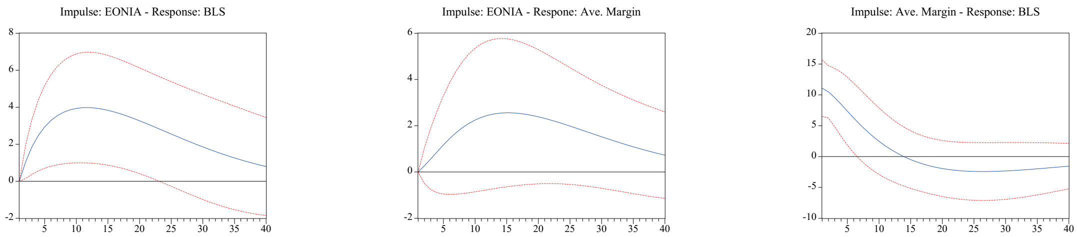






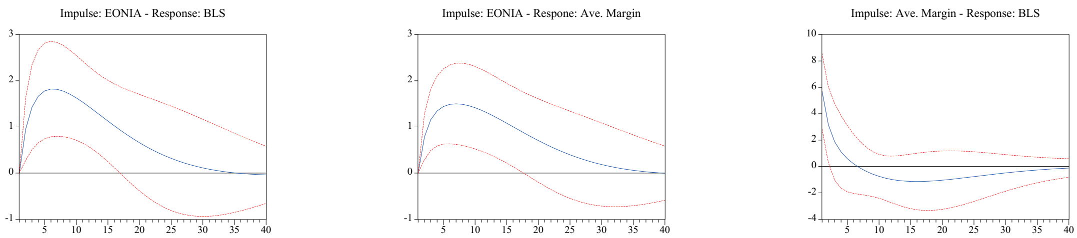
Portugal

(a) (b) (c)



Spain

(d) (e) (f)



Note: Figure 3.8 depicts selected impulse-response functions of VARs(1) for the countries Austria, Belgium, Germany, Finland Greece, Ireland, Italy, Luxembourg, Spain and Portugal. In column one, the responses in bank lending standards to an innovation in EONIA are presented over a forty-period forecasting horizon. The second column depicts the IRFs for the responses in banks' margins on the average loan to an EONIA shock. The last column presents the responses for banks' lending standards to an innovation in the margin on the average loan. The dashed lines indicate asymptotic ± 2 S.E. bands.
Source: own illustration

and therefore lower bank risk-taking. The responses range between one-fifth and one-third of a standard deviation in bank lending standards.[34] Within the sample, Ireland, Italy and Spain show the lowest responses of approximately one-fifth of a standard deviation. An intermediate response of close to one-fourth of a standard deviation of the respective national BLS measures is exhibited by Austria, Luxembourg and Portugal. The largest responses are shown by Belgium, Germany, Finland and Greece. The duration for which a shock to the margin significantly affects the lending standards is relatively similar in the cross-section of countries (most banking markets depict a significant tightening over a three to five quarter horizon with Spain being the exception) as well. Most of the countries depict an initial tightening as a direct response to an improvement in profitability that subsequently monotonically declines. Three countries (Finland, Greece and Luxembourg) exhibit a maximum response in lending standards that is delayed by one quarter. The previously shown reversal in bank lending standards for the aggregate Euro Area is only observable for Austria, Finland and Greece. Overall, the responses in BLS are qualitatively relatively alike.

In conclusion, the results obtained reconfirm the previous aggregate Euro area evidence in three important aspects. First, innovations to the policy rate result in a reduction of bank risk-taking. The responses of lending standards to a monetary policy innovation are fairly homogeneous across countries. This is noteworthy given the heterogeneity in competition in the cross-section of banking markets. Second, monetary policy tightening increases banks' margins. This can be interpreted in favor of a dominant pass-through effect for most markets. Third, increasing margins result in less bank risk-taking. The subsequent reversal in risk-taking behavior observed in aggregate Euro Area data is not shared by all countries. The cross-country evidence partly refines the picture. Supposedly less competitive banking markets exhibit stronger changes in margins on average. They also show slower responses in bank profitability to innovations in EONIA. Both aspects are in line with the predictions of the theory.

3.3 Interim Conclusion

Within this chapter, I have provided new, suggestive evidence focusing on the transmission of monetary policy into real economic output growth through the bank risk-taking channel. The limited data availability puts constraints on the number of endogenous variables included in the respective VAR spec-

[34] Note that the size of the innovation in bank profitability may differ in the cross-section of countries.

ification.[35] I contribute several aspects, which generally confirm the implications of the risk-taking channel.

First and foremost, I contribute further evidence on the responses of bank risk-taking to innovations in policy rates. Focusing on aggregate Euro area data, monetary policy impulses exert an effect on bank risk-taking. Once policy rates increase, bank risk-taking decreases in line with the theoretical considerations. This is robust to the definition of the bank profitability proxy. The pattern is also observable as a uniform pattern in the cross-section for all Euro area countries considered individually. This is noteworthy as less competitive countries do not necessarily exhibit higher responses in bank risk-taking to monetary policy shocks. This is counter to the supposedly linear effect of the two polar cases highlighting the influence of banking market competition discussed in Dell'Ariccia, Laeven and Marquez.

Focusing on the internal functioning of the bank risk-taking channel via banks' margins, I can provide further insights complying with the theoretical considerations. These are: First, I observe a significantly positive response of banks' profitability measures in response to innovations in monetary policy on an aggregate Euro area level. My findings also point into a direction of an incomplete pass-through from policy into retail rates on impact. Relative to the evidence contributed by the interest rate channel literature, the duration of a significant influence of EONIA on banks' profitability is most closely resembled in the spread over EONIA VAR specification's IRF. For my DSGE estimation, an increase in bank margins after monetary policy shocks should be observable. After the increase the effect should return to its steady state level, since this is a pattern observed for all proxies on an aggregate Euro area level.

The picture can be refined by considering the cross-section of Euro Area countries. There is considerable heterogeneity in the speed with which margins respond to monetary policy shocks. Countries that have been labeled to feature more competitive banking markets have lower margin changes on average and adjust more readily to policy innovations. This concurs with evidence from the interest rate channel literature.

Second, when it comes to the influence of banks' profitability on the bank risk-taking, the picture is fairly consistent with the theory.[36] I focus primarily on the behavior of the IRFs produced by proxies on the average

[35] The constraining effect, in turn, puts also limits on the ability to test for the ceteris paribus effect of the risk-taking channel in the presence of other channels.

[36] Although the response of the net percentage of banks tightening their lending standards exhibits the correct sign in response to a one standard deviation innovation to the banks' self-reported margin on new lending activities, the IRF does not depict any significant reaction.

loan's margin. In these cases, bank risk-taking exhibits an initial decrease resulting from an innovation to bank profitability on an aggregate Euro Area basis. As a new element, I observe a subsequent increase in bank risk-taking. The responses in bank risk-taking to innovations in bank profitability on a cross-sectional basis reconfirm the evidence for the aggregate Euro area. However, the subsequent inversion is only shared by a subset of individual countries. Interpreting these results with all necessary caution, the results speak in favor of a more relevant link between banks' profitability on their portfolio holdings and the risk-taking channel than between their marginal lending activity's profitability and bank risk-taking. With an eye on the DSGE estimation, it needs to be confirmed that the DSGE's IRF for risk-taking respond similarly to a bank profitability shock. Ideally, the model should also be capable to replicate a subsequent hump-shaped inversion in bank risk-taking.

Finally, aggregate Euro Area data also provide evidence of the relevance of the bank risk-taking channel. Tightening bank lending standards significantly contract economic activity growth in the short run.

Overall, the evidence provides a solid comparison for the DSGE's IRFs.

Chapter 4

A Medium-Scale DSGE Model with Bank Risk-Taking

The risk-taking channel of monetary policy transmission in accordance to Dell'Ariccia, Laeven and Marquez (2014) entails that bank margins respond to monetary policy decisions. The change in margins determines the monitoring effort (i.e. risk-taking) of the bank. The influence of monetary policy on margins is characterized by three effects – a pass-through effect, a risk-shifting effect, and an optimal leverage effect. An incorporation of all of these effects into a DSGE model is missing until now.

There are, however, DSGE models that already incorporate a dedicated banking sector. One of the most advanced of these models is the model originally proposed by Gerali et al. (2010). It comprises a modified version of the interest rate channel, which is applicable for patient households only. It also features a nominal debt channel, which affects the ex-post distribution of wealth among agents through the interplay of inflation and the nominally denoted interest and principal payments. For impatient households and entrepreneurs, a collateral constraint channel, which impacts consumption and investment through monetary policy's influence on the shadow value of borrowing, is observable, as is an asset price channel, where changes in the asset prices alter the value of collateral that impatient households and entrepreneurs can pledge. Finally, a pass-through effect in isolation of bank risk-taking has been introduced already, which shapes banks' profitability through their market power in loan and deposit markets in combination with Rotemberg (1982) cost parameters determining the stickiness of the response to policy rate changes. The already elaborate Gerali et al. model will subsequently be extended for a bank risk-taking channel.

In order to do so, the three effects that are subordinate to the bank risk-taking channel need to be incorporated. These effects arise from three assumptions. First, banking market competition determines how monetary policy decisions are reflected in interest rates on banks' assets. Dell'Ariccia, Laeven and Marquez assert that the resulting pass-through effect is stronger for more competitive markets. In response to monetary policy easing, the pass-through effect leads to an increase in bank risk-taking. As banks' unitary gross margin decreases after a reduction of the policy rate, costly monitoring of loans will be reduced as well. Second, limited liability protection in combination with deposits drives a wedge between the risk choice of a benevolent social planner and the risk choice of a leveraged bank. This exposes depositors to an expropriation risk as leveraged banks tend to undermonitor their investments. A reduction in the policy rate would reduce the interest rate on deposits. The reduction of banks' costs increases the margin obtainable and thus incentifies banks to monitor more. Third, information asymmetries concerning bank risk exist between the bank and its depositors. Information asymmetries are introduced as one way to defend interest rates on deposits that rise as banks become more leveraged. The bank deposit-ratio is optimized if the marginal costs of funding through bank capital and uninsured deposits are identical. On the one side, bank capital is costly due to an equity premium. On the other side, the expropriation risk for depositors increases in the deposit ratio. As undermonitoring increases in leverage, depositors will also increase their risk premium for interest rates on deposits. This introduces the optimal leverage effect. For a decrease in the policy rate, agency problems between the bank and its depositors are decreased and the bank can achieve a higher deposit-ratio.

These considerations have implications for how the model's microfoundations are developed. First, banks must be able to determine their risk-taking endogenously. Bank risk-taking should be negatively related to banks' profitability so as to introduce rent seeking behavior. Adhering to the notion of bank monitoring as a measure of bank risk, increasing marginal costs of monitoring are necessary to establish the desired relationship between bank risk-taking and bank margins. Second, banking market conditions reflected in competition need to be introduced into the DSGE model to accommodate a pass-through effect. Third, the existence of leverage and increases in policy rates should result in a wedge between the monitoring solution a benevolent social planner or unleveraged bank would choose, as compared to the solution a leveraged bank would choose for. Fourth, banks should be able to exercise some degree of control over their deposit ratio.

The current stance of the literature misses a stringent application of all implications of the Dell'Ariccia, Laeven and Marquez (2014) partial equilibrium framework within a general equilibrium context. Within this chapter, I attempt to fill this void. I illustrate how to incorporate all three effects into a general equilibrium model.

This chapter depicts the microeconomic foundations of a medium scale DSGE model, which incorporates the bank risk-taking channel. Since the three effects subordinate to the bank risk-taking channel depend on assumptions about banking markets, the model needs to encompass banking market competition, a wedge between the monitoring choices of leveraged and unleveraged banks, and an approach for selecting the optimal deposit share. Especially with regards to the first and third assumptions, some progress has been made outside of the bank risk-taking channel literature (Gerali et al. 2010, Hristov et al. 2014, Hülsewig et al. 2009). These models can generally provide a robust starting point for further modelling.

I take the estimated DSGE model of Gerali et al. (2010) as a backbone. The Gerali et al. (2010) model is selected for three reasons: First and foremost, the Gerali et al. model already features an elaborate banking sector. Each bank competing in the banking sector is divided into wholesale and two types of retail banks. The wholesale bank is tasked to ensure that the banks' balance sheet identity holds. Retail banking is subdivided into a unit for loans and a unit for deposits. Deposits are raised from households that are patient enough to save. The deposits together with bank capital are intermediated by the wholesale bank to the retail banks for loans. Loans are offered to entrepreneurs and impatient households. Borrowers' and depositors' ability to switch between banks can be parameterized per retail banking market. The resulting monopolistic power of retail banks allows them to adjust the respective interest rates and to obtain a mark-up (mark-down) relative to the risk-free rate in loan (deposit) markets. This market power is the foundation for banks' ability to reap a spread in the steady state. However, interest rate adjustments are costly to the bank (Rotemberg 1982).[1] This introduces interest rate stickiness.[2] The elasticity of substitution and interest rate stickiness determine the margins obtainable by banks either in the steady state

[1]While Calvo-style pricing has been the conventional form of introducing nominal rigidities into DSGE models for a long time, Rotemberg pricing has become more popular in the recent years, as it has some beneficial properties under certain conditions, e.g. a proximity to the zero-lower bound (cf. Born and Pfeifer (2020)). More generally, whereas agents behave heterogeneously under Calvo-style price setting and the model corrects in aggregation for the heterogeneity, under Rotemberg-style pricing agents face identical quadratic adjustment costs and therefore cast homogeneous decisions. However, both specifications can be parameterized to provide identical first order approximations around the steady state. By drawing on Rotemberg costs, banks render homogeneous choices, contrary to the application of Calvo-style pricing in similar contexts (Hristov et al. 2014, Hülsewig et al. 2009). Having homogenous interest rate choices results eventually in homogenous risk choices. This might be beneficial for future extensions of my work.

[2]The idea of interest rate stickiness to innovations in the risk-free rate originates from the interest rate channel literature. It can be traced back to the seminal work of Klein

or after a monetary policy shock. In consequence, the Gerali et al. model can proof helpful in terms of incorporating a pass-through effect.

Second, the wholesale bank optimizes the capital-ratio relative to an exogenous bank capital-ratio target. It faces quadratic adjustment costs for the bank capital-ratio relative to the exogenous target. Consequently, there is already an endogenous choice of the deposit ratio. As it will be argued, it is less a question of whether banks' optimal leverage decision is best defended with an equity premium in combination with information asymmetries or is best defended with a regulator enforcing a minimal capital-ratio target. Instead, the question is primarily one of calibration. Both approaches can provide similar optimality conditions.

Third, Gerali et al. (2010) provide estimates of relevant parameters for their model. I will use their Baysian posterior medians as a basis for my calibration.

The core innovation of my work is an extension of the Gerali et al. (2010) model for an endogenous choice of bank monitoring. I endow the wholesale bank with a monitoring technology in the spirit of Dell'Ariccia, Laeven and Marquez (2014). Through monitoring, the wholesale bank can determine the probability with which it collects the principal and the wholesale interest rate on loans from its retail branches. Likewise, the monitoring activity has implications for the probability with which the claims of retail banks for deposits and ultimately depositors are serviced. For the monitoring activity unfolded, the wholesale bank incurs increasing marginal costs.

Both endogenous choice variables (bank leverage and monitoring) of the wholesale bank provoke non-linear adjustment costs either around the exogenous bank capital-ratio target or the steady state level of monitoring. But the implications for the wholesale bank's choice are different. Deviations in bank leverage away from the steady state lead to quadratic increases in costs in both directions. Contrarily, deviations from the steady state level of monitoring result in non-linear influences on the costs of different signs. A reduction in monitoring reduces the cost burden to banks, whereas an in-

(1971) and Monti (1972). More recently, Scharler (2008) reasons that an incomplete pass-through from policy rates to retail rates can be defended on the basis of intermediation costs, which could lead to a smoothing of interest rates by banks, even in otherwise perfect financial markets. Güntner (2011) argues that the competitive landscape of the banking industry and standard cost arguments linked to the intermediation of banks drive the adjustment process and, hence, the spread between retail rates and policy rates. In this spirit, I consider sticky interest rates to be a result of market competition and not as a result of information asymmetries. An incomplete initial response of retail interest rates to policy rate changes is also well-documented in reduced form evidence (Mojon 2000, Sander & Kleimeier 2002, De Bondt 2005, Kok Sørensen & Werner 2006, Gropp et al. 2014, van Leuvensteijn et al. 2013, Leroy & Lucotte 2015).

crease in monitoring will increase the costs. Thus, the optimal choices with regards to the two choice variables might differ in response to shocks.

Through monopolistically competitive retail banks and interest rate stickiness, I establish a pass-through effect.[3] The endogenous choice of costly monitoring in combination with uninsured deposits and limited liability creates the necessary wedge in the choice for bank monitoring. Thus, a risk-shifting effect is incorporated in the model. Finally, drawing on quadratic adjustment costs for deviations of the capital-ratio from its exogenous target, I can replace the otherwise tedious incorporation of an equity premium and information asymmetries.[4] This short-cut leads to a largely similar solution and an endogenous optimal leverage effect for bank monitoring. Overall, the solution for bank monitoring in my model is identical to the solution of Dell'Ariccia, Laeven and Marquez (2014).

The remainder of the model is taken over from Gerali et al. (2010). It is fairly standard and shares most of the frictions incorporated in medium-scale DSGE models (Smets & Wouters 2003, Christiano & Eichenbaum 2005). However, since the Gerali et al. model is used as a cornerstone, I rely more heavily on Rotemberg-style adjustment costs to incorporate frictions in wage and price setting than it is the case in other DSGE models.

The adapted model depicted in figure 4.1 features a variety of economic agents. The economy is populated by two types of households, which derive utility from consumption and housing services. The major difference between the heterogeneous agents is to be found in a given agent's degree of impatience to consume. The heterogeneity in impatience to consume or to accumulate housing stock translates into a positive flow of funds through the banking sector in equilibrium. Patient households will save through uninsured deposits,[5] which will be used by the banking sector to provide loans to the impatient households and to the entrepreneurs. Each type of household offers a differentiated variant of labor. For each labor variation, there are two unions (one per type of household). The unions sell the labor to a perfectly competitive labor packer, who aggregates the labor into a homogenous labor index sold to entrepreneurs. Unions possess monopolistic price-setting

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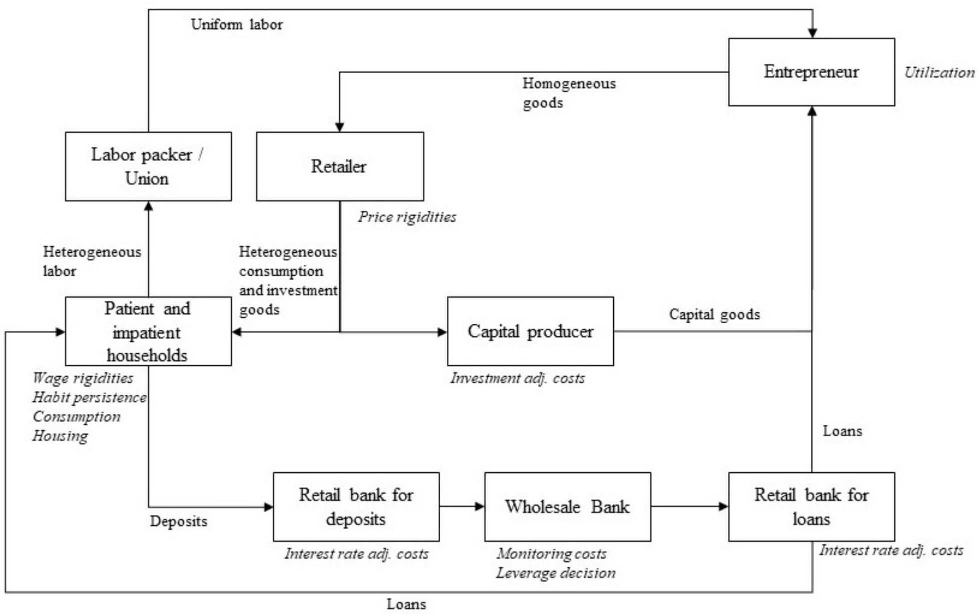
[3]This not only holds for loan markets, but also for deposit markets.

[4]I only consider the case, where banks' capital evolves as previous period's capital plus previous period's profits. The bank does not possess an endogenous choice over its capital.

[5]Although the funding instruments of the bank are called uninsured deposits, the reader may understand these as representing a wider class of short-term financing instruments, which are subject to runs and roll-over risks, such as asset-backed securities (ABS), Repos, or CDs, whose usage has grown significantly through the recent two decades (Shin & Shin 2011). Also the banking sector should be understood as comprising not only retail and commercial banks, but also investment banks and the shadow banking sector.

Figure 4.1: Model Structure



Note: Figure 4.1 depicts the structure of the model including the different rigidities (italic) and choice variables (roman) that the respective agent is subject to.
Source: own illustration

power and adjust the prices to maximize the utility of the household. As aforementioned, unions incur adjustment costs whenever the wages for the differentiated variant of labor are adjusted.

Entrepreneurs maximize their utility through consumption. They produce a homogeneous intermediate good in accordance to a conventional Cobb-Douglas (1928) production function. In production, the entrepreneur draws on the labor index and capital. In order to acquire the capital used in the subsequent period, entrepreneurs have to raise loans from banks. Next to entrepreneurs, there are two additional agents involved in producing goods within this stylized economy. Retailers act as final good producers. They acquire intermediate goods from entrepreneurs in a perfectly competitive market, augment them at no cost to a differentiated good, and then price them in a monopolistically competitive market. The price setting of retailers is subject to nominal rigidities introduced via Rotemberg costs once retailers want to index prices above (below) the lagged inflation rate. The other producing agent in the economy is a capital producer, who is employed to create a proxy for market prices of capital, i.e. Tobin's Q.

The following subchapters detail the microeconomic foundations of the model as well as its equations.

4.1 Microeconomic Foundations

4.1.1 Households

Patient households

The representative patient household indexed by p is a member of a continuum of households, $p \in [0, 1]$, of unit mass. Each household consumes, supplies labor to entrepreneurs via a union, and saves in (uninsured) deposits. I assume that there is a state-contingent insurance against wage risk[6] and that utility is additively separable.[7]

The representative household acts as a rational, utility maximizing agent. The patient household's objective is to maximize the stream of expected utility by choosing consumption, $C_t^P(p)$, housing, $H_t^P(p)$, labor hours, $N_t^P(p)$,

[6]The completeness of financial markets, either in the form of Arrow (1964) or Arrow-Debreu (1954) securities ensures that idiosyncratic risks introduced by the potentially heterogeneous income patterns are eliminated. Thus, the individual household's consumption is perfectly correlated with aggregate consumption.

[7]I further assume that a non-Ponzi scheme condition holds.

and retail deposits, $d_t(p)$:[8]

$$\max_{C_t^P(p),H_t^P(p),d_t(p)} E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\left(1-a^P\right) \varepsilon_t^C \log\left(C_t^P(p) - a^P C_{t-1}^P\right) \right. \\ \left. + \varepsilon_t^H j \log H_t^P(p) - \frac{N_t^P(p)^{1+\phi}}{1+\phi} \right]. \tag{4.1}$$

In the choice of consumption, the patient household is affected by habit persistence relative to the lagged consumption level of a representative household within the class of patient households. The parameter, a^P, reflects the degree of habit persistence.[9] For consumption and housing services, it is assumed that the household derives utility in accordance to a log-utility function, whereas an isoelastic variant is assumed for the disutility of labor. This is largely in line with most of the literature. Within the isoelastic utility function for labor, ϕ reflects the inverse Frisch elasticity of labor supply. The parameter j is used to scale the share of housing in the utility function. In the model, I assume that housing supply is exogenous.[10]

In order to assure positive flows to the bank, patient households are assumed to be characterized by a higher utils-discount factor, β_P, than impatient households, β_I, or entrepreneurs, β_E. The household's choice is subject to two different intratemporal shocks affecting the demand for consumption, ε_t^C, and housing, ε_t^H. In line with Gerali et al. (2010), I assume that these disturbances influence patient and impatient households homogeneously. Each disturbance follows an autoregressive (AR) process of order one of the type $\varepsilon_t^C = (1-\rho_{\varepsilon^C})\,\varepsilon^C + \rho_{\varepsilon^C}\varepsilon_{t-1}^c + e_t^{\varepsilon^C}$, where $e_t^{\varepsilon^C}$ represents an i.i.d. zero-mean normal random variable with standard deviation σ_C, ρ_{ε^C} is the autoregressive coefficient, and ε^C represents the steady state level to which ε_t^C will return to.

The household's maximization problem is subject to a budget constraint

[8] I abstract from money and do not include it in the utility function of the household, which does not make any difference to the solution of the model once utility is additively separable and monetary policy follows a Taylor rule to target interest rates and does not directly target money quantities. Consequently, I consider a limit case in which the economy becomes cashless and households do not derive utility from holding money as in Woodford (2003).

[9] The pre-multiplication by $1-a^P$ cancels out the effect in the steady state on the marginal utility of consumption, U_C. In the later application, I will impose the simplification that habit persistence is identical across patient and impatient households as well as entrepreneurs.

[10] The combined housing supply to both types of households sums up to unity.

expressed in real terms[11]

$$C_t^P(p) + q_t^H\left(H_t^P(p) - H_{t-1}^P(p)\right) + d_t(p)$$
$$= w_t^P N_t^P(p) + \left(1 + r_{t-1}^d\right) d_{t-1}(p)\,\pi_t^{-1} + T_t^P(p)\,. \tag{4.2}$$

The household needs to finance the expenses for consumption, expansion of housing stock relative to the previous period purchased at the real price of housing, q_t^H, and intratemporal saving in deposits, $d_t(p)$. On its savings, the household earns a nominal interest rate, r_t^d. The interest rate is determined in the period in which the savings are made. The household finances the expenses by labor income earned, where w_t^P reflects the real wage, past savings and potential lump-sum transfers, T_t^P, received. These lump-sum transfers may be understood as dividends issued by the production and banking sectors, which are owned exclusively by the patient households, plus a compensation to the union for negotiating the wage.[12] Within the budget constraint, the "gross inflation rate" (Gerali et al. 2010), π_t, is defined as $1 + \pi_t \equiv P_t P_{t-1}^{-1}$. For brevity, I skip those first-order conditions that are standard to medium-sized DSGE models.[13]

Impatient Households

Similar to patient households, impatient households, indexed by i, originate from a continuum of households of unitary measure, $i \in [0,1]$. Members of impatient households generally enjoy the same benefits in terms of state-contingent insurance, are subject to a non-Ponzi scheme condition, and act as fully rational, utility maximizing agents.

Not unlike patient households, impatient households maximize their objective function to optimize the utility that they derive from consumption, $C_t^I(i)$, housing, $H_t^I(i)$, and labor hours, $N_t^I(i)$:

$$\max_{C_t^I(i),H_t^I(i),l_t(I,d)} E_0 \sum_{t=0}^{\infty} \beta_I^t \Big[\left(1 - a^I\right)\varepsilon_t^C \log\left(C_t^I(i) - a^I C_{t-1}^I\right)$$
$$+\varepsilon_t^H j \log H_t^I(i) - \tfrac{N_t^I(i)^{1+\phi}}{1+\phi}\Big], \tag{4.3}$$

[11] Within writing the budget constraint, I follow the widely used approach of assigning the time stamp of the period to the interest rate and amounts of deposits and bonds, when the contract has been signed.

[12] In writing the source code, I use a slightly different notation and substitute $T_t^p(p) = \frac{\Pi_t^R}{\gamma^P}$, where γ_P represents the proportion of patient households in my economy.

[13] In appendix C, the interested reader can find a full set of first order conditions for all economic agents. In appendix D, the resulting steady state conditions are presented.

where a^I represents impatient households' habit persistence. The major difference to patient households rests in a generally smaller utility discount factor, β_I. The other parameters are defined in analogue to the ones of patient households. Impatient households are exposed to the same intratemporal disturbances, ε_t^C and ε_t^H, affecting utility derived from consumption and housing, respectively. The impatience to consume translates into a higher propensity of borrowing instead of saving reflected in the household's budget constraint

$$\begin{aligned} C_t^I(i) + q_t^H \left(H_t^I(i) - H_{t-1}^I(i)\right) + \left(1 + r_{t-1}^{LH}\right) l_{t-1}^{I,d}(i)\,\pi_t^{-1} \\ = w_t^I N_t^I(i) + l_t^{I,d}(i) + T_t^I, \end{aligned} \tag{4.4}$$

where the expenditures for consumption, C_t^I, expansion of housing stock, $H_t^I(i) - H_{t-1}^I(i)$, and repayment of previous period's loans, $l_{t-1}^{I,d}$, including the applicable real interest rate on loans, r_{t-1}^{LH}, granted to households, needs to equal the individual household's wage, w_t^I, times the labor hours worked, N_t^I, new loans raised, $l_t^{I,d}(i)$, and a potential transfer, T_t^I. Transfers for impatient households comprise only a union membership fee. The interest rate on the loans, r_t^{LH}, is agreed upon in the period when the loan is raised.

Next to the budget constraint, impatient households are additionally limited by a debt constraint imposed by the banking sector. The debt constraint establishes a ceiling on the household's ability to raise new debt. This ceiling is determined by banks relative to the discounted future value of impatient household's housing stock that the household pledges as collateral. Within the debt constraint, Gerali et al. (2010) introduce m_t^I, which serves as a stochastic loan-to-value ratio (LTV) for household's mortgages. Consequently, the debt constraint becomes

$$\left(1 + r_t^{LH}\right) l_t^{I,d}(i) \leq m_t^I E_t \left[q_{t+1}^H H_t^I(i)\,\pi_{t+1}\right]. \tag{4.5}$$

From a microeconomic banking literature perspective, m_t^I can be understood as the recoverage ratio of loans and the complement, $\left(1 - m_t^I\right)$, as the bank's unitary cost of liquidating the collateral in the case of household's default. Gerali et al. (2010) consider the LTV ratio to vary stochastically independent of the bank's condition or choices. They impose an exogenous stochastic AR(1) process in order to analyze the influence of credit supply restrictions on the real economy.[14] In order to preclude that the LTV ratio interferes with endogenous bank risk-taking, I keep it fixed at its steady state level m^I. This marks one divergence from the Gerali et al. model.

[14]While market data indicates swings in the LTV ratio applied by banks over the business cycle, which may serve as a proxy for bank risk-taking, I do not endogenize the LTV ratio and leave this for future extension of my work. This choice is motivated by the desire

4.1.2 Labor Market Dynamics

Nominal frictions in wage setting arise through the dynamics of the labor market embedded in the model. Each household supplies a differentiated variant of labor. For each variant of labor, there are two unions (one for patient and one for impatient households).[15] The unions provide the labor to a perfectly competitive labor packer. The labor packer draws on a standard constant elasticity of supply (CES) Digixt-Stiglitz (1977) aggregator function when combining the different forms of labor to a homogeneous labor index. The labor index is sold to entrepreneurs.

In the following discussion, I differentiate the two unions serving each type of households (i.e. impatient and patient households) by the index s, and the different variants of labor by n. Within negotiating the nominal wage for the individual household, the union (s, n) sets the wage $W_t^s(n)$ in such a way that it maximizes the utility of the respective household subject to a downward sloping demand function and quadratic adjustment costs. The downward sloping demand from the labor packer is given by

$$N_t^s(n) = \left(\frac{W_t^s(n)}{W_t^s}\right)^{-\varepsilon_t^N} N_t^s. \tag{4.6}$$

Within the demand function, the stochastic parameter ε_t^N may govern the time-varying markup in labor markets with innovations exogenous to the model.[16] Each union charges each member a lump-sum fee to cover the adjustment costs that it incurs in negotiating the wage. The respective objective function for unions becomes

$$\begin{aligned} &E_0 \sum_{t=0}^{\infty} \beta_s^t \left\{ U_{C_t^s(n)} \left[\tfrac{W_t^s(n)}{P_t} N_t^s(n) \right.\right. \\ &\left.\left. - \tfrac{\kappa^w}{2} \left(\tfrac{W_t^s(n)}{W_{t-1}^s(n)} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right)^2 \tfrac{W_t^s}{P_t} \right] - \tfrac{N_t^s(n)^{1+\phi}}{1+\phi} \right\}, \end{aligned} \tag{4.7}$$

and is subject to 4.6. Within the objective function, $U_{C_t^s(n)}$ reflects the marginal utility of consumption derived by the household through the wage change. The quadratic adjustment costs for wages are parameterized by κ^w and are incurred once the union attempts to achieve a wage that diverges

to stick as closely as possible to Dell'Ariccia, Laeven and Marquez's (2011) rationale. Consequently, I endogenize the bank's monitoring effort, but leave the LTV ratio determined by exogenous shocks.

[15] Each union represents one type of labor and there is one union for the particular labor type for each type of household.

[16] As before, the underlying process is assumed to follow a AR(1) process.

from a weighted average of steady state inflation, π, and lagged inflation, π_{t-1}, where the weights assigned are given by ι_w and $1-\iota_w$, respectively.[17] Imposing a symmetric equilibrium gives rise to the following non-linear wage-setting Phillips curves for the union serving patient households

$$\begin{aligned} &\kappa^w \left(\pi_t^{w^s} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right) \pi_t^{w^s} = \\ &\beta_s E_t \left[\frac{\lambda_{t+1}^s}{\lambda_t^s} \kappa^w \left(\pi_{t+1}^{w^s} - \pi_t^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_{t+1}^{w^s\,2}}{\pi_{t+1}}\right] + \left(1-\varepsilon_t^N\right) N_t^s + \frac{\varepsilon_t^N N_t^{s\,1+\phi}}{w_t^s \lambda_t^s}, \end{aligned} \tag{4.8}$$

where $\pi_t^{w^s}$ reflects the wage inflation rate, the term w_t^s is the real wage attributable to either of the two household types, and λ_t^s reflects the respective household type's Lagrange multiplier as defined in the previous sections.

4.1.3 Entrepreneurs

Each entrepreneur indexed by e is a member of a continuum with unitary mass, i.e. $e \in [0,1]$. The individual entrepreneur's objective function dictates to maximize the log-utility[18] derived from consumption, $C_t^E(e)$, relative to a lagged aggregate group consumption with habit persistence parameter a^E

$$\max_{K_t^E, L_t^E, u_t, N_t^E} E_0 \sum_{t=0}^{\infty} \beta_E^t \log\left(C_t^E(e) - a^E C_{t-1}^E\right). \tag{4.9}$$

The entrepreneur's maximization problem is subject to a budget constraint given by

$$\begin{aligned} &C_t^E(e) + w_t^P N_t^{E,P}(e) + w_t^I N_t^{E,I}(e) + \frac{1+r_{t-1}^{LE}}{\pi_t} l_{t-1}^E(e) + q_t^k K_t^E(e) \\ &+\psi\left(u_t(e)\right) K_{t-1}^E(e) = \frac{Y_t^E(e)}{x_t} + l_t^E(e) + q_t^k (1-\delta) K_{t-1}^E(e). \end{aligned} \tag{4.10}$$

The entrepreneur's choice variables are constituted by the demand for physical capital, $K_t^E(e)$, the loans acquired, $l_t^E(e)$, the choice of capital utilization, $u_t(e)$, and labor hired from the labor packers in a composite labor index, N_t^E. Within choosing the utilization rate of capital, the entrepreneur faces quadratic costs given by the conventional real cost function $\psi\left(u_t(e)\right) = \chi_1\left(u_t(e)-1\right) + \chi_2 (u_t(e)-1)^2$. In the cost function, χ_1 and χ_2 are parameters governing the adjustment costs and capital utilization is expected to be equal to one in the steady state.

[17]Put differently, similar to the dynamics of the Smeets and Wouters (2003) and Christiano et al. (2005) models, households benefit from a backward indexation of wages.

[18]Entrepreneurs do not receive utility from housing.

Within the budget constraint, the parameter δ represents the depreciation rate on physical capital, q_t^K is the unitary real price of capital, and x_t^{-1} is the relative price of the intermediate good produced by the respective entrepreneur given by $x_t^{-1} = P_t^I P_t^{-1}$. Each of the entrepreneurs has access to a Cobb-Douglas (1928) production technology of the form

$$Y_t^E(e) = A_t^E \left[K_{t-1}^E(e)\, u_t(e)\right]^\alpha N_t^E(e)^{1-\alpha}$$

to produce output, $Y_t^E(e)$. Therein, A_t^E is a stochastic AR(1) process governing TFP, α is the capital share in production, and $N_t^E(e)$ is an aggregate labor index composed of the labor inputs provided by patient, $N_t^{E,P}(e)$, and impatient households, $N_t^{E,I}(e)$, through the labor market. The share of patient households' labor input in the labor index is given by μ, so that the labor index becomes $N_t^E = \left(N_t^{E,P}\right)^\mu \left(N_t^{E,I}\right)^{1-\mu}$.

Similar to impatient households, entrepreneurs' debt contracts stipulate the triplet consisting of the debt granted to the entrepreneur, $l_t^E(e)$, the loan rate, r_t^{LE}, and an applicable debt constraint. The debt constraint governs the maximum amount of debt that the entrepreneur can acquire. The entrepreneur borrows against the discounted, depreciated amount of capital that can be liquidated in the subsequent period. Similar to the LTV ratio on impatient households' loans, also entrepreneurial debt is governed by a stochastic LTV ratio, m_t^E, in Gerali et al. (2010). The applicable borrowing constraint becomes

$$\left(1 + r_t^{LE}\right) l_t^E(e) \leq m_t^E E_t\left[q_{t+1}^k \pi_{t+1}(1-\delta) K_t^E(e)\right]. \tag{4.11}$$

I solve the model under the assumption that the borrowing constraint is binding at all times. Moreover, I affix the LTV ratio to its steady state value in the calculations to preclude that it interferes with responses in bank monitoring.[19]

Each entrepreneur sells the intermediate goods produced to a goods retailer. The retailer differentiates the goods and sells them either to the households or to a capital goods producer. From the capital producer, the entrepreneur also acquires the necessary capital for the subsequent period.

4.1.4 Retailers

The representative retailer, indexed by r, is a competitor in a monopolistically competitive market. Retailers can be understood as agents branding

[19] In contrast to Gerali et al. (2010), I consider the LTV to be a fixed parameter. It is not an endogenous variable.

an intermediate good and, thereby, differentiating it from the ones of the competitors. In order to do so, the retailer acquires intermediate goods at the wholesale price, P_t^W, from the entrepreneur. The branding is considered to be without costs for the retailer.

The differentiated product provides the retailer with price setting power in the market. However, prices are assumed to be sticky within the final goods market. Within pricing the goods, the retailer takes the demand for the specific variant of finished goods as given and applies a markup over the wholesale price. The downward-sloping demand for the single retailer's products is given by

$$Y_t(r) = \left(\frac{P_t(r)}{P_t}\right)^{-\varepsilon_t^Y} Y_t, \tag{4.12}$$

wherein ε_t^Y is the stochastic price elasticity of demand. In order to achieve price stickiness, Gerali et al. (2010) rely on Rotemberg-style (1982) adjustment costs. The retailer incurs the adjustment costs whenever the price set diverges from a weighted average of steady state inflation, π, and lagged inflation, π_{t-1}. Within the weighted average, the weight assigned to lagged inflation is parameterized by ι_P. The quadratic adjustment costs are parameterized by κ^P.

The representative retailer maximizes profits attributable to the patient household by choosing $\{P_t(r)\}_{t=0}^{\infty}$

$$\begin{aligned} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \Big[P_t(r) Y_t(r) - P_t^w Y_t(r) \\ - \tfrac{\kappa^p}{2} \left(\tfrac{P_t(r)}{P_{t-1}(r)} - \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} \right)^2 P_t Y_t \Big] \end{aligned} \tag{4.13}$$

subject to the demand constraint imposed by Eq. 4.12.

4.1.5 Capital Producers

The capital producing sector is populated by a continuum of individual firms, indexed by p, with unit mass, $p \in [0,1]$.[20] Capital good producers act in a perfectly competitive environment under a zero-profit condition. They acquire a quantity of capital from entrepreneurs, $\bar{K}_t$, at price Q_t^K which the

[20] The dynamics are closely related to those in the seminal Christiano et al. (2005) and Smeets and Wouters (2003) models, and the approach used in the New York Fed's (Del Negro, Eusepi, Giannoni, Sbordone, Tambalotti, Cocci, Hasegawa & Linder 2013) DSGE model for the US economy.

entrepreneurs have used and depreciated in the period.[21] Subsequently, the capital producers augment $\bar{K}_t$ by investments into new capital stock, I_t. In order to do so, they acquire a fraction of the final goods from retailers. At the end of the period, they sell the augmented capital, K_{t+1}, back to entrepreneurs at price Q_t^K. In the process of transforming final goods into capital, capital producers face quadratic adjustment costs of investment relative to past investment. Thus, they can exploit the following transformation technology[22]

$$K_{t+1} = \bar{K}_t + \left[1 - \frac{\kappa^i}{2}\left(\frac{I_t \varepsilon_t^{qk}}{I_{t-1}} - 1\right)^2\right] I_t, \tag{4.14}$$

where ε_t^{qk} is an exogenous shock process that influences the efficiency, with which consumption foregone is transformed into new capital good investments. The parameter κ^i governs the quadratic adjustment costs to investment.

The capital producer's problem, therefore, becomes

$$\max_{I_t} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^E \left[q_t^k \left(K_t - (1-\delta) K_{t-1}\right) - I_t\right], \tag{4.15}$$

which is subject to the constraint given by the evolution of capital. In the capital goods producer's objective function, $q_t^k \equiv \frac{Q_t^k}{P_t}$, reflects the real price of capital.

4.1.6 Banking Sector

The inclusion of endogenous bank risk-taking into the banking sector represents the main innovation of my model. Banks are pivotal to the functioning of the economy. They are the only source of financial intermediation and intertemporal substitution of consumption available to households and entrepreneurs.

[21] The capital purchased by the capital producer, $\bar{K}_t$, shall be understood as the capital installed at the beginning of the period, which has been exploited and depreciated over the period by the entrepreneur. Therefore, $\bar{K}_t = K_t (1-\delta)$.

[22] In general, there are two alternative approaches towards specifying the transformation technology. The approach chosen by Gerali et al. (2010) is in the tradition of Christiano, Eichenbaum and Evans (2005). An alternative setup has been proposed by Hayashi (1982). Hayashi measures the adjustment costs incurred relative to the current level of capital rather than to lagged investment. The approach of Christiano, Eichenbaum and Evans has a benefit in the sense that it offers the ability to generate hump-shaped, autocorrelated growth rates between capital and investment, while simultaneously maintaining the disentanglement of marginal product of capital from real interest rates. The Hayashi setup also offers the disentanglement, but fails to offer hump-shaped, autocorrelated growth rates.

The economy is populated by a continuum of banks. Banks are indexed by j ($j \in [0,1]$). Gerali et al. (2010) segregate banks into three units. Each bank j consists of a wholesale unit, a retail unit for deposits, and a retail unit for loans. The two retail branches offer differentiated loans and deposits to the bank's customers. Patient households save in a composite index of uninsured deposits. Likewise, impatient households and entrepreneurs finance themselves through a composite index of loans. There is one market for each of the three different types of products, i.e. deposits, loans for impatient households, and loans for entrepreneurs. Each index consists of different variants offered by the individual banks. The loan and deposit indices are constructed as CES portfolios of slightly differentiated products. For each of the three banking markets, there exists an individual elasticity of substitution. The difficulty with which households or entrepreneurs can substitute among different variants of loans (deposits) governs the mark-up (mark-down) relative to the risk-free rate in loan (deposit) markets.

On a retail bank level, differentiated financial products provide the retail branches with monopolistically competitive power. Retail banks act as price setters in their respective markets. If retail banks adapt their interest rates in response to changes in their environment,[23] they incur quadratic adjustment costs giving rise to an incomplete pass-through on impact.[24] Each retail branch faces a downward (upward) sloping demand for its loans (deposits) in the retail interest rate applicable.

On a wholesale level, each bank j operates in an environment of perfect competition. The wholesale banker cares about meeting the balance sheet identity. The stylized balance sheet consists of wholesale loans on the asset side. On the liabilities side, it consists of bank capital and uninsured deposits. Simultaneously, the wholesale bank manages the capital-ratio relative to an exogenously defined target ratio. Once the bank diverges from the exogenous capital-ratio target, it will incur quadratic costs. This establishes an optimal leverage effect in the Gerali et al. (2010) model.

My innovation rests in the additional introduction of an endogenous mon-

[23]Inter alia, these changes may contain innovations in the reference risk-free rate set by the monetary policy maker or changes in the loan markets forcing banks to alter their markups or markdowns relative to the risk-free rate as discussed in the subsequent subsections.

[24]Due to the formulation of the monitoring costs and costs for deviating from the exogenous capital-ratio target at the wholesale bank level and the formulation of interest rate stickiness in the form of Rotemberg (1982) costs at the retail bank level, banks cast homogeneous choices. As a consequence, little is lost if one imagines the banking sector consisting of one representative wholesale bank that is interested in homogeneous wholesale loans and wholesale deposits. These are subsequently differentiated by the retail banks at no cost. The solution would be isomorph.

itoring choice. In order to do so, I introduce the assumptions of Dell'Ariccia, Laeven and Marquez (2014) that banks are protected by limited liability and can only invest into risky loans. The riskiness of loans can be adjusted by the bank through monitoring. The wholesale bank is endowed with a monitoring technology to oversee its loans. Monitoring determines the probability with which loans (including interest) will be collected by the wholesale bank.[25] Within the individual bank j, there are no information asymmetries. Retail banks observe the wholesale banker's choice of monitoring. Thus, they will factor in the probability with which they either have to make payments on wholesale loans to the wholesale bank or receive payments on wholesale deposits from the wholesale bank into their own behavior. Thus, the monitoring that the wholesale bank exerts over wholesale loans channels through the retail bank without any further costs into retail loans. Monitoring is costly to the wholesale bank and provokes increasing marginal costs.

Since banks are protected by limited liability, there is no recourse to the bank capitalist. The wholesale banker will provide only a fractional return to retail banks for deposits once the monitoring effort is too small. This means that the monitoring choice also affects the payments made on wholesale deposits. However, the wholesale bank could also borrow from the central bank. Due to an arbitrage condition, the effective payments made to the retail bank for deposits will be intrinsically linked to the risk-free interest rate set by the monetary policy maker.

In my extended model, the wholesale bank will choose the capital-ratio and monitoring effort. Both will be intertwined through the influence of the deposit-ratio on the monitoring choice (optimal leverage effect). The difference between the two choice variables in the bank's optimization problem arises from monitoring's direct influence on bank's revenues and through a different specification of the costs. A reduction of the bank capital-ratio below the exogenous capital-ratio target will increase costs. A reduction in monitoring will reduce the probability with which loans are collected and will decrease monitoring costs.

In the following, I will first highlight the aggregation of heterogeneous retail bank products into homogeneous indices for loans and deposits. Subsequently, I will turn to the wholesale bank and its FOCs. These establish the optimal leverage effect and the risk-shifting effect. Thereafter, I will discuss the two retail branches. The combination of the wholesale bank's monitoring choice and the dynamics in the retail market for loans establish the pass-through effect. Finally, I will discuss the evolution of bank capital

[25] As a consequence, the wholesale bank's choice of monitoring is limited to be between 0 and 1.

through retained bank profits.

Aggregation of Loan and Deposit Demand

Aggregation in loan and deposit markets takes place in the context of a conventional Dixit-Stiglitz CES aggregator. Patient households, who are willing to save, invest in a composite CES basket of differentiated variants of deposits. Likewise, impatient households and entrepreneurs, who need to finance their investments into housing and capital respectively, will borrow a composite CES basket of differentiated loans. Within the CES baskets for impatient household's loans, entrepreneurial loans, and patient household's deposits, each unit supplied by the individual bank j represents a slightly differentiated variant with a stochastic elasticity of substitution given by ε_t^{LH}, ε_t^{LE}, and ε_t^{d}, respectively.

On the one side, the elasticities of substitution for loans govern a markup over the risk-free policy rate, r_t. Therefore, the elasticity of substitution for loans to households and entrepreneurs are both positive, i.e. $\varepsilon_t^{LH} > 1$ and $\varepsilon_t^{LE} > 1$. On the other side, the elasticity of substitution for deposits results in a markdown relative to r_t. The elasticity of substitution in deposit markets is negative, i.e. $\varepsilon_t^{D} < -1$.[26] Innovations to the stochastic processes that determine the individual elasticity of substitution will translate into changes in the intermediation margin (i.e. spreads between loan and deposit rates) of banks independent of monetary policy.

The demand for each bank's unitary contribution to the loan or deposit market depends on the overall size of the market and on the interest rate applied by bank j relative to the composite interest rate index applicable for the financial instrument.[27] The demand is thus respectively expressed by

$$l_t^I(j) = \left(\frac{r_t^{LH}(j)}{r_t^{LH}}\right)^{-\varepsilon_t^{LH}} l_t^I, \tag{4.16}$$

$$l_t^E(j) = \left(\frac{r_t^{LE}(j)}{r_t^{LE}}\right)^{-\varepsilon_t^{LE}} l_t^E, \tag{4.17}$$

[26]As will be shown, the elasticities of substitution govern a markup (markdown) for loans (deposits) relative to the policy rate leading to a positive intermediation margin in general. Innovations to the elasticities of substitution, which reduce the probability of households/entrepreneurs switching between banks, will, ceteris paribus, widen the spreads between loan and deposit rates.

[27]For loans to households, entrepreneurs and for deposits the rate indices are given by $r_t^{LH} = \left[\int_0^1 r_t^{LH}(j)^{1-\varepsilon_t^{LH}} dj\right]^{\frac{1}{1-\varepsilon_t^{LH}}}$, $r_t^{LE} = \left[\int_0^1 r_t^{LE}(j)^{1-\varepsilon_t^{LE}} dj\right]^{\frac{1}{1-\varepsilon_t^{LE}}}$, and $r_t^{D} = \left[\int_0^1 r_t^{D}(j)^{1-\varepsilon_t^{D}} dj\right]^{\frac{1}{1-\varepsilon_t^{D}}}$, respectively.

and

$$d_t(j) = \left(\frac{r_t^d(j)}{r_t^d}\right)^{-\varepsilon_t^d} d_t \tag{4.18}$$

for loans granted to impatient households, loans granted to entrepreneurs, and deposits bought by patient households. Within writing the demand equations, retail loans to impatient households and entrepreneurs as well as retail deposits are depicted by the lower-case letters, l_t^I, l_t^E, and d_t, respectively.

Wholesale Bank

In my model, wholesale banks act in an environment of perfect competition. As a consequence, a zero-profit condition holds. Each wholesale bank warrants that the balance sheet identity for the individual bank, j, holds. The wholesale bank raises wholesale deposits from households via the retail branch for deposits. It combines them with bank capital and intermediates the funds in the form of wholesale loans to the retail bank issuing loans. On a wholesale bank level, the balance sheet consists of wholesale loans, L_t,[28] on the asset side, as well as bank capital, K_t^B, and wholesale deposits, D_t, on the liabilities side.

Similar to Gerali et al. (2010), the wholesale bank faces quadratic costs, which are parameterized by κ^{KB}, once the capital-to-asset ratio, k_t, defined as $k_t(j) \equiv \left(1 - \frac{D_t(j)}{L_t(j)}\right) = \frac{K_t^B(j)}{L_t(j)}$, diverges from an exogenous capital-ratio target ratio, υ^B. The resulting cost component of the capital choice is given by $\frac{\kappa^{KB}}{2}\left(\frac{K_t^B}{L_t} - \upsilon^B\right)^2 K_t^B$.

Core to this paper is the extension of the model for endogenous bank risk-taking. In order to introduce bank risk-taking, the assumptions of Dell'Ariccia, Laeven and Marquez's (2014) partial equilibrium model need to be transferred to the general equilibrium context. The two new assumptions necessary are as follows. First, banks are protected by limited liability. Without any recourse to the bank capitalist, depositors will only receive the funds liquidated by the wholesale bank. Second, loans granted by banks are generally risky and thus require monitoring. Monitoring serves as a measure of bank risk-taking. It influences the proceedings to the wholesale bank. It provokes increasing marginal costs.

Next to the capital-ratio decision, the wholesale bank can decide on monitoring, m_t. Monitoring governs the probability with which the wholesale bank will collect wholesale loans (incl. interest payments) from the retail branch.

[28] I follow the convention that wholesale quantities are written in capital letters, whereas retail quantities are represented by minuscules.

The monitoring effort is known by the retail bank and will be forwarded to the ultimate borrower without any further costs.[29] At the wholesale level, monitoring is costly. Banks are endowed with a monitoring technology that provokes increasing marginal costs in monitoring. The monitoring costs are expected to be proportionate to the outstanding volume of wholesale loans, L_t, and are scaled by κ^m.[30] I thereby introduce the rational of a bank risk-taking channel in the spirit of Dell'Ariccia, Laeven and Marquez (2014) into the model.

In contrast to Dell'Ariccia, Laeven and Marquez (2014), I am primarily interested in the behavior of economic agents in response to shocks around the steady state. Consequently, the wholesale bank incurs increasing marginal costs relative to an exogenous steady state level of monitoring, m.[31] In comparison to the widely used approach of creating quadratic costs around a steady state value, I intend to preserve the sign of the deviation relative to the steady state level. Put differently, values of $m_t < m$ will reduce the wholesale bank's costs, whereas $m_t > m$ will lead to additional costs. The reference value of monitoring in the steady state, m, is subject to a shock ε_t^m. As a consequence, the cost component attributable to monitoring in the wholesale bank's objective function is given by $\frac{\kappa^m}{2}\left(m_t^2 - \frac{m^2}{\varepsilon_t^m}\right)$.

Next to the increasing marginal costs for monitoring around the steady state level, I assume that the wholesale bank incurs additional costs to achieve the steady state level of monitoring. These costs are scaled by ξ and are assumed to be proportionate to K_t^B. An innovation to ε_t^m will not only shift the reference point for the convex costs but will also shift the cost block incurred to achieve the steady state level. These costs are similar in their formulation to the depreciation on bank capital for managing the bank introduced in Gerali et al. (2010).

[29]While the choice of the capital-ratio is rivaling with m_t in terms of marginal costs from a wholesale bank's perspective, the bank-capital-ratio is neutral relative to the retail rates, r_t^D, r_t^{LH} and r_t^{LE}, whereas m_t has a direct influence on marginal benefits originating from the retail rates relative to the policy rate by degree one as will be shown in the subsequent paragraphs.

[30]The assumption that monitoring is tied to the loan volume outstanding warrants simplification in the steady state, but is also realistic in terms of Dell'Ariccia, Laeven and Marquez's (2014) arguments.

[31]An application of a pure-form Dell'Ariccia, Leaven and Marquez approach would lead to quadratic costs of the form $\frac{\kappa^m}{2}m_t^2$. The wholesale bank's FOC for monitoring would be unaffected, however, the optimality condition for R_t^L derived in Eq. 4.24 would result in $0 = m_t R_t^L - m_t R_t^D + \kappa^{KB}\left(\frac{K_t^B}{L_t} - \upsilon^B\right)^2\left(\frac{K_t^B}{L_t}\right)^2 - \frac{\kappa^m}{2}m_t^2$. Calibrating banks' monitoring costs so that monitoring matches empirical evidence would result in a spread between the rate on wholesale loans and deposits of approximately 10 percentage points per quarter, which is not reconcilable with empirical evidence.

The wholesale bank manager's choice variables consist of the monitoring effort that will be exerted, the amount of wholesale loans granted, and wholesale deposits that will be drawn on. The objective is to maximize the discounted sum of cash flows

$$\max_{m_t,L_t,D_t} E_0 \sum_{t=0}^{\infty} \Lambda^P_{0,t} \left[m_t \left(1+R^L_t\right) L_t - L_{t+1}\pi_{t+1} + D_{t+1}\pi_{t+1} - m_t \left(1+R^D_t\right) D_t \right.$$

$$\left. + K^B_{t+1}\pi_{t+1} - K^B_t - \tfrac{\kappa^{KB}}{2}\left(\tfrac{K^B_t}{L_t} - \upsilon^B\right)^2 K^B_t - \tfrac{\kappa^m}{2}\left(m^2_t - \tfrac{m^2}{\varepsilon^m_t}\right) L_t - \xi \tfrac{m^2}{\varepsilon^m_t} K^B_t \right]$$

subject to the balance sheet constraint $L_t = D_t + K^B_t$. Within the wholesale bank's objective function, the bank discounts future real cash flows at the patient household's discount factor, $\Lambda^P_{0,t}$. The discount factor reflects the ownership structure of the bank. Moreover, the bank takes both, the wholesale interest rate on deposit, R^D_t, and on loans, R^L_t, as given. Creating an unconstrained problem by plugging in the balance sheet identity twice (once in period t and once at $t+1$) leads to

$$\begin{aligned} \max_{m_t,L_t,D_t} \; & \Lambda^P_{0,t} \left[m_t R^L_t L_t - m_t R^D_t D_t + (m_t - 1) K^B_t \right. \\ & \left. - \tfrac{\kappa^{KB}}{2}\left(\tfrac{K^B_t}{L_t} - \upsilon^B\right)^2 K^B_t - \tfrac{\kappa^m}{2}\left(m^2_t - \tfrac{m^2}{\varepsilon^m_t}\right) L_t - \xi \tfrac{m^2}{\varepsilon^m_t} K^B_t \right]. \end{aligned} \tag{4.19}$$

Differentiating Eq. 4.19 with respect to the bank's choice variables results in the optimality conditions for the bank. The FOC for monitoring will be discussed first. Subsequently the FOCs for wholesale deposits and loans will be discussed.

The FOC for the wholesale bank's monitoring activity, m_t, is

$$m_t = \min\left(\frac{R^L_t L_t - R^D_t D_t + K^B_t}{\kappa^m L_t}, 1\right). \tag{4.20}$$

In writing the FOC, I assume that the bank will neither receive, nor will pay a return higher than the contractually agreed interest rate on either loans granted or deposits raised. Put differently, monitoring cannot take on values higher than one. This establishes the upper bound for monitoring. The bank's monitoring choice is also constrained to be larger than zero, since the bank capital-ratio, k_t, and monitoring cost parameter, κ^m, are strictly positive and $R^L_t \geq R^D_t$.[32]

[32]The condition that $R^L_t \geq R^D_t$ follows from the zero-profit condition of wholesale banks and the resulting wholesale bank spread discussed at the end of this subsection (cf. Eq. 4.26.

The optimality condition for monitoring bears close resemblance to the considerations of Dell'Ariccia, Laeven and Marquez (2014).[33] It also becomes apparent from the FOC that their basic rationales with regards to the bank's monitoring activity carry over to my DSGE model. Monitoring namely declines in the cost of monitoring, κ^m. Monitoring is positively related to the intermediation margin of the wholesale bank, $R_t^L L_t - R_t^D D_t$. Finally, monitoring increases in the equity stake, K_t^B, which the bank holds in the loan portfolio.

Log-linearizing around the steady state allows for a better understanding of the directions of influence. A log-linearization results in

$$\tilde{m}_t = \frac{R^L}{m\kappa^m}\tilde{R}_t^L - \frac{dR^D}{m\kappa^m}\tilde{R}_t^D - \frac{\left(1+R^D\right)d}{m\kappa^m}\tilde{d}_t, \tag{4.21}$$

wherein the tilde notation indicates percentage deviations from the steady state value of the respective variable. Within writing the log-linearization, I make use of the convention that steady state values are expressed without a time subscript. Moreover, d_t may be understood as a the deposit ratio, which is equal to $1 - k_t$ due to the balance sheet identity of the bank. In general the elasticities of influence are scaled by the steady state marginal costs of monitoring, $\kappa^m m$, in the respective denominator. Positive deviations in the wholesale interest rate on loans, $\tilde{R}_t^L$, will increase monitoring. Its influence is scaled by the steady-state interest rate on wholesale loans relative to the marginal cost of monitoring. The positive sign already shows that the model correctly incorporates the direction of the pass-through effect. In order to completely understand the pass-through effect, the microeconomic foundations of the retail bank for loans need to be considered as well. The dynamics embedded in the retail bank shape the behavior of retail loan rates. In order to issue loans, the retail bank needs to acquire the same loan volume as wholesale loans from the wholesale bank. As the demand curve for retail

[33] For comparison, the optimality condition of Dell'Ariccia, Laeven and Marquez (2014) reads

$$\widehat{q} = \min\left\{\frac{r_L - r_D\left(1-k\right)}{c}, 1\right\},$$

where $\widehat{q}$, r_L, r_D, k, and c are the optimal choice of monitoring, the gross interest rates on loans, the gross interest rate on deposits, the capital-ratio, and the monitoring costs in Dell'Ariccia, Laeven and Marquez's terminology, respectively. Exploiting the wholesale bank's balance sheet identity, the FOC can be rewritten as

$$m_t = \min\left(\frac{\left(R_t^L\right) - \left(R_t^D\right)\left(1-k_t\right) + k_t}{\kappa^m}, 1\right).$$

loans is downward-sloping in the retail rates, the dynamics in the retail rate become relevant for wholesale loan demand. The wholesale interest rate that the wholesale bank takes as given will be affected by the wholesale loan demand of the retail bank. Therefore, the pass-through effect will be discussed in the subsequent section in greater detail. Monitoring will decrease in increasing interest rates on wholesale deposits and the deposit ratio, $d_t = 1 - k_t$. The negative signs attached to deviations from the steady state in $\tilde{d}_t$ and $\tilde{R}_t^D$ reflect the expected directions of the optimal leverage and risk-shifting effect, respectively. The effects are similar to the ones discussed in Dell'Ariccia, Laeven and Marquez (2014), where an increase in the interest rate on loans improves the margin obtainable by banks and incentifies banks to increase monitoring. The opposite effect on the margin was exerted by higher interest rates on deposits and higher deposit ratios in their partial equilibrium context. Consequently, my model reflects their basic rationales in the wholesale bank's FOC.

Since I assume that banks face an exogenous capital-to-assets ratio target, I can abstract the bank's monitoring activity from information asymmetries between depositors and the bank. Moreover, arbitrage dictates that the wholesale deposit rate is given by

$$1 + R_t^D \equiv \frac{1 + r_t}{m_t}, \tag{4.22}$$

where r_t reflects the policy rate.[34] This arises since the bank can also borrow from the central bank's lending window,[35] and the central bank will enforce that banks repay their borrowings from the lending window with certainty. This resembles the arbitrage condition introduced by Dell'Ariccia, Laeven and Marquez (2014). It introduces the link between the wholesale bank's costs and monetary policy. Combining the arbitrage condition in Eq. 4.22 with the FOC for monitoring in Eq. 4.20 yields an explicit solution for m_t

$$m_t = \min\left\{\frac{1 + R_t^L}{2\kappa^m} \pm \sqrt{\left(\frac{1 + R_t^L}{2\kappa^m}\right)^2 - \frac{(1 + r_t)(1 - k_t)}{\kappa^m}}, 1\right\}, \tag{4.23}$$

[34]To show that this equivalence holds (holds for the FOC shown above), consider the alternative in which the bank borrows directly from the central bank. In this case, the wholesale bank's objective function Eq. 4.19, becomes $\max_{m_t, L_t, D_t} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[m_t\left(1 + R_t^L\right) L_t - (1 + r_t) D_t - K_t^B - \frac{\kappa^{KB}}{2}\left(\frac{K_t^B}{L_t} - \upsilon^B\right)^2 K_t^B - \frac{\kappa^m}{2} m_t^2\right]$. The analogue of Eq. 4.24 yields $m_t\left(1 + R_t^L\right) = (1 + r_t) - \kappa^{KB}\left(\frac{K_t^B}{L_t} - \upsilon^B\right)\left(\frac{K_t^B}{L_t}\right)^2$. Taking the difference to Eq. 4.24 proofs that the condition holds also at first order.

[35]This assumption is also introduced in the reference framework of Gerali et al. (2010) to assure that banks respond to monetary policy impulses.

whereby the additive case is relevant for my application. The additive case ensures that the directions of influence exerted by the individual variables are preserved.[36]

Risk-shifting Effect. In Dell'Ariccia, Laeven and Marquez (2014), limited liability protection granted to banks in combination with uninsured deposits created a wedge in the monitoring decision of banks. A benevolent social planner (or a fully equity-funded bank) would choose for a higher monitoring level than the manager of a deposit-funded bank would choose for. Consequently, banks tend to shift risks to uninsured depositors. The interest burden for deposits reduces the monitoring effort. A further analysis of Eq. 4.23 helps to better understand and helps to prove the wedge in monitoring behavior introduced by the risk-shifting effect as expressed in my model.

Dell'Ariccia, Laeven and Marquez (2014) showed that the benevolent social planner's choice of monitoring coincides with the choice of a purely equity financed bank. If a risk-shifting effect has indeed been correctly incorporated into my model, the presence of leverage, i.e. $(1-k_t)>0$, should then logically decrease monitoring. To prove this, consider the polar case in which the bank is purely equity financed, i.e. $K_t^B = L_t$. In this case, Eq. 4.23 collapses to $m_t = \min\left\{\frac{1+R_t^L}{\kappa^m}, 1\right\}$ as $k_t = 1$. The second term under the root vanishes. Once more, this is isomorph to the solution found by Dell'Ariccia, Laeven and Marquez for a benevolent social planner.[37] For the more general case of $K_t^B < L_t$, the second term under the root does not vanish. The existence of deposits introduces a wedge into the monitoring decision. Monitoring decreases, as r_t, k_t, and κ^m are expected to take on positive values.[38] Lower bank capital-ratios (i.e. higher deposit-ratios) and higher policy rates exacerbate the wedge in the monitoring choice of a leveraged bank relative to the one of a benevolent social planner. Leverage introduces a second order agency conflict between the bank and its depositors. This proves the existence of a risk-shifting effect in the model in close resemblance of the arguments presented by Dell'Ariccia, Laeven and Marquez.

[36]From Eq. 4.23, it becomes apparent that the reformulation does not change the directions of influence of the different variables on the monitoring decision. Keeping the respectively other variables constant, m_t is increasing in R_t^L. It is decreasing in r_t and the bank's leverage ratio, $(1-k_t) \equiv \left(1-\frac{K_t^B}{L_t}\right)$. Once more, the direction of the respective variable's influence on monitoring complies with the rationale developed by Dell'Ariccia, Laeven and Marquez (2014).

[37]The first best solution found for a benevolent social planner, $\hat{q}^{FB}$, in Dell'Ariccia, Laeven and Marquez's (2014) partial equilibrium context is given by $\hat{q}^{FB} = \min\left\{\frac{r_L}{c}, 1\right\}$, where r_L and c are the gross interest rate on loans and monitoring costs in Dell'Ariccia, Laeven and Marquez's terminology, respectively.

[38]This relies on the existence of a zero-lower bound.

Combining the FOC[39] for L_t and D_t yields an optimality condition analogue to the one of Gerali et al. (2010)[40]

$$m_t R_t^L = m_t R_t^D - \kappa^{KB}\left(\frac{K_t^B}{L_t} - \upsilon^B\right)^2\left(\frac{K_t^B}{L_t}\right)^2 + \frac{\kappa^m}{2}\left(m_t^2 - \frac{m^2}{\varepsilon_t^m}\right). \quad (4.24)$$

The optimality condition depicts that the spread between wholesale lending and deposit rates is intrinsically linked to the monitoring activity, m_t, and the bank's capital-to-loan ratio, k_t.

Optimal leverage effect. Dell'Ariccia, Laeven and Marquez (2014) rationalize the optimal leverage effect on the basis of information asymmetries, limited liability protection and an equity premium. In their partial equilibrium context, uninsured depositors are aware that limited liability will result in undermonitoring of loan portfolios by leveraged banks, and are thus aware that they are exposed to risk. This said, depositors are not able to directly observe the bank's monitoring effort. Since undermonitoring increases as bank leverage increases, depositors will infer monitoring from the deposit ratio. The interest rate on deposits is increasing in the deposit-ratio, as the spread over the risk-free rate widens. This creates an optimization problem for banks. The optimal solution is found once marginal costs of funding via deposits and bank capital are identical. Diverting from the optimal choice will result in increasing costs. On the one side, lower than optimal leverage choices are more expensive due to the equity premium. On the other side, higher than optimal leverage choices will increase costs due to an increasing spread on deposits.

It would be a tedious task to explicitly embed an equity premium and information asymmetries into the model. The exogenous bank capital-ratio target in combination with quadratic costs in Gerali et al. (2010) leads to a largely identical result as did the assumptions of Dell'Ariccia, Laeven and Marquez (2014). The exogenous bank capital target determines the steady state level of the bank capital-ratio. The wholesale bank faces quadratic costs around the exogenous capital-ratio target. In this environment, the wholesale bank will find the same optimum solution as a bank under the conditions imposed by Dell'Ariccia, Laeven and Marquez if υ^B is parameterized equivalently. I parameterize υ^B so that it matches bank capital requirements similar to the situation before and after the subprime crisis.[41]

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[39] The two FOCs read $0 = m_t R_t^D$ and $0 = m_t R_t^L + \kappa^{KB}\left(\frac{K_t^B}{L_t} - \upsilon^B\right)^2\left(\frac{K_t^B}{L_t}\right)^2 - \frac{\kappa^m}{2}\left(m_t^2 - \frac{m^2}{\varepsilon_t^m}\right)$ for D_t and L_t, respectively.

[40] It becomes apparent that my model encompasses the Gerali et al. model as a special case once $m = m_t = 1$ and $\varepsilon_t^m = 1$.

[41] For details on the parameterization of the model, see chapter 4.2. However, since I

Diverting from the exogenous target will have similar consequences upon the wholesale bank as the increasing spread due to information asymmetries as imposed in Dell'Ariccia, Laeven and Marquez. An excessively high capital-ratio will increase costs. In this first case, the quadratic costs might reflect the influence of an equity premium. This is similar to the considerations in the partial equilibrium model. An excessively low capital-ratio, which violates the exogenous capital requirement target, will increase costs, too. In the second case, the regulator may impose a penalty to enforce the capital-ratio target. Eventually, it is a question of how to parameterize κ^{KB}. It is the cost parameter for diverting from the exogenous capital-ratio target, which governs the optimal leverage effect in response to shocks.

The Gerali et al. (2010) model in its original version already contains an optimal leverage effect. Three elements are relevant to the functioning of the optimal leverage effect in the context of an endogenous bank risk-taking channel. First, monitoring should respond to the bank's leverage, so that the optimal leverage effect shifts the relative strength of the risk-shifting effect. Second, the monitoring decision of the bank should exert an influence on leverage. In Dell'Ariccia, Laeven and Marquez (2014) this was established through the information asymmetries. Third, the leverage decision should be linked to monetary policy. The deposit-ratio should be decreasing in the policy rate.

First, consider the response of monitoring to the bank's leverage. The wholesale bank's choice of leverage should shift the relative strength of the risk-shifting effect. Put differently, a decrease in the bank capital-ratio (i.e. an increase in the deposit-ratio) should increase the wedge between the solution for monitoring of a benevolent social planner and the solution for monitoring of the leveraged bank. Considering the influence on monitoring, Eq. 4.21 has depicted that a decrease in the capital-ratio will decrease monitoring. The influence of the capital-ratio on monitoring complies with Dell'Ariccia, Laeven and Marquez (2014).

In order to prove that the monitoring choice exerts an influence on the bank's leverage and that bank's leverage is linked to monetary policy decisions, consider the capital choice of a wholesale bank in response to deviations from the steady state. The effect of a decrease in monitoring relative to the steady state should impact the leverage decision of the bank. In Dell'Ariccia, Laeven and Marquez (2014), lower monitoring would increase the risk-premium, which in turn would reduce the deposit ratio. Moreover,

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am primarily interested in the response of the model to shocks, the steady state level is of subordinate importance. The response towards shocks will be governed primarily by the parameterization of the cost parameter, κ^{KB}.

Dell'Ariccia, Laeven and Marquez show that an increase in the interest rate on deposits, which is intrinsically linked to the risk-free rate, should reduce the quantity of deposits.[42] Having log-linearized Eq. 4.24 around the steady state, having exploited the fact that $\tilde{L}_t = \tilde{K}_t^B + \tilde{D}_t$, and having rearranged, the following formulation emerges:

$$\tilde{D}_t = \frac{mR^L - \kappa^m m^2}{z}\tilde{m}_t + \frac{mR^L}{z}\tilde{R}_t^L - \frac{mR^D}{z}\tilde{R}_t^D, \tag{4.25}$$

where $z = 2\kappa^{KB}k^2\left[2k^2 - 3\upsilon^B k + \left(\upsilon^B\right)^2\right]$. The auxiliary scale factor z results from the quadratic costs for deviating from the exogenous capital-ratio target. The log-linearization shows that bank's wholesale deposits will decrease in increasing interest rates on wholesale deposits. Since the interest rate on wholesale deposits is intrinsically linked to the risk-free interest rate set by the monetary policy maker (cf. Eq. 4.22), tightening monetary policy will exert the same effect as in Dell'Ariccia, Laeven and Marquez. It will cause a reduction in the banks' deposit-ratio. Also in line with the discussion in Dell'Ariccia, Laeven and Marquez, increasing monitoring and wholesale interest rates on loans will increase the share of deposit funding. Consequently, the model's formulation is expected to correctly replicate the optimal leverage effect of Dell'Ariccia, Laeven and Marquez in a general equilibrium context. Overall, it has been shown that the exogenous capital-ratio target establishes an optimal leverage effect. It yields similar predictions as do the considerations in Dell'Ariccia, Laeven and Marquez.

Lastly, the zero-profit condition in combination with the arbitrage condition over the policy rate allow for a wholesale bank spread to be formulated. The wholesale spread establishes the relationship between the interest rate on wholesale loans and the risk-free policy rate. Exploiting Eq. 4.24 in combination with the arbitrage condition, the wholesale bank's spread, S_t^W, can be defined as

$$\begin{aligned} S_t^W \equiv m_t R_t^L - r_t = -\kappa^{KB}\left(\tfrac{K_t^B}{L_t} - \upsilon^B\right)\left(\tfrac{K_t^B}{L_t}\right)^2 \\ + \tfrac{\kappa^m}{2}\left(m_t^2 - \tfrac{m^2}{\varepsilon_t^m}\right) + (1 - m_t)\,. \end{aligned} \tag{4.26}$$

The equation shows a negative relation exists between the banks' capital-to-loan ratio and the spread. Overall, weakly capitalized banks would tend to extend their leverage ratio, as margins widen. The FOC dictates a trade off. On the left-hand side, there is the intermediation margin between R_t^L and

[42] With fixed bank capital, it should reduce the bank's deposit-ratio.

the policy rate r_t. The intermediation margin represents the marginal benefit attributable to the wholesale bank for extending the lending activity. On the right-hand side, there are the marginal costs attributable to extended lending either due to overextending its leverage away from the exogenous target capital-ratio, υ^B, or from higher monitoring costs due to higher loan volumes. Despite the imposition of an exogenous capital-to-asset ratio, this trade off once more exemplifies that there is an optimal leverage effect embedded into the model.

Retail Bank for Loans

In order to issue loans to impatient households and entrepreneurs, the retail bank for loans needs to acquire a homogeneous real quantity of wholesale loans, $L_t(j)$. It acquires the wholesale loans at the monitoring-weighted wholesale interest rate, $m_t\left(1+R_t^L\right)$, from the wholesale bank. Since the retail bank for loans knows the monitoring effort of the wholesale bank with certainty, the retail bank will weigh the interest rate on wholesale loans by the probability with which it will be demanded to pay its debt plus interest to the wholesale bank. Higher monitoring will, ceteris paribus, increase the effective costs to the retail bank. The monopolistically competitive retail bank will set the interest rates on retail loans for impatient households and entrepreneurs. The effective costs on wholesale loans create the basis for the interest rate setting in retail markets.

After acquiring the wholesale loans, the retail bank can differentiate them without incurring additional costs to offer them as mortgages to impatient households, $l_t^I(j)$, or entrepreneurial loans, $l_t^E(j)$. For each of the two types of loans, the bank may apply different markups originating from the competition in the markets.[43, 44] The competition between monopolistically competitive retail banks (cf. Eq. 4.16 and Eq. 4.17) is governed by ε_t^{LH} and ε_t^{LE} in markets for loans to households and entrepreneurs, respectively. For changing the interest rate, the retail bank incurs quadratic adjustment costs relative to the previous period's interest rate. These adjustment costs are charged proportionately to the total return on loans held. The retail banks' adjustment costs are parameterized by κ^{LH} and κ^{LE} for loans to impatient households and entrepreneurs, respectively. This allows to adjust the pass-

[43]Incorporating individual interest rates per banking market allows for different degrees of market competition. This becomes relevant for the policy experiments considering the role of the pass-through effect in the application presented in chapter 6.

[44]The two markups are subject to shocks leading to time-varying markups, which are further discussed in subsection 4.1.9.

through for the different markets individually.[45]

By choosing $r_t^{LE}(j)$ and $r_t^{LH}(j)$, the retail bank maximizes

$$\max_{r_t^{LH}(j),r_t^{LE}(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \Big[\left(1 + r_t^{LH}(j)\right) l_t^I(j) + \left(1 + r_t^{LE}(j)\right) l_t^E(j)$$

$$-m_t \left(1 + R_t^L\right) L_t(j) \tag{4.27}$$

$$-\frac{\kappa^{LH}}{2}\left(\frac{r_t^{LH}(j)}{r_{t-1}^{LH}(j)} - 1\right)^2 r_t^{LH} l_t^I - \frac{\kappa^{LE}}{2}\left(\frac{r_t^{LE}(j)}{r_{t-1}^{LE}(j)} - 1\right)^2 r_t^{LE} l_t^E \Big]$$

subject to the identity $L_t(j) = l_t(j) = l_t^I(j) + l_t^E(j)$ and the two demand constraints given by Eqs. 4.17 and 4.16. Creating an unconstrained version, differentiating towards $r_t^{LH}(j)$, imposing a symmetric equilibrium, and dividing by l_t^I yields the optimality condition for loans to impatient households

$$\begin{aligned} 0 = \left(1 - \varepsilon_t^{LH}\right) + \frac{\varepsilon_t^{LH}}{r_t^{LH}}\left[m_t R_t^L - (1 - m_t)\right] - \kappa^{LH}\left(\frac{r_t^{LH}}{r_{t-1}^{LH}} - 1\right)\frac{r_t^{LH}}{r_{t-1}^{LH}} \\ +\beta_P E_0 \frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^{LH}\left(\frac{r_{t+1}^{LH}}{r_t^{LH}} - 1\right)\left(\frac{r_{t+1}^{LH}}{r_t^{LH}}\right)^2 \frac{l_{t+1}^I}{l_t^I} \end{aligned} \tag{4.28}$$

Likewise, differentiating towards $r_t^{LE}(j)$ eventually yields

$$\begin{aligned} 0 = \left(1 - \varepsilon_t^{LE}\right) + \frac{\varepsilon_t^{LE}}{r_t^{LE}}\left[m_t R_t^L - (1 - m_t)\right] - \kappa^{LE}\left(\frac{r_t^{LE}}{r_{t-1}^{LE}} - 1\right)\frac{r_t^{LE}}{r_{t-1}^{LE}} \\ +\beta_P E_0 \frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^{LE}\left(\frac{r_{t+1}^{LE}}{r_t^{LE}} - 1\right)\left(\frac{r_{t+1}^{LE}}{r_t^{LE}}\right)^2 \frac{l_{t+1}^E}{l_t^E} \end{aligned} \tag{4.29}$$

Again, the retail bank applies the patient households' discount factor, $\Lambda_{0,t}^P$, which translates into $\frac{\lambda_{t+1}^P}{\lambda_t^P}$ in the optimality conditions, wherein λ_t^P is the patient households' Lagrange multiplier on the budget constraint.[46]

[45] This allows to incorporate individual interest rate adjustment costs for the two different markets. These adjustment costs will provide the opportunity to parameterize interest rate stickiness differently across markets. On the one side, this appeals to evidence of the interest rate channel literature, wherein it has been documented that the pass-through is more complete for non-financial firms on impact than for households (Belke, Beckmann & Verheyen 2013). On the other side, it also allows to investigate the role of market competition in the context of the subordinate pass-through effect in greater detail.

[46] In the original Gerali et al. (2010) specification, the comparable FOC for loans to impatient household was given by $1 - \varepsilon_t^{LH} + \varepsilon_t^{LH}\frac{R_t^L}{r_t^{LH}} - \kappa^{LH}\left(\frac{r_t^{LH}}{r_{t-1}^{LH}} - 1\right)\frac{r_t^{LH}}{r_{t-1}^{LH}} +$

Log-linearizing Eqs. 4.28 and 4.29 yields

$$\begin{aligned}\tilde{r}_t^{LH} &= \tfrac{\kappa^{LH}}{\varepsilon^{LH}-1+(1+\beta_P)\kappa^{LH}}\tilde{r}_{t-1}^{LH} + \tfrac{\kappa^{LH}\beta_P}{\varepsilon^{LH}-1+(1+\beta_P)\kappa^{LH}}E_t\tilde{r}_{t+1}^{LH} \\ &+ \tfrac{\left(\varepsilon^{LH}-1\right)m}{\varepsilon^{LH}-1+(1+\beta_P)\kappa^{LH}}\tilde{R}_t^{L} - \tfrac{1}{\varepsilon^{LH}-1+(1+\beta_P)\kappa^{LH}}\tilde{\varepsilon}_t^{LH} + \tfrac{\left(R^L-1\right)\left(\varepsilon^{LH}-1\right)}{\varepsilon^{LH}-1+(1+\beta_P)\kappa^{LH}}\tilde{m}_t\end{aligned} \tag{4.30}$$

and

$$\begin{aligned}\tilde{r}_t^{LE} &= \tfrac{\kappa^{LE}}{\varepsilon^{LE}-1+(1+\beta_P)\kappa^{LE}}\tilde{r}_{t-1}^{LE} + \tfrac{\kappa^{LE}\beta_P}{\varepsilon^{LE}-1+(1+\beta_P)\kappa^{LE}}E_t\tilde{r}_{t+1}^{LE} \\ &+ \tfrac{\left(\varepsilon^{LE}-1\right)m}{\varepsilon^{LE}-1+(1+\beta_P)\kappa^{LE}}\tilde{R}_t^{L} - \tfrac{1}{\varepsilon^{LE}-1+(1+\beta_P)\kappa^{LE}}\tilde{\varepsilon}_t^{LE} + \tfrac{\left(R^L-1\right)\left(\varepsilon^{LE}-1\right)}{\varepsilon^{LE}-1+(1+\beta_P)\kappa^{LE}}\tilde{m}_t,\end{aligned} \tag{4.31}$$

respectively. By solving the equations forward, it becomes apparent how retail interest rates on loans will depend on deviations from the steady state value of (i) current and (ii) expected future retail interest rates, (iii) the wholesale interest rate on loans, (iv) monitoring, and (v) shocks to the elasticity of substitution in the respective market.

Pass-through effect. In the context of Dell'Ariccia, Laeven and Marquez (2014), the pass-through effect determines how changes in the policy rate feed into the interest rate on loans. In their context, the interest rate on loans influences banks' margins. Higher margins incentify banks to increase monitoring. The strength of the pass-through effect depends on the degree of market competition. This should hold for the steady state and in response to shocks.

In the previous section, I have shown that the intrinsic link between the wholesale interest rate on loans and monitoring complies with Dell'Ariccia, Laeven and Marquez's (2014) rationale. The log-linerarized FOC for monitoring (cf. Eq. 4.21) has depicted that monitoring increases in the wholesale interest rate obtainable. Subsequently, competition needs to be factored in. In this context, the retail bank for loans, which subsumes the microeconomic foundations of banking market competition, acts as a propagator / accelerator for the wholesale interest rate on loans. Retail banks are confronted with

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$\beta_P E_t\left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^{LH}\left(\frac{r_{t+1}^{LH}}{r_t^{LH}}-1\right)\left(\frac{r_{t+1}^{LH}}{r_t^{LH}}\right)^2\frac{l_{t+1}^I}{l_t^I}\right]$. The one for entrepreneurial loans would result in an analogous formulation, which is left skipped for the sake of brevity. Comparing the two optimality conditions reveals that both interest rates will trade at a discount in my model relative to the Gerali et al. model as long as the wholesale bank's monitoring activity does not equal one. If monitoring equals one, my model collapses to the Gerali et al. specification. Relative to the Gerali et al. specification, where the interest costs to the retail bank for loans are governed by $1+R_t^L$, my model adds additional dynamics through m_t. Since m_t is declining in r_t (cf. Eq. 4.21), it might add an attenuating effect relative to Gerali et al. in response to a monetary policy shock.

a downward-sloping loan demand. Changes in retail rates affect retail loan demand. However, changes in retail rates are subject to the microeconomic foundations of the retail bank. The retail loan demand has consequences for the intra-bank market for wholesale loans. Retail banks need to acquire a wholesale loan volume identical to the volume of retail loan demand. The microeconomic foundations for retail loans thus affect the wholesale interest rate. From the perspective of the pass-through effect, it is of particular interest how deviations from the steady state of the interest rate on wholesale loans, monitoring, and the elasticity of substitution in the respective market are linked to the retail rate on loans.

Innovations to the elasticity of substitution in the respective market will influence the retail interest rate on loans. Larger spreads between the risk-free policy rate and the retail rate on loans will be obtainable if borrowers find it more difficult to switch between different banks (i.e. a lower elasticity of substitution). This complies with evidence originating from the interest rate channel literature, which shows that less competitive markets are characterized by higher steady state margins (Leroy & Lucotte 2015, van Leuvensteijn et al. 2013). This also complies with the evidence found in chapter three.[47] If the mark-up on loans over the risk-free rate is higher, loan volumes will then decrease due to the downward-sloping loan demand in retail markets. In the intra-bank market for wholesale loans, the increase in the mark-up will decrease the wholesale interest rate on loans. This mechanism establishes the correct direction for the pass-through effect.

Dell'Ariccia, Laeven and Marquez (2014) have also shown that interest rates for loans depend positively on the risk-free rate. In the previous section, it has been established that the wholesale interest rate on loans positively depends on the risk-free interest rate. It needs to be shown that the retail rates on loans also react accordingly. The interest rates for both types of retail loans react to changes in the wholesale interest rate with the expected

[47]There is, however, a difference to Dell'Ariccia, Laeven and Marquez (2014) in my model. They assume that the bank is concerned with its retail rate on loans directly and that monitoring responds to market conditions in retail markets. In my application, the usual approaches toward modeling nominal frictions by assigning different functions to individual agents leads to a focus of the wholesale bank on the wholesale rate on loans instead. Here, $m_t \left(1 + R_t^L\right)$ enters into the retail bank's objective function. Although the retail rate on loans does not directly factor in into the monitoring decision of the wholesale bank, it may affect the monitoring choice in two ways. First, it may result in lower retail loan demand and, hence, in lower wholesale loan demand. The wholesale interest rate on loans may respond, which will indirectly influence the monitoring choice in the same period. Second, through higher bank profits and in combination with the evolution of bank capital (cf. Eq. 4.35), bank capital will increase in the subsequent period. This will exert a lagged effect on monitoring.

positive sign. As the wholesale interest rate on loans increases in response to positive deviations in the policy rate from its steady-state value, the response in retail rates to policy rate changes is as expected. The response depends positively on the steady state level of competition in the respective market and steady state monitoring. It also depends inversely on the adjustment costs. The positive dependence on the steady state level of competition reflects the expected effect of widening margins in the policy rate as supposed by Dell'Ariccia, Laeven and Marquez. The dependence on adjustment costs also indicates that the retail interest rate will respond slower to changes in monetary policy in markets that are characterized by higher interest rate stickiness.

Likewise, the adjustment to changes in monitoring depends positively on the steady state level of competition and the wholesale interest rate, as well as inversely on adjustment costs. Overall, the relationships between the retail interest rates and deviations in the respective variables comply with the expectations. More competitive markets will exhibit lower spreads over the policy rate. Consequently, they will show a smaller monitoring effort. This works through the link to the wholesale interest rate and through a reduced accumulation of bank capital (cf. Eq. 4.35). Likewise, higher interest rate stickiness will depress margins in response to monetary policy shocks.

Assuming that the adjustment costs become nil, i.e. $\kappa^{LH} = 0$ or $\kappa^{LE} = 0$, the pricing equation collapses to the conventional markup over the monitoring-weighted wholesale loan rate given by

$$r_t^{LH} = \frac{\varepsilon_t^{LH}}{\varepsilon_t^{LH} - 1} \left[m_t R_t^L + (1 - m_t) \right] \tag{4.32}$$

and

$$r_t^{LE} = \frac{\varepsilon_t^{LE}}{\varepsilon_t^{LE} - 1} \left[m_t R_t^L + (1 - m_t) \right] \tag{4.33}$$

for loans granted to either impatient households or entrepreneurs, respectively.[48]

Exploiting Eqs. 4.32 and 4.33 in combination with Eq. 4.26 yields the spreads for the two types of loans over the policy rate

$$S_t^{LH} \equiv r_t^{LH} - r_t = \frac{\varepsilon_t^{LH}}{\varepsilon_t^{LH} - 1} S_t^W + \frac{1}{\varepsilon_t^{LH} - 1} r_t + \frac{\varepsilon_t^{LH}}{\varepsilon_t^{LH} - 1} (1 - m_t)$$

and

$$S_t^{LE} \equiv r_t^{LE} - r_t = \frac{\varepsilon_t^{LE}}{\varepsilon_t^{LE} - 1} S_t^W + \frac{1}{\varepsilon_t^{LE} - 1} r_t + \frac{\varepsilon_t^{LE}}{\varepsilon_t^{LE} - 1} (1 - m_t)$$

[48]The same applies for the steady state or a situation where $r_t^{LE} = r_{t-1}^{LE} = r_{t+1}^{LE}$

As in Gerali et al. (2010), the spread for the respective retail loan rate increases in the policy rate set by the monetary policy maker, in the market power of the bank in the respective market and the wholesale spread. Once again, this illustrates that an increase in banks' market power will, ceteris paribus, positively affect the spread that banks reap. The wholesale spread, in turn, depends on the bank's capital-to-loan ratio (as in Gerali et al. (2010)), but also on the wholesale bank's monitoring activity, which again hinges on the monitoring costs.

Retail Bank for Deposits

The retail branch for deposits of bank j enters the deposit market and acquires $d_t(j)$ units of retail deposits from households, which are passed on to the wholesale branch. In the subsequent period, the wholesale unit remunerates the retail unit at the monitoring-weighted wholesale rate for deposits, $m_t\left(1+R_t^D\right)$. By setting $r_t^d(j)$, the retail unit not only incurs quadratic adjustment costs relative to the previous period parameterized by κ^d, it also maximizes its profits

$$\max_{r_t^d(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,1}^P \left[m_t\left(1+R_t^D\right) D_t(j)\right. \tag{4.34}$$
$$\left. -\left(1+r_t^d(j)\right) d_t^P(j) - \frac{\kappa^d}{2}\left(\frac{r_t^d(j)}{r_{t-1}^d(j)}-1\right)^2 r_t^d d_t\right]$$

subject to its demand equation for deposits

$$d_t(j) = \left(\frac{r_t^d(j)}{r_t^d}\right)^{-\varepsilon_t^d} d_t$$

and the identity $D_t(j) = d_t^P(j) = d_t(j)$, wherein ε_t^d is the elasticity of substitution in deposit markets. Creating an unconstrained problem and imposing a symmetric equilibrium, the optimality condition for the retail bank for deposits becomes

$$0 = -\frac{\varepsilon_t^d}{r_t^d}\left(m_t R_t^D + (m_t-1)\right) + \left(\varepsilon_t^d - 1\right) - \kappa^d\left(\frac{r_t^d}{r_{t-1}^d}-1\right)\left(\frac{r_t^d}{r_{t-1}^d}\right)$$
$$+\beta_P E_t \frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^d\left(\frac{r_{t+1}^d}{r_t^d}-1\right)\left(\frac{r_{t+1}^d}{r_t^d}\right)^2 \frac{d_{t+1}}{d_t}.$$

Exploiting the arbitrage condition once more, the formulation becomes identical to Gerali et al. (2010)

$$0 = -\frac{\varepsilon_t^d}{r_t^d}(r_t) + \left(\varepsilon_t^d - 1\right) - \kappa^d \left(\frac{r_t^d}{r_{t-1}^d} - 1\right)\left(\frac{r_t^d}{r_{t-1}^d}\right)$$

$$+\beta_P E_t \frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^d \left(\frac{r_{t+1}^d}{r_t^d} - 1\right)\left(\frac{r_{t+1}^d}{r_t^d}\right)^2 \frac{d_{t+1}}{d_t}.$$

As a consequence of the arbitrage condition, banks' monitoring choice may directly work through the asset side of banks' balance sheets in the period of the shock but may hold indirect effects for deposits through the balance sheet identity of wholesale banks. The FOC results in a log-linearized form given by

$$\tilde{r}_t^d = \frac{\kappa^d}{1+\varepsilon^d+(1+\beta_P)\kappa^d}\tilde{r}_{t-1}^d + \frac{\beta_P\kappa^d}{1+\varepsilon^d+(1+\beta_P)\kappa^d}E_t\tilde{r}_{t+1}^d$$

$$+\frac{1+\varepsilon^d}{1+\varepsilon^d+(1+\beta_P)\kappa^d}\tilde{r}_t - \frac{1}{1+\varepsilon^d+(1+\beta_P)\kappa^d}\tilde{\varepsilon}_t^d,$$

where the tilde denotes percentage deviations from steady state values. By solving forward, the following becomes apparent. The adjustment in the retail rate to policy rate changes depends inversely on the adjustment costs and positively on the steady state level of banking market competition (the inverse of ε^d). Assuming once again that adjustment costs become nil, i.e. $\kappa^d = 0$, the retail interest rate on deposits becomes a function of the monitoring weighted return on wholesale interest rates on deposits. By extension this becomes a function upon the policy rate, that is given by

$$\frac{\varepsilon_t^d}{\left(\varepsilon_t^d - 1\right)} r_t = r_t^d$$

The formulation above clearly depicts that the retail deposit interest rate relative to the policy rate trades at a markdown in dependence on the market structure, ε_t^d.

Bank profits

In the model, bank capital evolves purely through retained profits[49] in accordance to

$$K_t^B \pi_t = K_{t-1}^B + \omega^B \Pi_{t-1}^B, \tag{4.35}$$

[49] This allows us to circumvent the otherwise necessary requirement to embed an endogenous equity premium into the general equilibrium model.

where ω^B reflects the dividend policy of the bank.[50] The dividend policy is considered to be time-invariant and exogenous to the wholesale bank manager's choice. Π_t^B are the cumulative profits generated by the retail bank branches and the wholesale bank. In the sense of Dell'Ariccia, Laeven and Marquez (2014), I only consider the limiting case, in which banks are constrained in their ability to raise or redeem bank capital.

Consolidating the intra-bank transaction leads to a formulation of bank profits, Π_t^B, which is given by

$$\Pi_t^B = r_t^{LH} l_t^H + r_t^{LE} l_t^E - r_t^d d_t - \tfrac{\kappa^{KB}}{2}\left(\tfrac{K_t^B}{l_t^H + l_t^E} - \upsilon^B\right)^2 K_t^B - \tfrac{\kappa^m}{2}\left(m_t^2 - \tfrac{m^2}{\varepsilon_t^m}\right) L_t$$

$$-\xi \tfrac{m^2}{\varepsilon_t^m} K_t^B - \tfrac{\kappa^{LH}}{2}\left(\tfrac{r_t^{LH}}{r_{t-1}^{LH}} - 1\right)^2 r_t^{LH} l_t^I - \tfrac{\kappa^{LE}}{2}\left(\tfrac{r_t^{LE}}{r_{t-1}^{LE}} - 1\right)^2 r_t^{LE} l_t^E$$

$$-\tfrac{\kappa^d}{2}\left(\tfrac{r_t^d}{r_{t-1}^d} - 1\right)^2 r_t^d d_t.$$

The formulation used is largely similar to the formulation of Gerali et al. (2010). They assume a linear depreciation rate on bank capital to capture the resources consumed in managing the bank. I replace this by a cost component for steady state monitoring introduced before.

4.1.7 Public Sector

The policy maker is assumed to follow a conventional Taylor (1993) rule, which ignores bank risk[51]

$$1 + r_t = (1 + r)^{1-\phi_R}(1 + r_{t-1})^{\phi_R}\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi(1-\phi_R)}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_y(1-\phi_R)} \varepsilon_t^r \qquad (4.36)$$

where ϕ_π and ϕ_y represent the weights that the policy maker attaches towards inflation and output growth, respectively. Moreover, the monetary policy maker partly-adjusts the policy rate around a steady state policy rate, r. Lastly, the monetary policy shock, ε_t^r is assumed to $\varepsilon_t^r \sim N(0, \sigma_r^2)$.

[50] The dividend policy serves a similar purpose as the finite survival schemes used in other models, such as Angeloni, Faia and Lo Duca (2015), which are meant to preclude that banks are able to circumvent the necessity to raise deposits from patient households and can finance loans through bank capital entirely.

[51] In a potential extension of my work, an incorporation of bank risk-taking into the Taylor rule is possible to capture the shift in monetary policy conduct (Cecchetti 2016). Likewise, an introduction of the ZLB is possible by extending the Taylor rule for a period of a fixed policy rate. This quasi-peg replicates the most important feature of the proximity to the ZLB, i.e. the non-responsiveness of the policy rate.

4.1.8 Market Clearing Conditions

The goods markets clear under the condition that

$$Y_t = C_t^P + C_t^I + C_t^E + Q_t^K \left[K_t - (1-\delta) K_{t-1}\right] + \psi(u_t) K_{t-1} + \Xi_t,$$

where Ξ_t subsumes the adjustment costs incurred in the model and Y_t reflects aggregate output. The housing market is characterized by an exogenously fixed housing supply, $\bar{h}$, so that the clearing condition becomes $\bar{h} = H_t^P + H_t^I$. Likewise, the banking markets clear so that $L_t = l_t^H + l_t^E$.

4.1.9 Shocks

As already stated before, most of the shocks in the model follow an AR(1) process. In total, there are 12 shock processes given by

$$\varepsilon_t^C = 1 - \rho_{\varepsilon^C} + \rho_{\varepsilon^C}\varepsilon_{t-1}^C + e_t^C$$

$$A_t = 1 - \rho_A + \rho_A A_{t-1} + e_t^A$$

$$\varepsilon_t^H = 1 - \rho_{\varepsilon^H} + \rho_{\varepsilon^H}\varepsilon_{t-1}^H + e_t^H$$

$$m_t^I = (1 - \rho_{m^I}) m^I + \rho_{m^I}\left(m_{t-1}^I\right) + e_t^{m^I}$$

$$m_t^E = (1 - \rho_{m^E}) m^E + \rho_{m^E}\left(m_{t-1}^E\right) + e_t^{m^E}$$

$$\varepsilon_t^{LE} = (1 - \rho_{\varepsilon^{LE}}) \varepsilon^{LE} + \rho_{\varepsilon^{LE}}\varepsilon_{t-1}^{LE} + e_t^{\varepsilon^{LE}}$$

$$\varepsilon_t^{LH} = (1 - \rho_{\varepsilon^{LH}}) \varepsilon^{LH} + \rho_{\varepsilon^{LH}}\varepsilon_{t-1}^{LH} + e_t^{\varepsilon^{LH}}$$

$$\varepsilon_t^D = (1 - \rho_{\varepsilon^D}) \varepsilon^D + \rho_{\varepsilon^D}\varepsilon_{t-1}^D + e_t^{\varepsilon^D}$$

$$\varepsilon_t^Y = (1 - \rho_{\varepsilon^Y}) \varepsilon^Y + \rho_{\varepsilon^Y}\varepsilon_{t-1}^Y + e_t^{\varepsilon^Y}$$

$$\varepsilon_t^N = (1 - \rho_{\varepsilon^N}) \varepsilon^N + \rho_{\varepsilon^N}\varepsilon_{t-1}^N + e_t^{\varepsilon^N}$$

$$\varepsilon_t^m = (1 - \rho_{\varepsilon^m}) \varepsilon^m + \rho_{\varepsilon^m}\varepsilon_{t-1}^m + e_t^{\varepsilon^m}$$

where terms without a subscript indicate steady state values and the autoregressive coefficients, ρ_{ε^C}, ρ_A, ρ_{ε^H}, ρ_{m^I}, ρ_{m^E}, $\rho_{\varepsilon^{LH}}$, $\rho_{\varepsilon^{LE}}$, ρ_{ε^D}, ρ_{ε^Y}, ρ_{ε^N}, and ρ_{ε^m} are assumed to guarantee stationarity of the processes.

4.2 Parameterization

The parameter calibration of the DSGE model is largely consistent with the values chosen or estimated for the calibrated parameters of most medium-sized DSGE models. While it is generally possible to estimate parameters via Baysian inference,[52, 53] I use the parameters estimated in Gerali et al. (2010) and do not estimate them myself. The parameters determine the steady state values and the responses to shocks. I orient myself along Gerali et al. for two reasons. First, as the model is intended to replicate the dynamics of the Euro Area, their estimated parameters provide reliable guidance.[54] Second, I intend to preserve comparability to their paper. My extension of the model adds one endogenous choice variable. By keeping the parameter values already included in their specification constant, I can identify the influence of monitoring on the model's propagation mechanism. Similar to Gerali et al., I apply constant rescaling of the populations of different agents.

Households. The parameters governing households' behavior are set in the following way. For both types of households, the average weight assigned to housing within the respective utility function, j, is equal to 0.2.[55] Due to constant rescaling the shares of household types (as well as entrepreneurs and banks) are set equal to unity, i.e. $\gamma_I = \gamma_P = \gamma_E = \gamma_B = 1$. I also set the habit persistence parameter for consumption to be identical across

[52]Gerali et al. (2010) use Baysian inference to estimate the parameters of the banking market without endogeneous bank risk-taking. Subsequently, I will rely on their estimated posterior median values particularly with regards to the parameters for the banking sector.

[53]There are generally different approaches towards specifying a DSGE model. One approach uses Bayesian inference to estimate the model's parameters based on underlying data. Another popular approach parameterizes the model so that the parameter values resemble characteristics observed in the economy and compares the resulting IRFs to a VAR comparable. In what follows, I adhere to the latter approach. The reason can be found in the multiplicity of connotations attached to the bank monitoring (Hellwig 1991) and the scarcity of data. Bank monitoring as discussed in the context of the DSGE model can be understood as the probability of loan collection by the bank. However, this probability will be the cumulative outcome of the screening, preventing, and auditing / punishing functions subordinate to bank monitoring. Data on the probability of loan collection is generally unavailable. Only a fraction of bank monitoring is observable. This precludes the usage of Bayesian inference to estimate the parameters attached to the bank's monitoring decision.

[54]Since the Euro Area's dynamics are intended to be replicated, also the VAR evidence of chapter 3 can serve as a comparable for the responses in bank risk-taking. The calibration is oriented towards a replication of the dynamics within the Euro area as a whole and would require adaptation to capture the dynamics of individual markets (showing idiosyncratic dynamics within the Euro area) or markets outside of the Euro area.

[55]This resembles the value chosen by Iacoviello and Neri (2010).

households (and entrepreneurs), $a^P = a^I = a^E$. The value is set to 0.867.[56] The inverse Frisch elasticity of labor supply, ϕ, for both households is set to 1.0. Aggregate housing supply to both types of households, $\bar{h}$ is exogenously fixed by assumption. The parameter value is set to 1.0. In order to ensure a positive flow of funds in banking markets, I calibrate the utility discount factors differently across household types. The patient households' discount factor, β_P, is calibrated so that a steady state deposit rate is obtained that is close to the M2 deposits' long-run average interest rate in the Euro area of approximately 2 per cent.[57] Therefore, β_P is set to 0.9943. The utility discount factor for impatient households, β_I, is set in the range of previous work by Iacoviello (2005) and Iacoviello and Neri (2010) to 0.975. Finally, I set the LTV ratio, m^I, to 0.7. This reflects a typical value given the estimates for mortgages obtained across different Euro area countries contributed by Calza et al. (2013).

Entrepreneurs. For the entrepreneur, the utility discount factor is set identically to the one for impatient households, $\beta_E = 0.975$. The LTV ratio, m^E, is equal to 0.35. This reflects the middle of Gerali et al.'s (2010) estimates obtained based on the loan-to-equity value of non-financial firms using either long-term or short-term debt. Their respective estimated values are 0.41 and 0.2.[58] In compliance with most of the DSGE literature, the depreciation rate per year is set to be 10 per cent, i.e. $\delta = 0.025$ as the model is calculated at a quarterly frequency. Within the Cobb-Douglas production function, the capital share, α, and the patient households' labor share in production, μ, are calibrated to be 0.25 and 0.8, respectively. The latter one is calibrated as in Iaccoviello and Neri (2010) to reflect the wage's proportion for unconstrained households. Since the costs of capital utilization follow an analogue formulation as in Schmitt-Grohé and Uribe (2005), χ_1 is given by the steady state marginal product of capital relative to the markup. This results in a parameter value of 0.05. Similar to most of the literature χ_2 is equal to $0.1\chi_1$.

Capital producer. For the capital producer, the parameter governing the Rotemberg adjustment cost of investment, κ^i, is set to approximately 10.03. In a first order approximation, this is close to but slightly higher than

[56] A summary of the values used for the various parameters can be found in table 4.1

[57] Over the time frame considered the annualized monthly average interest rate has been around 2 per cent for the time period before the Lehman collapse. I believe that this time period is more adequately reflecting patient households' preferences.

[58] This value is also somewhat lower than the estimate of Iacoviello (2005) of 0.89 for US non-financial companies, where just commercial real estate was considered as a collateral, but also close to the broader definition of collateral of Christensen et al. (2007, 2016) of 0.32 for Canada.

the Calvo parameterization used in Smeets and Wouters (2003). The degree of backward indexation of wages, ι_w, is set to approximately 0.3.

Labor Packer. Turning to the labor packer, there are three additional parameters that need to be chosen. The steady state elasticity of labor, ε^N, is chosen in such a way that it results in a markup of 15 per cent. This is comparable to most of the values used in the literature. The resulting parameter value is 5. For the wage adjustment costs, κ^w, I use a calibrated value of 107.352.

Retailer. In the case of the retailer, I calibrate the steady state elasticity of demand, ε^Y, in line with most of the literature's parameter choices. It is chosen in such a way that it reflects a markup of 20 per cent. This translates into a parameter value of 6. The Rotemberg cost parameter for price adjustment, κ^P, is close to 33.77 and the backward indexation of prices, ι_P, equals 15.81 per cent. These parameter values concur with the estimates of, among others, Hülsewig et al. (2009) at a first order approximation to their Calvo approach.

Banking Sector. As research into DSGE models incorporating financial market frictions (and especially banks) is currently in an infant stage, comparable values for the calibration of banks' parameters are rare. In order to maintain comparability, I thus strongly rely on the insights generated by Gerali et al. (2010). Since the bank is owned by patient households, the bank uses the patient households' utility discount factor.[59]

The capital-to-asset ratio is set such that it is slightly above the bank-capital requirements as applied under Basel II, i.e. $\upsilon^B = 0.09$. The Rotemberg costs incurred by the bank once it deviates from the target capital-ratio, κ^{KB}, are set to reflect Gerali et al.'s (2010) Bayesian estimates of the posterior distribution's median of approximately 8.91.

The newly added element within the banking sector has been the endogenous monitoring choice. From the assumptions on banks' monitoring, it becomes apparent that monitoring can be understood as the probability with which the wholesale bank recovers the fund loaned (incl. interest).[60] On an annualized basis, the expected default frequency of non-financial corporate loans has remained below one percent for most of the time considered within the European Union (European Central Bank 2020). Consequently, I set the quarterly steady state level of monitoring m to 0.997. This matches the annualized probability.

The three parameters ε^D, ε^{LH}, and ε^{LE} govern (in conjunction with m)

[59]In writing the source code, I introduce a dedicated discount factor for the bank, to potentially allow for a bank-specific utility discount factor, β_b for future research.

[60]See the assumptions in Dell'Ariccia, Laeven and Marquez (2014), which carried over to Eq. 4.19.

the mark-down on deposits and mark-ups on loans relative to the monetary policy maker's policy rate. Due to the arbitrage condition (cf. Eq. 4.22), the mark-down for deposits is isomorph to the specification of Gerali et al. (2010). Similar to their calibration, ε^D is chosen to reflect a 125 bp annualized mark down on deposits. This results in a parameter value of approximately -1.46. For loans, the level of steady state monitoring influences the mark-up relative to the risk-free rate. However, m is close to 1 in the steady state. As a result, the distortion introduced by the extension of the model for endogeneous bank risk-taking remains relatively small. I set the elasticity of substitutions for both loan markets, ε^{LE} and ε^{LH}, to 2.93, which is in the middle of the two values used in Gerali et al. (2010). This keeps the mark-up on loans comparable to their calibration and matches the characteristics of the Euro area. Since the elasticity of substitution is identical in both loan markets, differences in the steady state are primarily driven by the LTV ratios. Based on the elasticities of substitution for deposit, mortgage and entrepreneurial loan markets, the respective mark-downs and mark-ups, mk_d^{ss}, mk_{LH}^{ss}, and mk_{LE}^{ss}, can be calculated to be 0.59, 1.52 and 1.52, respectively.

Based on the mark-ups and mark-down and the steady state monitoring, I can parameterize the cost components of monitoring. The parameter values ensure that bank monitoring converges to the steady state value. Overall, since m is close to unity, banks are expected to be efficient in monitoring. This renders both cost components comparably small. The two parameters, ξ and κ^m, are set to equal approximately 0.167 and 0.09, respectively.

Lastly, I parameterize the Rotemberg cost parameters characterizing the interest rate stickiness for the three retail bank markets. The values for κ^d, κ^{LH}, and κ^{LE} are, 2.78, 9.04, and 7.98, respectively.[61]

Public Sector. The inflation rate in the non-stochastic steady state is one. This also enters via the parameter π into the public sector's Taylor rule. The AR parameters for the weight attached to inflation, ϕ_π, and the weight attached to the output gap, ϕ^y, are close to 2.00 and 0.30. The parameter values ensure determinacy of the model. The parameter for the interest rate smoothing around the steady state policy rate, ϕ^R, is 0.75.

Table 4.1 summarizes the parameters plus the AR coefficients for the shock processes.[62]

[61]Given the smaller value for κ^{LE}, my model reflects the more complete pass-through for non-financial firms found in the interest rate channel literature. See among others, Belke, Beckmann and Verheyen (2013) and de Bondt (De Bondt 2005).

[62]Based on the parameter values, the non-stochastic steady state values can be derived. These will provide the initial values for the model and, thereby, the starting point for the estimation procedures. The calculation of the non-stochastic steady state can be obtained from appendix D.

Table 4.1: Calibration Values of Parameters

Parameter	Description	Value
	Calibrated Parameters	
	Households	
β_p	Utility discount factor of patient households	0.9943
β_i	Utility discount factor of impatient households	0.9750
j	Weight of housing in households' utility function	0.2000
ϕ	Inverse Frisch elasticity of labor supply	1.0000
a^p	Habit persistence of consumption of patient households	0.8670
a^i	Habit persistence of consumption of impatient households	0.8670
$\bar{h}$	Fixed housing supply	1.0000
γ_p	Share of patient households	1.0000
γ_i	Share of impatient households	1.0000
ν	Wage share of patient households	0.8000
ι_w	Backward indexation of wages	0.3002
m_i^{ss}	Loan-to-Value ratio of impatient households in the steady state	0.7000
	Entrepreneurs	
β_e	Utility discount factor of entrepreneurs	0.9750
α	Capital share in production function	0.2500
χ_1	Parameter 1 governing utilization costs	0.0500
χ_2	Parameter 2 governing utilization costs	0.0050
m_e^{ss}	Loan-to-Value ratio of entrepreneurs in the steady state	0.3500
a^e	Habit persistence of consumption of entrepreneurs	0.8600
γ_e	Share of entrepreneurs	1.0000
δ_K	Depreciation rate of capital	0.0250
κ^i	Rotemberg costs for investment	10.0306
	Labor Packer	
ϵ_n	Steady state elasticity of labor	5.0000
κ^w	Wage adjustment cost	107.3520
	Retailers	
ε_y^{ss}	Steady state level of price elasticity of demand	6.0000
κ^p	Rotemberg costs for price adjustment	33.7705
ι_p	Backward indexation of prices	0.1581
	Banks	
β_b	Utility discount factor banks	0.9943
γ_b	Share of bankers	1.0000
ε_d	Elasticity of substitution between deposits	−1.4603
ε_{lh}	Elasticity of substitution between loans to households	2.9328
ε_{le}	Elasticity of substitution between loans to entrepreneurs	2.9328
mk_d^{ss}	Steady state deposit rate markup	0.5935
mk_{LH}^{ss}	Steady state loan rate for households' markup	1.5174
mk_{LE}^{ss}	Steady state loan rate for entrepreneurs' markup	1.5174
r_{LE}^{ss}	Steady state interest rate on loans to entrepreneurs	0.0238
r_{LH}^{ss}	Steady state interest rate on loans to household	0.0238
r_k^{ss}	Steady state real return on capital	0.0500
υ^B	Banking capital-ratio over loans (Basel II)	0.0900
κ^{KB}	Rotemberg costs for deviations from optimal bank capital	8.9148
κ^m	Rotemberg costs for bank monitoring	0.0914
xi	Steady state cost component for monitoring	0.1673
m_{ss}	Steady state bank monitoring level	0.9970
κ^d	Rotemberg costs for deposit interest rate adjustment	2.7754
κ^{LE}	Rotemberg costs for entrepreneurial loan interest rate adjustment	7.9801
κ^{LH}	Rotemberg costs for household loan interest rate adjustment	9.0443
	Public Sector	
ρ_{ib}	AR parameter in Taylor rule	0.7505
ϕ_π	Weight attached to inflation in Taylor rule	2.0038
ϕ_y	Weight attached to output in Taylor rule	0.3033
π_{ss}	Steady State inflation	1.0000

Table 4.1: Calibration Values of Parameters

Parameter	Description	Value
	Calibrated Parameters	
r_ib^{ss}	Steady State policy rate	0.0097
	Shock Processes	
ρ^{ϵ_c}	AR coefficient for consumption preferences	0.3860
ρ^{A}	AR coefficient for TFP	0.9382
ρ^{ϵ_h}	AR coefficient for housing preferences	0.9219
ρ^{m_i}	AR coefficient for households' LTV ratio	0.9224
ρ^{m_e}	AR coefficient for entrepreneurs' LTV ratio	0.9013
ρ^{ϵ_y}	AR coefficient for price markup	0.2942
ρ^{mk_d}	AR coefficient for deposit markdown	0.8927
$\rho^{mk_{le}}$	AR coefficient for entrepreneurs' loan markup	0.8739
$\rho^{mk_{lh}}$	AR coefficient for households' loan markup	0.8512
ρ^{ϵ_q}	AR coefficient for MEI	0.5717
ρ^{ϵ_l}	AR coefficient for wage markup	0.5962
ρ^{ϵ_m}	AR coefficient for bank monitoring	0.8130

Note: Table 4.1 summarizes the calibrated parameter values comprised in my model. The values are largely similar to the estimated results of Gerali et al. (2010) for two reasons. First, the estimated parameter values provide reliable guidance for critical parameter values to preserve a match of the Euro area characteristics. And second, I preserve comparability to Gerali et al. to identify the influence of monitoring on the capabilities of the model.

4.3 Calculation Procedure

The simulations of the model are carried out using Dynare (Adjemian, Bastani, Juillard, Karame, Maih, Mihoubi, Perendia, Pfeifer, Ratto & Villemot 2011) version 4.6.1 running under Matlab 2019b. The stochastic simulations are calculated as log-linear Taylor series approximations around the steady state. As the algorithm used to find the steady state, Dynare's default algorithm is used. All equations are specified in exponents. The algorithm segregates the model into recursive blocks and solves these individually.[63]

[63] I also check the results' robustness using Sims's (2001) solver, but the results are virtually indifferent.

Chapter 5

Properties of a DSGE Model with Bank Risk-Taking

Within this chapter, I investigate two aspects. First, I am interested in how the introduction of endogenous bank risk-taking into the DSGE model alters the transmission of monetary policy and total factor productivity shocks. Second, I examine how the model's endogenous bank risk-taking responds to the two shocks.

Bank monitoring has been introduced as an endogenous choice variable and as a measure of bank risk-taking. The extension adds additional complexity to the model originally developed by Gerali et al. (2010). The original model without bank risk-taking is already an elaborate medium-scale DSGE model. It features heterogeneous agents, financial market frictions, and financial intermediation. In order to visualize how bank risk-taking alters the transmission of shocks, I contrast the impulse-response functions (IRFs) of the model with endogenous bank risk-taking (blue) to an otherwise identically specified model without bank risk-taking (red).[1] Since bank monitoring is removed in the latter case, it does not appear in the IRF of bank monitoring.

5.1 Monetary Policy Shock

Figure 5.1 depicts the impulse-response functions to a 50 bp perturbation to the policy rate, r_t. The responses produced by the model with endoge-

[1]For the sake of brevity, I provide the IRFs of the Gerali et al. (2010) model calibrated to match the posterior medians estimated by the authors as a benchmark. The reader interested in a decomposition of the respective influences of the various financial accelerator-type channels may refer to Gerali et al. (2010) for an in-depth treatment.

nous bank risk-taking (blue) are qualitatively fairly standard. They are in line with most of the IRFs produced by medium-scale New-Keynesian type models. In response to monetary policy tightening, real output contracts and inflation falls. The real interest rates for households and entrepreneurs increase. Interest rate stickiness results in the expected incomplete pass-through into retail rates on impact. Real asset prices decline. However, capital and housing prices react differently. The decline in asset prices and the increase in interest rates tighten borrowers' credit constraints. As a result, loan demand contracts. Bank profits increase since the increase in the spread outweighs the reduction in intermediated volume.[2] As bank capital grows initially and loan volume contracts, the bank capital-ratio increases. After three quarters, banks' spreads start to decline and turn negative after five quarters. In combination with an increase in intermediated funds, the bank capital-ratio declines again and the response turns negative after nine quarters.

Bank monitoring initially responds with an increase to monetary policy tightening. Thus, monetary policy tightening results in the expected immediate decline in bank risk-taking. The increase in bank monitoring lasts for four quarters before it turns negative. The hump-shaped reversion in bank monitoring bottoms out seven quarters after the initial monetary policy shock. The IRF for bank risk-taking closely resembles the path of monetary policy. However, the response in bank risk-taking appears to precede the response in monetary policy by approximately one quarter.[3] The observed pattern in bank risk-taking can be explained by the three subordinate effects. At a wholesale bank level, the initial response in the interest rate on wholesale loans is smaller than the increase in the policy rate due to interest rate stickiness in the retail markets for loans. In isolation, the pass-through effect would be outweighed by the risk-shifting effect. However, the increase in the bank capital-ratio tilts the relative strength of the two effects. As the bank capital-ratio increases, the influence of the risk-shifting effect on the choice for bank monitoring declines. Consequently, the combination of the pass-through effect and the optimal leverage effect lead to the initial reduction bank risk-taking in response to monetary policy tightening. The model's IRFs correctly reflect the functioning of the bank risk-taking channel and the underlying rationales (Dell'Ariccia et al. 2014).

In terms of the endogenous response in bank risk-taking, the model should produce IRFs similar to those of the reduced form evidence of my VAR.

[2] The patterns resemble the ones found for the response of bank margins in the VAR evidence of chapter three.

[3] The policy rate reaches its lowest point after eight quarters.

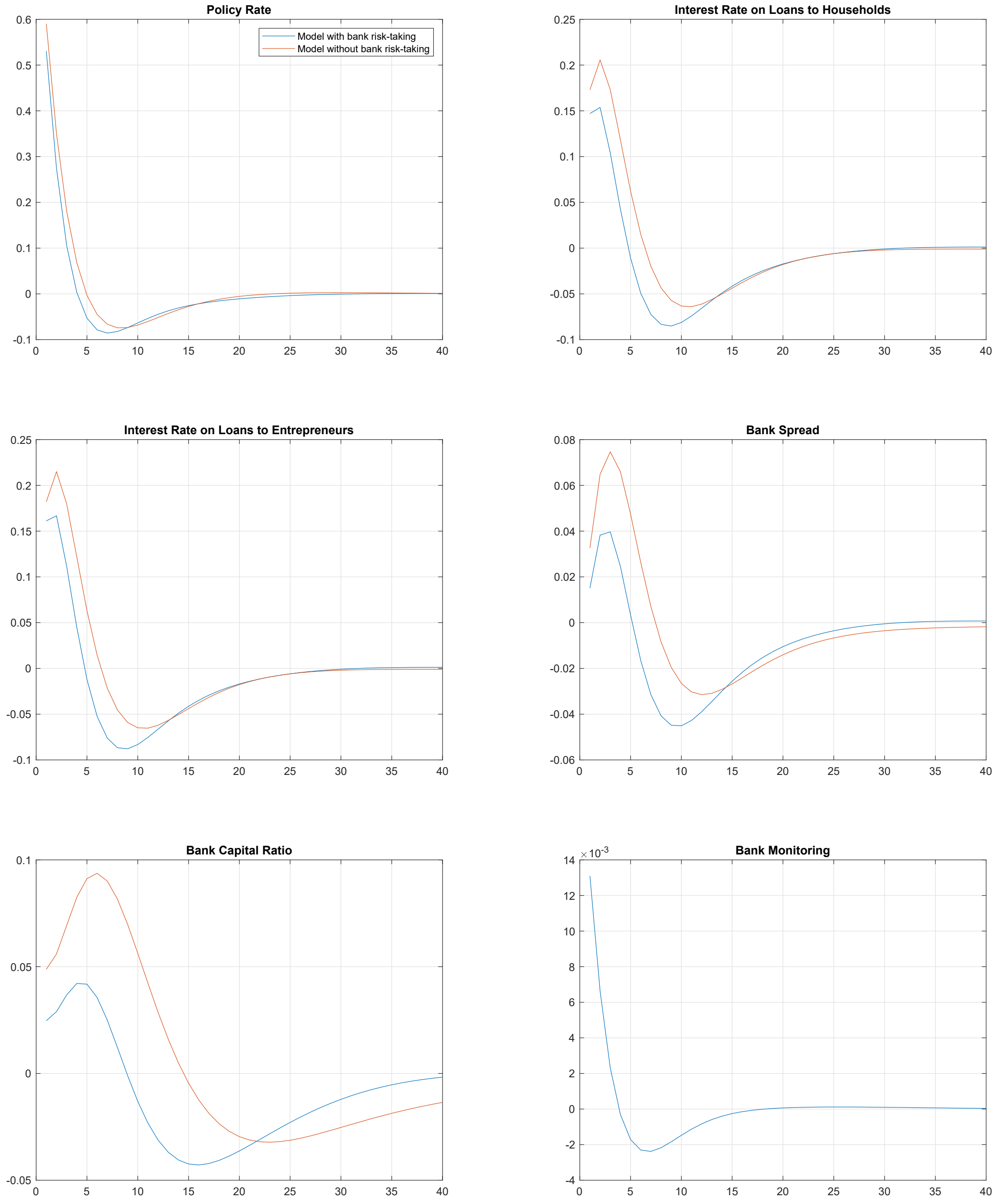
Within the VAR evidence, an initial decrease of bank risk-taking in response to monetary policy tightening was observable. Subsequently, a hump-shaped increase in bank risk-taking in excess of the initial level was depicted.

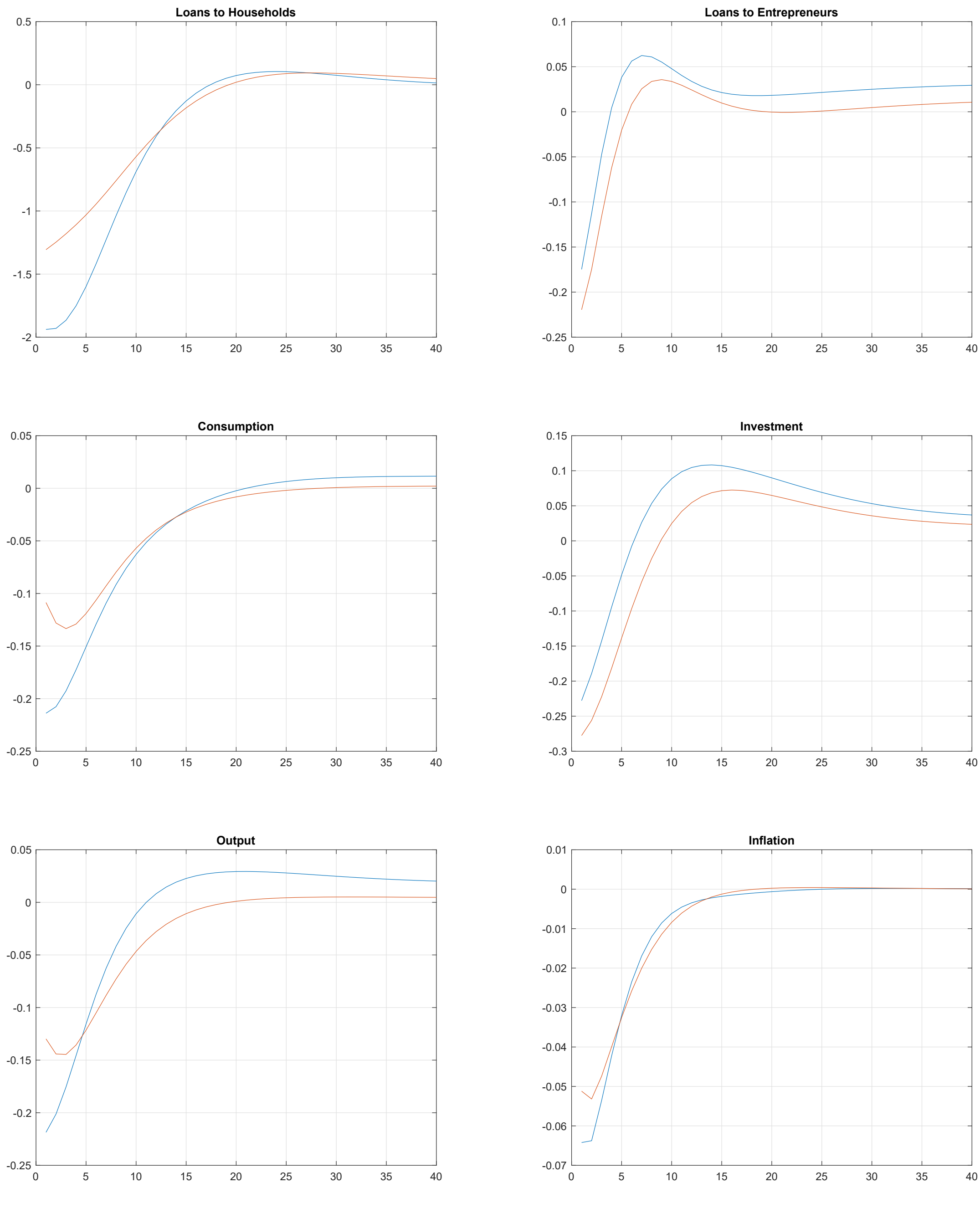
In comparison to the VAR evidence, the model replicates the responses in bank profitability and bank risk-taking well. The maximum response in bank spreads produced by my DSGE model is reached one quarter after the maximum response in banks' spread over EONIA in my VAR evidence. More importantly, the initial increase in bank monitoring and especially the timing of the subsequent reversion closely match the VAR evidence.[4] In both cases, the strongest, subsequent increase in bank risk-taking is observed after seven quarters. Thus, the model appears to capture the stylized responses in bank risk-taking well.

Although the maximum response in bank monitoring appears to be small (approximately 0.0014), the introduction of bank monitoring as an endogenous choice variable alters the responses of real economic variables relative to the model without bank risk-taking. The initial responses in output and inflation are more pronounced. Particularly for output, the model with bank risk-taking does not produce a delayed maximum response. Output is also rising faster again. The difference in the response in output can be explained by a change in the composition of output due to endogenous bank risk-taking. Although the responses in both retail interest rates for loans are identical, the decline in loans to entrepreneurs is initially attenuated. Contrarily, the decline in the volume of loans for impatient households is amplified and propagated. This translates into an amplified and propagated decrease in consumption for impatient households. Entrepreneurs' response in investment, on the other side, is attenuated. The differential effect can be explained by the responses of housing and capital good prices.

[4]This holds true especially if the indirect effect of monetary policy via bank profitability is taken into consideration.

Figure 5.1: Responses to a Monetary Policy Shock





Note: Figure 5.1 depicts responses to a monetary policy shock for a model with bank risk-taking (blue lines) and one without bank risk-taking (red lines). The time is given in quarters and the values represent percentage deviations from steady state values. *Source:* own illustration

5.2 Total Factor Productivity Shock

In figure 5.2, I contrast the responses to a one-standard deviation shock in total factor productivity of a model with bank risk-taking to the ones produced by a model without bank risk-taking. Once more, the responses are fairly standard. Real output expands immediately and continues to increase for 11 quarters. Investment and consumption (as the two components of output) expand. Inflation drops on impact. As a result, the policy rate drops. The decline in the policy rate affects the interest rates in retail markets. Depending on interest rate stickiness, retail rates react sluggishly. Banks intermediate more funds to households and entrepreneurs. The bank capital-ratio drops. Banks' profitability declines due to the decrease in interest rates.

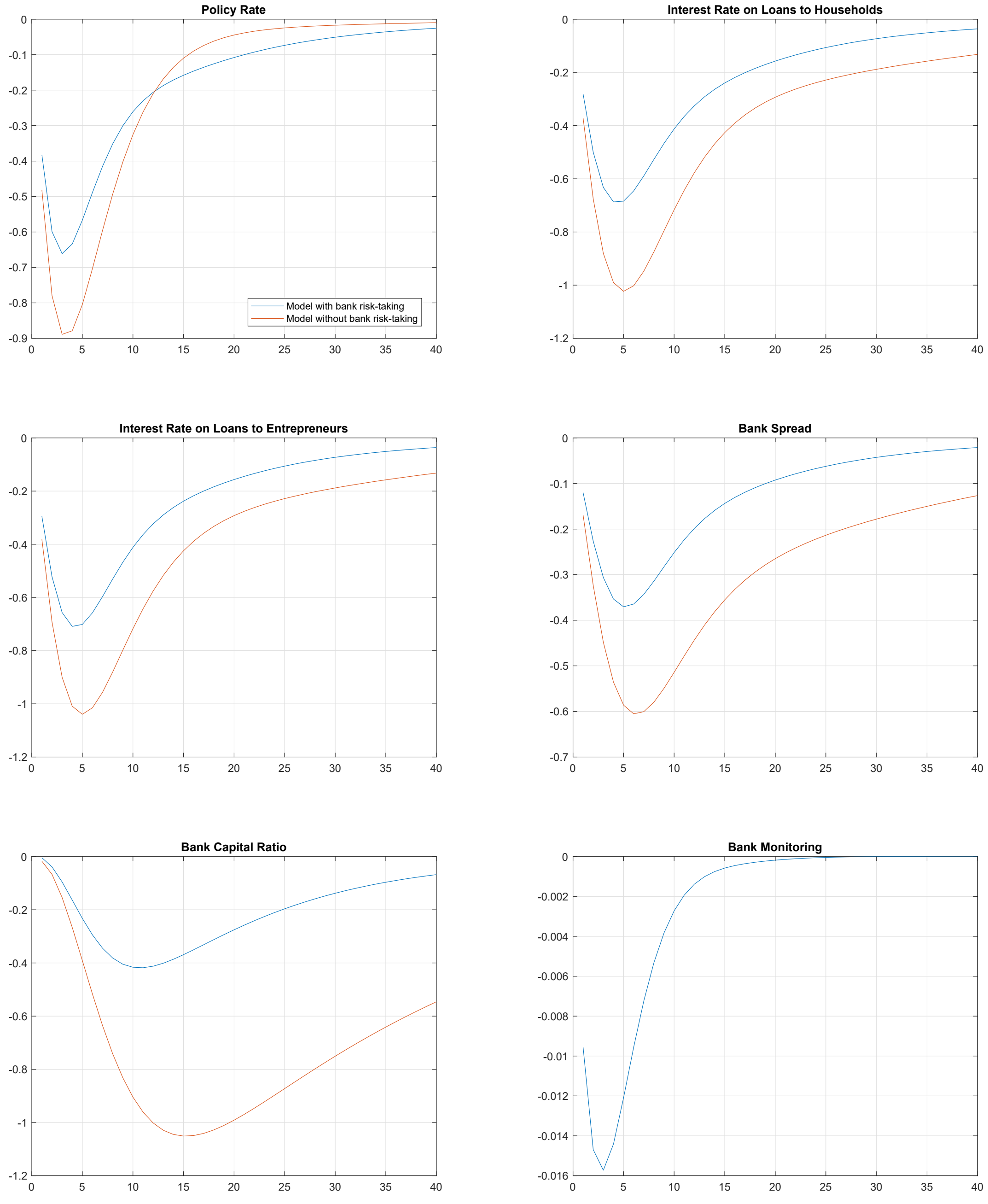
The response in bank monitoring depicts that banks become more lenient for three quarters. Subsequently, bank monitoring reverts to its steady state level. In this case, there is no hump-shaped reversion in bank risk-taking in excess of the steady state level. The response in bank risk-taking can be explained by the three subordinate channels. The response in the wholesale interest rate on loans, R_t^L, is affected by the interest rate stickiness in retail markets. It reacts incompletely on impact relative to the policy rate. Keeping bank leverage constant, this would result in an increase in bank monitoring as the wholesale margin would improve. However, the decrease in the bank capital-ratio tilts the relative strength of the two effects. As a consequence, bank monitoring increases, i.e. risk-taking declines.

Relative to a model specification without endogenous bank risk-taking, bank monitoring attenuates the initial responses in output and inflation. It partly mitigates the influence of the other factors of financial intermediation included in the model. Most of these effects are in the spirit of a financial accelerator (Bernanke & Gertler 1989).[5] Financial accelerator effects are based on the assumption that information asymmetries widen once interest rates increase. Thus, risk decreases once interest rates decline. The opposite effect is predicted for the bank risk-taking channel. Once interest rates decline, bank risk-taking increases. The model correctly replicates the effect in terms of the responses in bank capital-ratios and in real economic quantities. The attenuated responses in output and inflation reflect the influence of bank risk-taking. Bank risk-taking partly offsets the otherwise strong influence of financial accelerators. The IRFs produced are closer to those of a quasi-New-Keynesian model without financial market friction.[6]

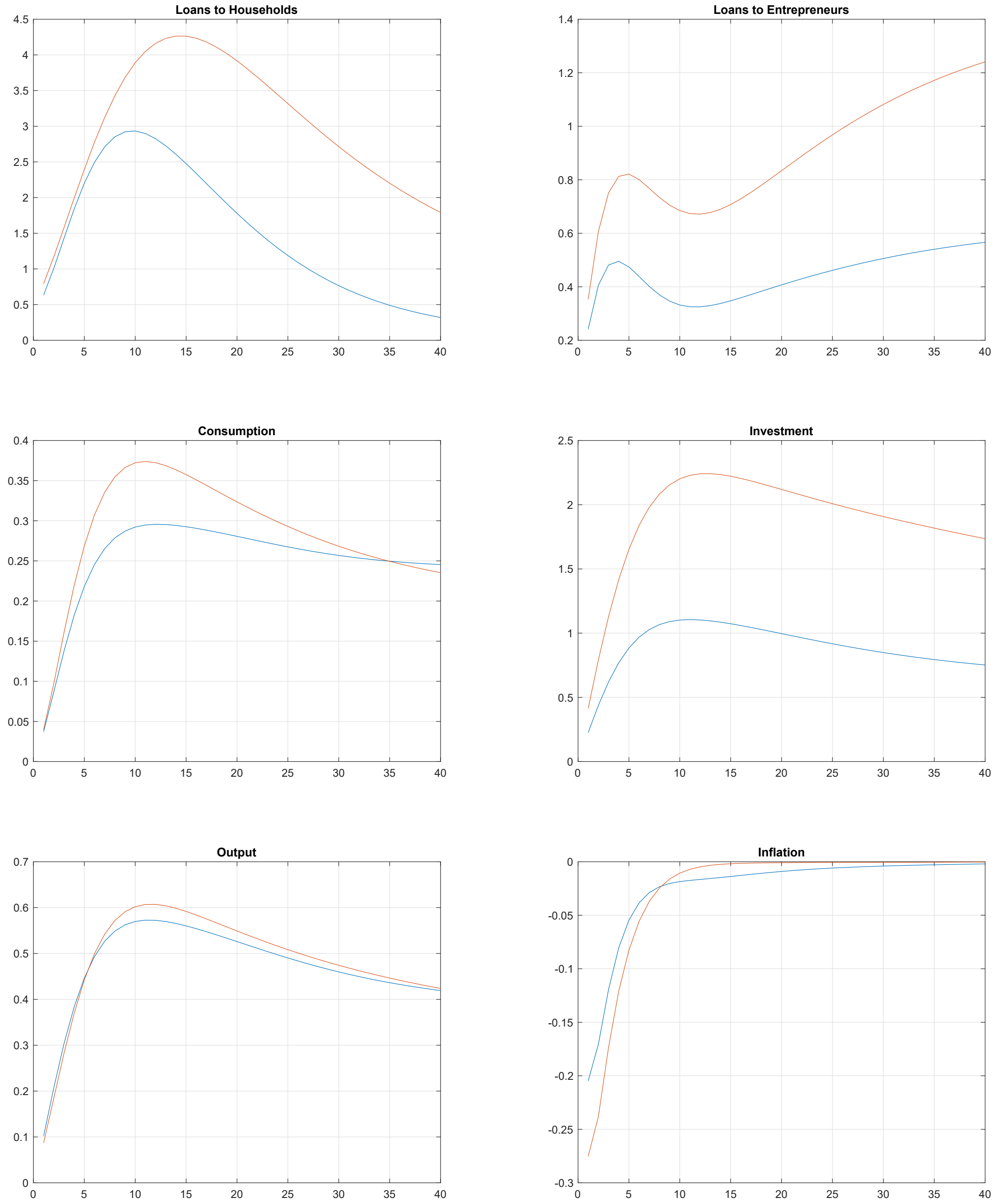
[5]Consider, for instance, the influence of the deposit ratio and the costs attached to deviating from the capital-ratio target. They are examples of financial accelerators already present in the Gerali et al. (2010) model.

[6]Estimates on how the individual features of banking influence responses in real eco-

Figure 5.2: Responses to a TFP Shock



nomic quantities can be found in Gerali et al. (2010).



Note: Figure 5.2 depicts responses to a TFP shock for a model with bank risk-taking (blue lines) and one without bank risk-taking (red lines). The time is given in quarters and the values represent percentage deviations from steady state values. *Source:* own illustration

5.3 Interim Conclusion

Within this chapter, I have studied how the introduction of model-endogenous bank risk-taking affects the transmission of monetary policy and total factor productivity shocks. Further, I have analyzed the responses in bank risk-taking to these two shocks and I have compared these responses to the stylized reduced form evidence previously gathered.

Overall, the model produces responses in output and inflation to the two shocks that are qualitatively similar to the responses produced by other medium-scale DSGE models. The introduction of bank monitoring as an additional endogenous choice variable exhibits an influence that is mainly opposing the financial accelerator effects already embedded in the model's banking sector. This is in line with the expectations because the bank risk-taking channel and financial accelerators have generally opposite influences on banks and the intermediation of credit.

With regards to the reaction of bank risk-taking, the model is able to produce IRFs that are comparable to the estimated IRFs of the VAR evidence. Also the responses of bank risk-taking are as expected. Subsequent to monetary policy tightening, bank monitoring increases. The resulting reduction in bank risk-taking lasts for a duration comparable to the narrative VAR evidence before a temporary increase in bank risk-taking becomes visible.[7] In response to a TFP shock, monetary policy exhibits a temporary increase in bank risk-taking. Although no direct reduced form evidence has been gathered on TFP shocks, the sign and duration match the predictions of the only other DSGE model incorporating a measure of bank risk-taking (Angeloni et al. 2015).

Considering the effects subordinate to the bank risk-taking channel, the model correctly incorporates their respective influences. Subsequent to monetary policy tightening, the pass-through effect promotes bank monitoring. Given interest rate stickiness in retail markets, the increase in the interest rate on wholesale loans is exceeded by the policy rate. Thus, the risk-shifting effect would dominate unless the optimal leverage effect were to tilt the relative influence in favor of the pass-through, which is actually the case.

[7] With regards to the innovation in monetary policy, my model appears to match the stylized VAR evidence better than the only rivaling DSGE model incorporating a bank risk-taking channel (Angeloni & Faia 2013, Angeloni et al. 2015). Their model does not produce the subsequent increase in bank risk-taking and requires, due to its sole dependence on an optimal leverage effect, a response in the deposit-ratio that is greater by a factor of 10.

Chapter 6

Application: Banking Market Competition and Bank Risk-Taking

In the previous chapter, the model's propagation mechanism of monetary policy shocks has been examined. This chapter explores how the model can provide further insights into the bank risk-taking channel. In their partial equilibrium model, Dell'Ariccia, Laeven and Marquez (2014) highlight the existence of three subordinate effects – the pass-through, risk-shifting, and optimal leverage effect. Each of these effects originates from dedicated assumptions about financial markets. Banking market competition shapes the pass-through from policy into loan rates. Limited liability protection results in risk-shifting. Information asymmetries in combination with an equity premium between the bank and its uninsured depositors provoke an optimal leverage effect. Due to scarcity of data and the complexity of finding suitable bank risk proxies,[1] dedicated insights into the contribution of the individual assumptions about financial markets on bank risk-taking are largely missing. This applies in particular to the influence of competition on the bank risk-taking.[2] By conducting policy experiments with the proposed model, the central bank's understanding of the determinants of the bank risk-taking channel can be further improved.

Within this application of the model, I am focusing on the role of banking market competition in the context of the bank risk-taking channel. From the

[1] See the discussion in chapter two.

[2] Chapter three has depicted potential heterogeneities in the cross-section of Euro area banking markets with regards to the average margin's response to monetary policy. For the ECB, it becomes necessary to understand how these differences might affect bank risk-taking.

literature on the interest rate channel, it becomes apparent that competition in banking markets affects (i) the elasticity of substitution among competing banking products, and (ii) the interest rate stickiness in response to a monetary policy shock. Empirical evidence supports the claim that less competitive banking markets exhibit higher interest rate stickiness (Cottarelli & Kourelis 1994, Borio & Fritz 1995, Mojon 2000, Sander & Kleimeier 2002, De Bondt 2005, Kok Sørensen & Werner 2006, Gropp et al. 2014, van Leuvensteijn et al. 2013, Leroy & Lucotte 2015). Likewise, more competitive banking markets are characterized by a generally higher elasticity of substitution, which results in lower (steady state) margins (van Leuvensteijn et al. 2013, Leroy & Lucotte 2015).[3]

By defining banking market competition in terms of elasticity of substitution and interest rate stickiness, I refine the crude assessment of Dell'Ariccia, Laeven and Marquez (2014). In their work, they only consider the influence of competition on the pass-through effect from two polar extremes. At the one extreme, they consider a perfectly competitive market, where the pass-through effect exerts the strongest influence. At the other extreme, they consider a market, in which a monopolist faces inelastic loan demand. In such a market, the influence of the pass-through effect is the lowest. By considering the elasticity of substitution and interest rate stickiness explicitly, I thus contribute to the current discussion on the bank risk-taking channel. Both of these characteristics may indeed influence the pass-through effect. While the elasticity of substitution affects bank's pass-through effect in the steady state and in response to a monetary policy shock, interest rate stickiness only becomes relevant after an innovation to the policy rate. I am primarily interested in the question concerning how the propagation of monetary policy shocks into the economy at large and how bank risk-taking in particular is affected by the competitive conditions within banking markets. For this reason, I limit my analysis to the study of competitive conditions' influence on the transmission of monetary policy innovations. I leave aside the influence of changes in competition on the steady state.

There are two implications for the pass-through effect from banking market competition. First, a more competitive environment makes it easier for borrowers to switch between banks. This results in a higher elasticity of substitution in loan markets. In turn, this should amplify the responses in the wholesale interest rate to an increase in the policy rate. As the response in the wholesale interest rate is amplified, the response in bank monitoring

[3]The narrative VAR evidence of chapter three has depicted the following. Banking markets that are commonly considered to be less competitive show higher margins on average. These markets also exhibit stronger responses to EONIA shocks in bank margins.

to monetary policy tightening is also amplified. The reasoning is as follows. In more competitive banking markets, borrowers face smaller challenges to switch between banks. If the elasticity of substitution is higher, the result will be a lower mark-up over the policy rate in loan markets. The lower mark-up over the risk-free rate, which acts as a multiplier, will result in an attenuated retail interest rate.[4] As loan demand is decreasing in the interest rate, a higher elasticity of substitution will translate into a comparably higher demand in retail loan markets. If the retail bank needs to acquire comparably more wholesale loans, the wholesale interest rate's response to a monetary policy shock will be amplified. Thus, a more competitive banking market will tend to amplify the response to monetary policy tightening in the wholesale interest rate on loans. It is the wholesale interest rate on loans, which is relevant to the bank's monitoring choice. As a result, the influence of the pass-through effect should be amplified relative to the risk-shifting effect. Bank risk-taking should decline stronger in response to monetary policy tightening in *more* competitive markets.

Second, interest rate stickiness should also influence bank risk-taking. Less competitive banking markets are expected to exhibit higher interest rate stickiness for retail loans. This has an influence on loan demand. If retail rates respond incompletely to monetary policy tightening on impact, the response in loan demand will be attenuated. To accommodate the relatively higher loan volume, retail banks need to acquire more wholesale loans from wholesale banks. In order for the intra-bank market for wholesale loans to clear, wholesale interest rate's response to monetary policy tightening will be amplified. The transmission in wholesale interest rates will reinforce the pass-through effect. Higher wholesale interest rates will motivate the wholesale bank to monitor more. Bank risk-taking's response to monetary policy tightening should be amplified in *less* competitive markets.

It emerges that the response in bank risk-taking should differ across the two characteristics of banking market competition. The elasticity of substitution predicts the pattern discussed by Dell'Ariccia, Laeven and Marquez (2014). More competitive markets lead to a stronger pass-through effect. Contrarily, interest rate stickiness might actually work in the opposite direction.

In order to analyze in how far these assumptions about banking market competition affect bank risk-taking, I have conducted two stochastic policy experiments. In each, I repeat the same experiment with regards to a 50 bp monetary policy shock as before. In the first experiment, the monetary policy

[4]This is analogue to Dell'Ariccia, Laeven and Marquez (2014) argument that banks' margins widen in increasing policy rates.

shock hits the economy under different parameter values for the elasticity of substitution in the respective retail loan markets. To isolate the influence of the elasticity of substitution, interest rate stickiness is turned off. In the second experiment, I analyze how the propagation mechanism into bank risk-taking changes under different parameter values of interest rate stickiness in the retail loan markets.

6.1 Elasticity of Substitution and Bank Risk-Taking

In the subsequent policy experiment, I study how the elasticity of substitution between different banking products in the two loan markets influences bank risk-taking in response to monetary policy tightening. In order to clearly isolate the effect of the elasticity of substitution on the transmission of monetary policy tightening in bank risk-taking, I consider a specification of the model where interest rate stickiness is turned off (i.e. $\kappa^{LE} = \kappa^{LH} = 0$).

In the spirit of Dell'Ariccia, Laeven and Marquez, a more competitive banking market will reinforce the pass-through effect. For this experiment, the assumption is that competition in banking markets manifests in the elasticity of substitution. The more competitive a banking market, the easier it will be for borrowers to switch between different banks. So, the elasticity of substitution will increase in competition. The mark-up for retail interest rates on loans over the policy rate decreases in the elasticity of substitution.[5] In response to monetary policy tightening, more competitive banking markets should result in a stronger pass-through effect. In the context of my DSGE model, the pass-through into the wholesale interest rate on loans is relevant as the wholesale bank takes this as given in its monitoring decision. A smaller mark-up over the risk-free rate should attenuate the transmission of monetary policy tightening into retail rates. The attenuated response in retail rates in more competitive markets should also attenuate the decline in intermediated loan volume. If loan demand is relatively higher in more competitive markets, the wholesale interest rate's response to the monetary policy shock should be amplified. As a result, bank monitoring's response to monetary policy tightening should be amplified in more competitive markets through the pass-through effect.

To depict differences in the IRFs, figure 6.1 compares a baseline specification (blue), wherein the elasticity of substitution parameters are calibrated as

[5] As the mark-up acts as a multiplier, this concurs with the argument of Dell'Ariccia, Laeven and Marquez that banks' margins increase in the policy rate.

before (i.e. $\varepsilon^{LH} = \varepsilon^{LE} = 2.9328$). However, interest rate stickiness is turned off. In the first variation (yellow), the elasticity of substitution among bank loans to impatient households, ε^{LH}, is increased by +1.0 (i.e. to 3.9328). In the second variation (red), its comparable in the market for loans to entrepreneurs, ε^{LE}, is increased by +1.0 (i.e. to 3.9328).[6] In each of the cases, the economy experiences a perturbation of a one-standard deviation (50bp) in the policy rate.

Overall, the changes in parameter values qualitatively preserve the transmission mechanism of the model. The exclusion of interest rate stickiness results in an amplified response in retail loan rates on impact. The other responses are qualitatively similar to the ones discussed before. Real output contracts and inflation declines in general. Bank monitoring increases initially and exhibits a subsequent, hump-shaped decline in excess of the steady state level for all specifications. In both variations from the baseline specification, the reaction in banks' monitoring activity is initially similar after a monetary policy shock. This complies with the expectations formulated towards the influence of banking market competition manifesting in the elasticity of substitution. In markets, where borrowers face smaller difficulties to switch between banks, the pass-through effect is reinforced. The transmission into bank monitoring works as expected. Higher elasticities of substitution decrease the mark-up over the policy rate. For more competitive markets, the decline in loan volumes is attenuated and the response in the wholesale interest rate is amplified. However, the amplifying influence of increasing market competition on bank monitoring is comparably small and largely proportionate to the endogenous path of monetary policy.

In a general equilibrium model, market competition does not solely affect the wholesale interest rate on loans. While the model does correctly reflect the expected direction of influence on the wholesale interest rate on loans, it is worth noting that the larger loan volume intermediated also exerts an influence on the monitoring decision via the optimal leverage effect. Since bank capital evolves endogenously in my model and since bank managers are unable to raise or redeem equity, an attenuated response in loan volumes also alters the response in the capital-ratio. This partly offsets the influence of the pass-through effect through a reinforced risk-shifting effect.

There are observable differences among loan markets. While the response for an increase in ε^{LH} leads to only a small amplification in the response of

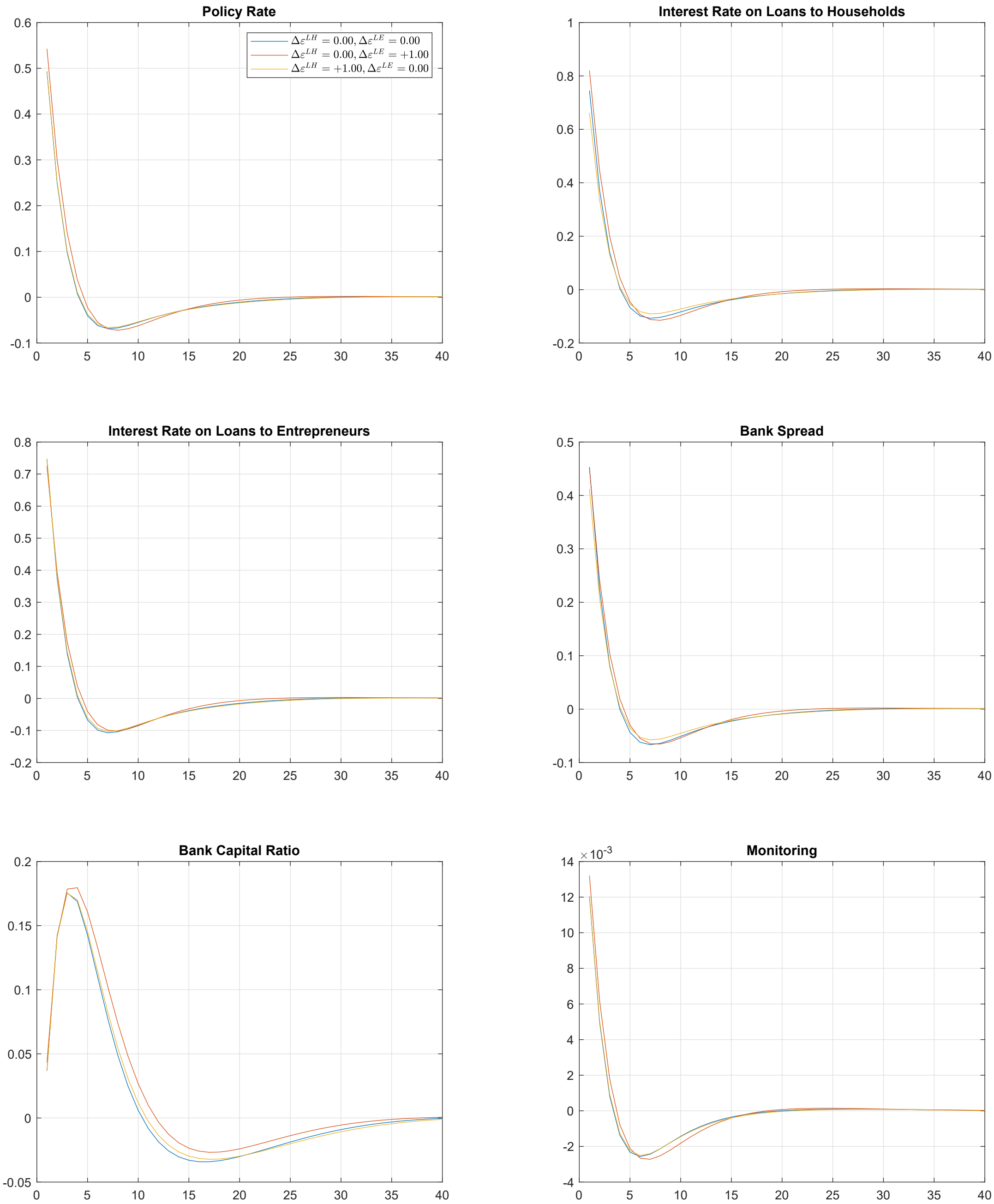
[6] Based on the estimates of Dell'Ariccia, Laeven and Marquez (2014), the changes in parameter values reflect changes equal to approximately one and three standard deviations of the markets for loans to entrepreneurs and households, respectively. Considering even larger increases in parameter values could introduce additional complexities, as they would require a correction for different steady state values of the DSGE model.

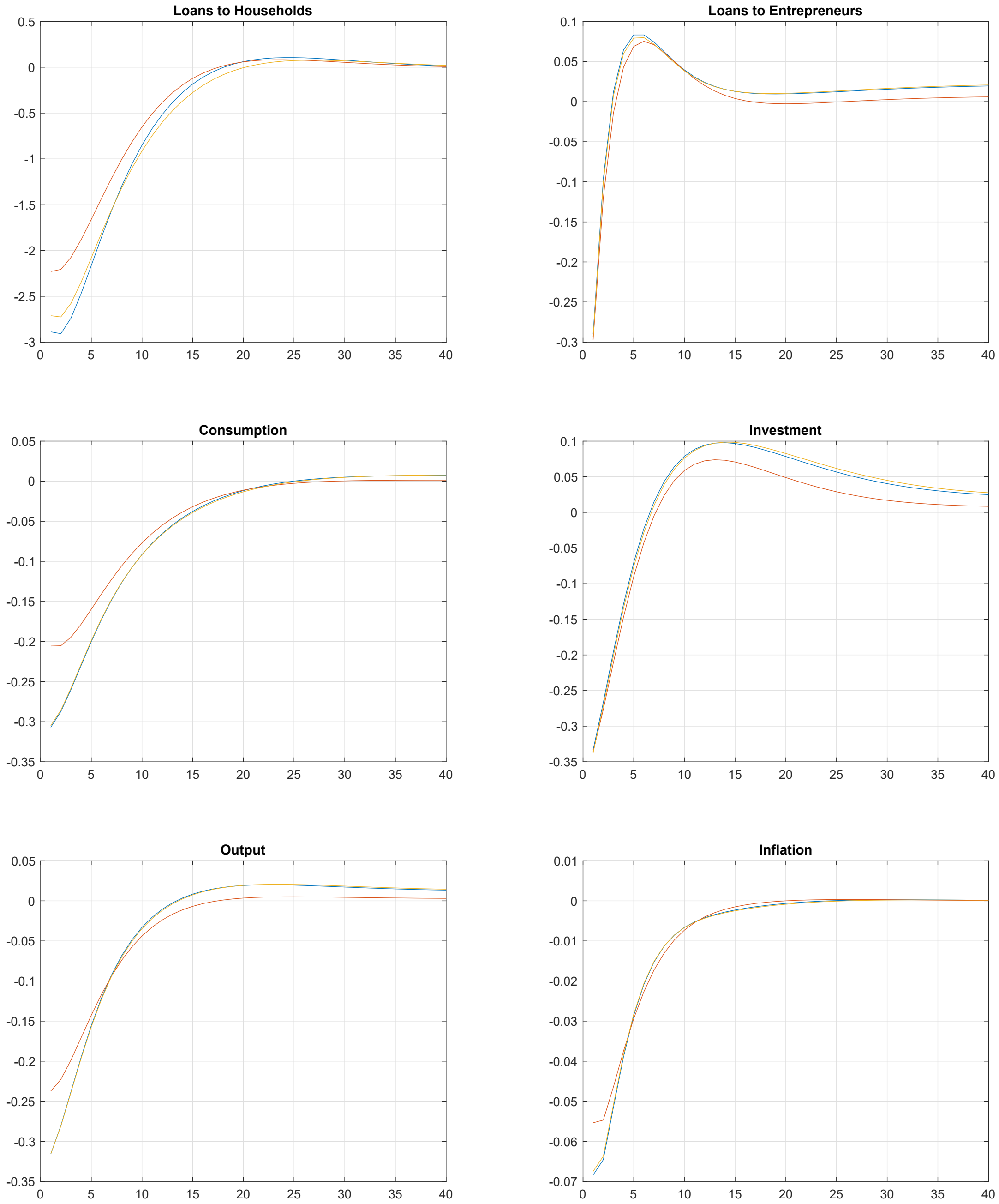
monitoring, the variation in ε^{LE} has a more sizable influence. The differences are reconcilable with the roles played by the two different interest rates on loans. It is primarily impatient households which are affected by an increase in the parameter value for the elasticity of substitution in markets for loans to impatient households, ε^{LH}. Impatient households' demand for housing and consumption is amplified in response to monetary policy tightening once the elasticity of substitution in the loan market for household loans is increased. This said, impatient households' influence on output is, however, minor as the change in output is partly offset by the corresponding reduction in patient households' demand. Changing the parameterization of the elasticity of substitution in loan markets for impatient households affects the transmission mechanism into real economic quantities and bank risk-taking little.

A change in parameterization of ε^{LE} affects the model's transmission mechanism differently. Increasing the elasticity of substitution in markets for entrepreneurial loans has implications for the supply side of output. The change in the parameter value attenuates the response in output and investment. A lower interest rate decreases the return required on capital by entrepreneurs. They invest and produce more. Inflation's response is attenuated relative to the baseline parameterization. This provokes a reinforcing, endogenous response in monetary policy. The path of monetary policy contributes to the differential effect on bank risk-taking.

Overall, the transmission of monetary policy shocks into bank risk-taking is affected by borrowers' ability to switch between banking products. The resulting responses comply with the expectations. More competitive markets reinforce bank risk-taking through a stronger pass-through effect. Changes in the elasticity of substitution in loan markets influence bank risk-taking only slightly. The effect is asymmetrically stronger for competition in loan markets to entrepreneurs. This is due to the endogenous reaction of monetary policy to the resulting changes in output and inflation.

Figure 6.1: The Role of the Elasticity of Substitution in Loan Markets on Monetary Policy Transmission into Bank Risk-Raking





Note: Figure 6.1 depicts responses to a monetary policy shock. The baseline specification (blue) is contrasted to two cases where the elasticity of substitution in loan markets is increased by 1.0 once for markets where loans are intermediated to impatient households (yellow) and once for loans to entrepreneurs (red). In all cases, interest rate adjustment costs are zero. *Source:* own illustration

6.2 Interest Rate Stickiness and Bank Risk-Taking

In the second experiment, I investigate how interest rate stickiness affects the transmission mechanism of monetary policy shocks into bank risk-taking. In the interest rate channel literature, one of the explanations for interest rate stickiness put forward is imperfect market competition.[7] In the discussion of the bank risk-taking channel, interest rate stickiness has not been considered so far. It may, however, bear relevance for bank risk-taking in response to monetary policy shocks. In the context of bank risk-taking, interest rate stickiness in loan markets may particularly influence the pass-through effect. If the response in retail rates to monetary policy tightening is attenuated, borrowers' otherwise declining demand for loans will be attenuated. An incomplete pass-through of monetary policy decisions into retail loan rates on impact may affect the monitoring decision of the wholesale bank through its impact on the wholesale interest rate on loans. Within its monitoring decision, the wholesale bank takes the interest rate on wholesale loans as given. However, the interest rate on wholesale loans will increase if demand from retail banks increases. Thus, the wholesale interest rate's response incentifies banks to monitor more. Bank risk-taking is attenuated in less competitive markets.

Figure 6.2 presents the IRFs to a one-standard deviation stochastic innovation to the policy rate. In order to highlight the contribution of interest rate stickiness, I present four different specifications of the model.[8] As a baseline

[7]Various explanations have been brought forward. Among others, Scharler (2008) defends interest rate stickiness on the basis of intermediation costs. Güntner (2011) argues that the competitive landscape and standard costs result in interest rate stickiness. Others have defended the observed pattern based on information asymmetries. Within this context, I consider interest rate stickiness to be a result of incomplete competition in the spirit of Güntner.

[8]There are generally two possibilities to approach the envisioned policy experiment. It is either possible to utilize the aforementioned parameter values (or another arbitrarily chosen starting point) for the three interest rate adjustment cost parameters, κ^d, κ^{LH}, and κ^{LE}, and to introduce a cost-free backward indexation to past interest rate adjustments. An adapted specification of the model with backward indexation is presented in appendix F. Alternatively, it is possible to use a fully flexible environment, i.e. $= \kappa^{LH} = \kappa^{LE} = 0$, and to, ceteris paribus, increase the individual interest rate adjustment cost parameters. In this application, I prefer the latter approach due to two reasons. First, I consider the fully flexible environment as the more natural benchmark, to which it becomes relatively easier to identify the ceteris paribus effects of changing one of the parameter values. Second, using backward indexation introduces a lagging effect exerted by past interest rate adjustments, which might render the results opaque with regards to the influence of the pass-through effect. Nonetheless, I provide the resulting IRFs for a specification including

specification (blue), I replicate the IFRs of the parameterization discussed before (cf. chapter 5.1). Therein, both loan markets are characterized by interest rate stickiness. Next to this, I present the IRFs of a specification (yellow) in which both loan markets react fully flexibly to monetary policy, i.e. $\kappa^{LH} = \kappa^{LE} = 0$. Moreover, I present two specifications in which adjustment costs for interest rates in loan markets are turned off individually. These two cases, where either interest rate stickiness in loan markets to entrepreneurs ($\kappa^{LE} = 0$, red) or impatient households ($\kappa^{LH} = 0$, purple) are set to zero, help to isolate the relative effect of interest rate stickiness on bank risk-taking in the respective markets.

The retail interest rate on loans, which is subject to interest rate stickiness, will respond incompletely in response to monetary policy tightening on impact. As expected, the initial response is attenuated. The respective IRF peaks after two quarters and shows also an attenuated subsequent reduction. Lower retail interest rates attenuate the otherwise contractionary influence on loan demand in the market affected by interest rate stickiness. In a fully flexible parameterization, interest rates respond fully and the decline in loan volumes is amplified. In order to supply a relatively higher loan volume under interest rate stickiness, the retail bank needs to acquire more wholesale loans. To accommodate a higher loan volume, a higher wholesale interest rate in the intra-bank market for wholesale loans is necessary to clear the market. The contractionary response in the retail bank's profitability is amplified, which is also reflected in the response of the overall bank spread. At a wholesale bank level, interest rate stickiness increases the wholesale interest rate on loans obtainable. It reinforces the pass-through effect and amplifies bank monitoring. Bank risk-taking is decreasing in less competitive loan markets that exhibit higher interest rate stickiness.

Interest rate stickiness exerts a second effect. Interest rate stickiness attenuates the responses in intermediated loan volumes. Given that bank capital is a predetermined state variable in the bank manager's choice, relatively higher loan volumes reduce the capital-ratio. A higher deposit share strengthens the risk-shifting through the optimal leverage effect. The stronger influence of the risk-shifting effect partly offsets the influence of the pass-through effect on impact. This is also reinforced by the endogenous evolution of bank capital. Due to the reduced bank spread, bank capital grows more slowly in less competitive markets. Thus, interest rate stickiness also exerts a lagged[9] influence on the monitoring decision through the optimal leverage effect.

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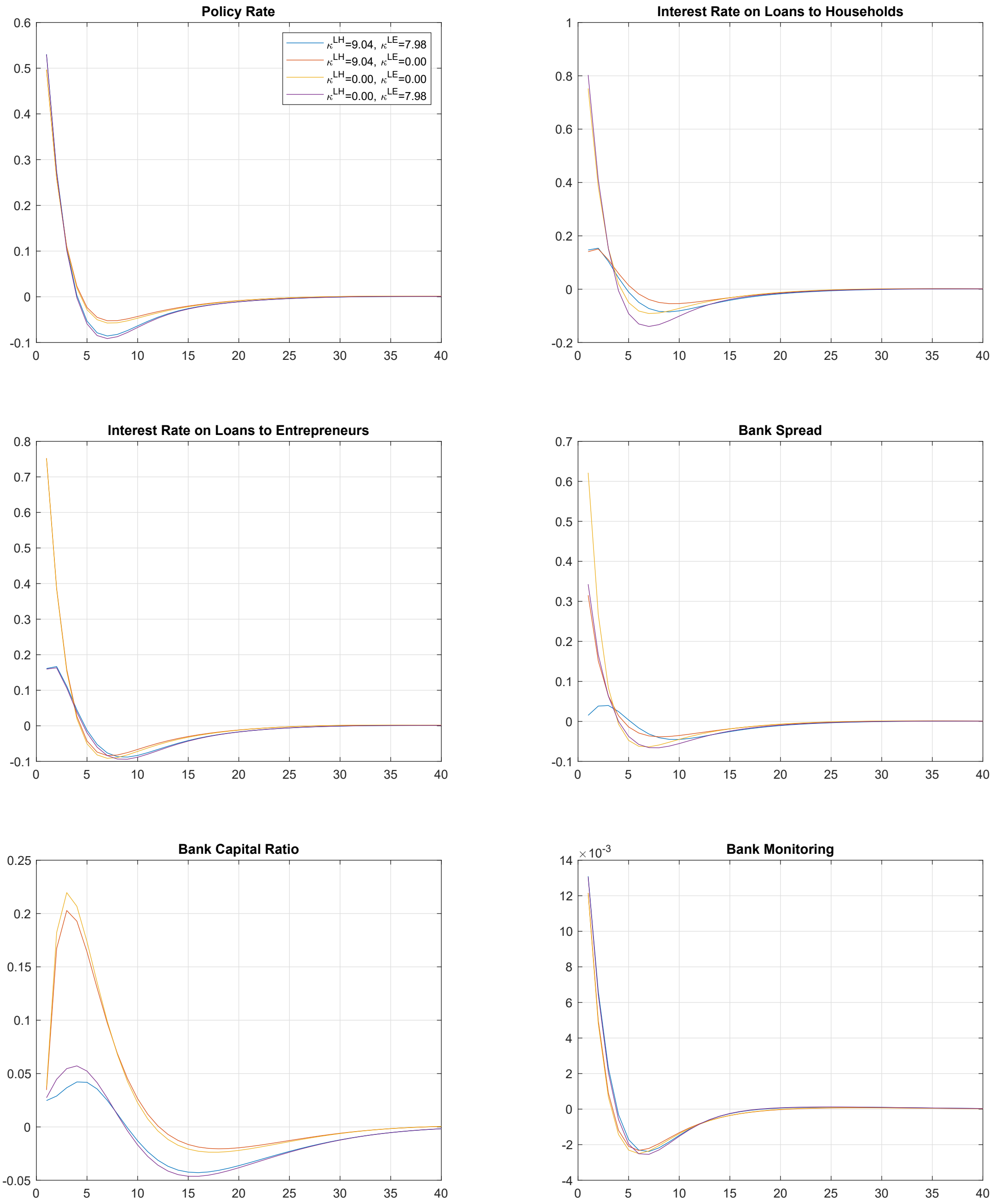
partial backward indexation in appendix G. Overall, the results reconfirm the findings discussed below.

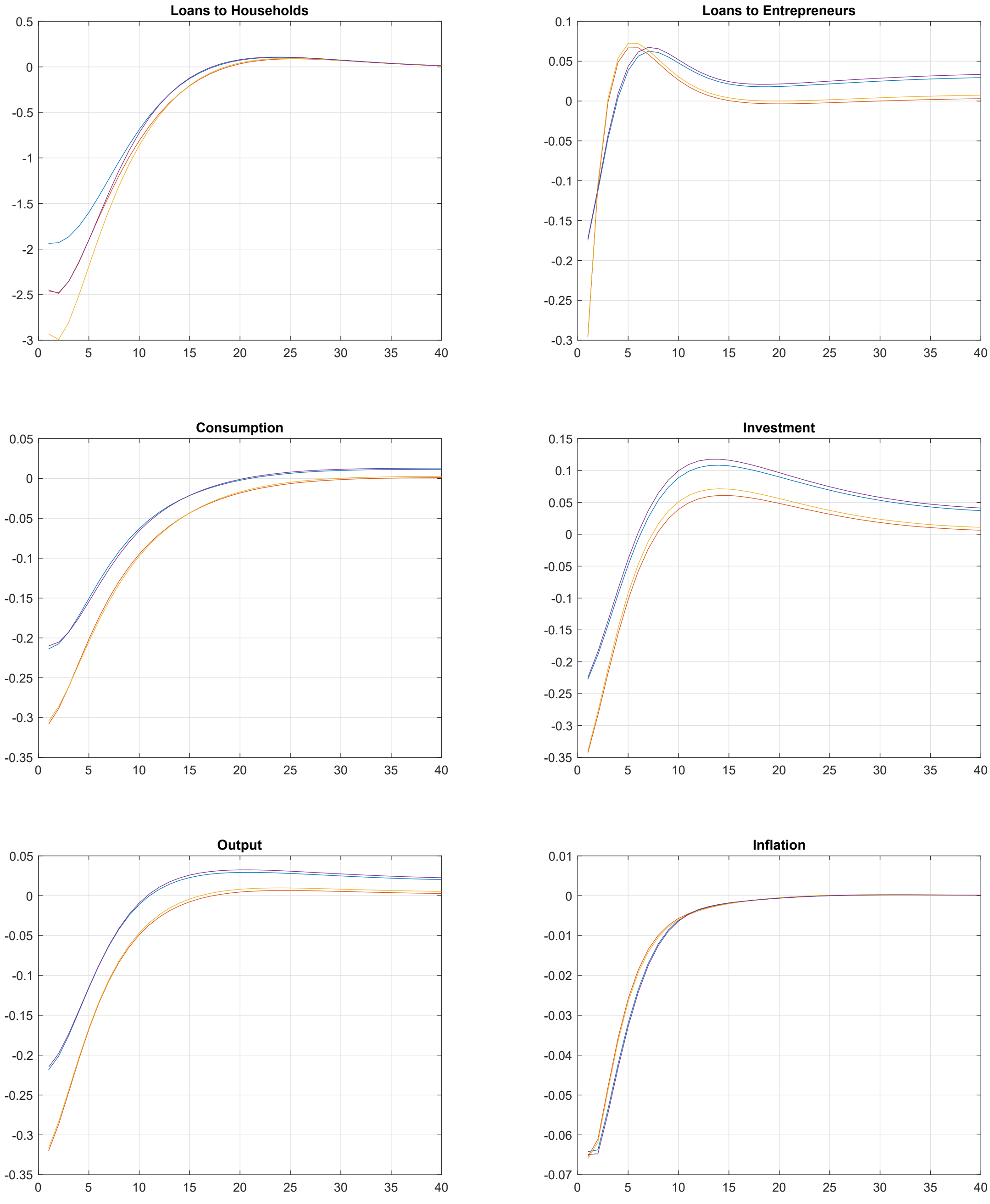
[9]Banks are precluded to raise or redeem equity in my model. Bank capital evolves only through retained earnings.

Considering the differential influence of interest rate stickiness in both of the retail loan markets, the influence is once more stronger for loans granted to entrepreneurs rather than the influence for loans granted to households. The explanation is largely similar as before. For impatient households, interest rate stickiness attenuates the decline in loan demand. In a fully flexible interest rate environment (perfect competition), impatient households would experience an amplified demand in housing and consumption goods. The attenuated decline under interest rate stickiness is partly offset by the change in demand by patient households. This cushions the response in output and inflation. In this case, interest rate stickiness influences output and inflation little. For entrepreneurs, a fully flexible interest rate environment would result in a lower loan demand. It would also reduce the demand for capital through the required return. As interest rate stickiness increases, the decline in loan and capital demand is attenuated. Output's contraction would be attenuated. Monetary policy would, once again, respond endogenously to the now larger effect of interest rate stickiness on output and inflation. Once more, the transmission through the market for loans to entrepreneurs is stronger and is endogenously reinforced by monetary policy.

Overall, the response in bank risk-taking is as expected within the context of the model and its parameterization. Interest rate stickiness influences the wholesale interest rate primarily through the demand for loans.

Figure 6.2: The Role of Interest Rate Stickiness in Loan Markets on Monetary Policy Transmission into Bank Risk-Taking





Note: Figure 6.2 depicts responses to a monetary policy shock. The baseline specification (blue) is contrasted to two cases where the interest stickiness in either the market for loans to entrepreneurs (i.e. $\kappa^{LE} = 0$, red) and impatient households (i.e. $\kappa^{LH} = 0$, purple) is turned off. Moreover, the yellow specification exhibits fully flexible interest rates in both markets (i.e. $\kappa^{LH} = \kappa^{LE} = 0$) for retail loans. *Source:* own illustration

6.3 Interim Conclusion

Within this application of the model, I have provided additional policy experiments. The intention has been to improve and extend the understanding of the pass-through effect subordinate to the bank risk-taking channel. In order to do so, I have extended the rationale of Dell'Ariccia, Laeven and Marquez (2014) for the influence of interest rate stickiness. After this extension, both aspects resulting from incomplete banking market competition (elasticity of substitution and interest rate stickiness) can be considered in the context of the bank risk-taking channel.

From these considerations, it has emerged that banking market competition might result in two opposing influences on the pass-through effect. If banking markets are more competitive, a higher elasticity of substitution will, ceteris paribus, reinforce the pass-through effect. However, higher competition will also decrease interest rate stickiness, which, in turn, attenuates the pass-through effect.

My model exhibits that the expected responses and transmission patterns emerge in a general equilibrium context. However, the differentiating changes of influence of banking market competition on bank risk-taking are relatively small. This is partly due to the fact that competition does not only influence the pass-through effect in isolation in a general equilibrium environment. Competition also changes the relative strength of the risk-shifting effect through loan demand's influence via the optimal leverage effect.

For both characteristics of competition in the banking market, the resulting shift in monitoring is stronger when competition in markets for loans to entrepreneurs increases. This can be explained by the effect of the retail interest rate on entrepreneur's capital and output decisions. As a result, output is more strongly affected. A stronger response in output alters the path of monetary policy, which contributes to the response in bank risk-taking.

The results offer a potential explanation for (i) the non-linear relationships between competition and bank risk-responses to monetary policy decisions (Martinez-Miera & Repullo 2010), (ii) the relative homogeneous responses in BLS in the cross-section of Euro area countries, and (iii) potentially differing responses in the strength of the bank risk-taking channel to changes in competition. To illustrate this, assume that market competition affects the elasticity of substitution and the interest rate stickiness differently across countries. Different influences of market competition on the elasticity of substitution and interest rate stickiness may be the result of, among others, institutional or legal conditions. As a result, it may not necessarily be the case that the pass-through effect is stronger in more competitive banking markets. Changes in competition might affect the pass-through effect differently in the cross-section of countries depending on country-specific factors. For instance, consider two markets that are identical in the competition in banking markets. Both markets might exhibit the same initial strength of the pass-through effect and may experience the same change in banking market competition. However, the resulting strength of the pass-through effect might differ. In the first market, the institutional environment is such that the change in competition primarily affects the elasticity of substitution but leaves interest rate stickiness unaffected. In the second market, interest rate stickiness will respond to changes in competition, whereas the elasticity of substitution remains unchanged. If both markets experience the same increase in banking market competition, the first market will experience a greater change in the elasticity of substitution. Since an increase in the elasticity of substitution would strengthen the pass-through effect, bank risk-taking declines more strongly in response to an otherwise identical monetary policy shock after an increase in competition. In the second market, the pass-through effect would be weakened despite an increase in competition. If an increase in banking market competition primarily influences interest rate stickiness, then the pass-through effect is attenuated. These insights help to further understand the non-linear relationship between banking market competition, bank profitability and bank risk-taking.

Moreover, the mutually offsetting influence of the elasticity of substitution and interest rate stickiness on the pass-through effect may also explain the relatively homogeneous responses in the heterogeneous banking markets of the Euro area documented in chapter three. If countries are characterized by different degrees of market competition, but the two characteristics of market competition offset their respective influences on the pass-through effect, a relatively homogeneous bank risk-taking response may arise. Overall, these insights help to understand how i) the elasticity of substitution and interest rate stickiness mutually offset each other, and ii) how their combined influence upon the pass-through effect help to explain why heterogeneous banking markets within the Euro area respond in such a fairly homogeneous manner.

Chapter 7

Concluding Remarks

Dell'Ariccia, Laeven and Marquez (2014) have established a rationale for the bank risk-taking channel of monetary policy transmission. They rationalize the empirical regularity that banks increase their risk-taking in response to monetary policy easing in a partial equilibrium model. Banks can only invest into risky loan projects. Costly monitoring by the bank can be used to determine the probability that loans will be collected. In general, the margin obtainable on the loans collected incentifies the bank to monitor. Decreasing margins obtainable will result in declining monitoring effort, and a corresponding increase in bank risk-taking. The link between monetary policy and the bank's monitoring choice is established through three effects. The pass-through effect predicts that if monetary policy eases, retail loan rates will also decrease. The decline in retail loan rates reduces the bank's revenue if the loan is collected. The margin obtainable by banks shrinks. The risk-shifting effect works in the opposite direction for leveraged banks. A decrease in the policy rate will also reduce the interest rate payable on deposits. This will improve the margin obtainable on loans. The optimal leverage effect shifts the relative strength of the two aforementioned effects.

Each of the subordinate effects arises from a dedicated assumption about banking markets. The pass-through effect results from banking market competition. It is the strongest under perfect competition. Atomic banks are forced to fully and instantaneously incorporate policy rate changes into their retail rates on loans. In a market where a monopolistic bank faces inelastic loan demand, the relative strength of the pass-through effect is expected to be minimal. The monopolist will not respond to any changes in the policy rate. The risk-shifting effect arises for leveraged banks that are protected by limited liability. It provokes a second order agency conflict between the bank and its uninsured depositors. A leveraged bank will generally undermonitor its loan portfolio relative to a benevolent social planner's choice. The risk-shifting effect opposes the pass-through effect. Banks that are deposit-financed experience a decline in interest expenses if monetary policy eases. The margin increases and so does monitoring. In an environment in which bank leverage is fixed, the pass-through effect needs to take precedence so as to provoke a pattern in which bank risk increases once the policy rate drops. The optimal leverage effect grounds on an equity premium in combination with information asymmetries between the bank and its depositors. Depositors are unable to directly observe the bank's monitoring decisions. Since the bank is protected by limited liability and since deposits are uninsured, undermonitoring will expose depositors to an expropriation risk. As the risk-shifting effect drives a wedge between the monitoring choice of a purely equity-financed bank[1] and the one of a leveraged counterpart, depositors infer the monitoring decision from a bank's equity stake. If the deposit-ratio increases, the risk-adjusted interest rate on deposits will also increase. The bank optimally chooses the deposit-ratio if the marginal costs of financing via equity and deposits are identical. Agency problems between the bank and its depositors decrease once monetary policy eases. Banks' optimal deposit-ratio will then increase, which will in turn change the relative strength of the risk-shifting effect. As policy rates decline, banks will leverage up, which will alter the relative influences of the pass-through effect and the risk-shifting effect.

Against the conceptual background and empirical evidence previously established, I pursue the question as to how these theoretical considerations can be transferred to a general equilibrium context.

My contribution is divided into four aspects. First and most importantly, the paper provides an extension for endogenous bank risk-taking to the seminal Gerali et al. (2010) DSGE model. For the first time, I transfer all three effects of Dell'Ariccia, Laeven and Marquez's (2014) bank risk-taking channel to a general equilibrium context. Until now, the only rivaling DSGE model (Angeloni & Faia 2013, Angeloni et al. 2015) draws exclusively on a variation of the optimal leverage effect.

Within the model's microeconomic foundations, banks intermediate funds among heterogeneous agents in imperfectly competitive markets. The bank raises uninsured deposits from patient households, bundles them with bank capital, and supplies these funds as loans to impatient households and entrepreneurs. The retail bank markets are characterized by monopolistically competitive retail banks and interest rate stickiness. Within the retail loan (deposit) markets, the elasticity of substitution governs the mark-up (mark-

[1] The choice of an unleveraged bank coincides with the choice of a benevolent social planner.

down) obtainable by banks relative to the risk-free rate set by the monetary policy maker. Banks are endowed with a monitoring technology, through which they can affect wholesale loans' probability of repayment. Bank monitoring, however, provokes increasing marginal costs. Thus, the monitoring choice is inherently linked to the bank's margin obtainable on loans. The bank's marginal benefit of increasing monitoring depends on the elasticity of substitution, interest rate stickiness, the leverage choice of the bank, and the risk-free rate. Through the elasticity of substitution and interest rate stickiness, a pass-through effect is embedded into the model. The leverage choice relative to an exogenous capital-ratio target establishes an optimal leverage effect. The presence of uninsured deposits results in a risk-shifting effect that leads to undermonitoring for leveraged banks.

Second, I provide new narrative VAR evidence. The results indicate that there is the expected response of bank risk-taking to policy rate changes. Once monetary policy tightens, bank risk-taking decreases. Despite considerable heterogeneity in banking market competition among the individual Euro area countries, the patterns in bank risk-taking appear to be relatively alike across ten different Euro Area countries in the reduced form evidence. This is somewhat surprising given that the influence of the pass-through effect on bank risk-taking should differ in dependence on banking market competition. In the theoretical considerations, the response in bank margins plays a pivotal role. It subsumes the influences of three subordinate effects and also influences the bank's risk-taking decision. My VAR evidence also contributes insights to this. Banks' margins show a temporary improvement in response to tightening monetary policy. This is expected if the pass-through effect dominates. An improvement in bank profitability also leads to a response in bank lending standards, which is in line with the theoretical considerations. Bank risk-taking decreases. A novel observation is that an improvement in bank margins results not only in an initial reduction in bank risk-taking, but also in a subsequent reversal for the aggregate Euro area. In the cross-section of ten Euro area countries, not all countries share this subsequent relaxation of bank lending standards. As might have been expected, bank risk-taking is determined more by banks' profitability on the average loan in the portfolio than by banks' profitability on their marginal lending activity. The suggestive VAR evidence also indicates that bank risk-taking bears economic consequences for bank profitability and aggregate economic output for the aggregate Euro Area.

Third, I study the perturbation mechanism of my DSGE model. I use a TFP and monetary policy shock to investigate how the newly added endogenous bank monitoring choice alters the transmission into real economic quantities. Moreover, I also review the model's endogenous reaction in bank risk-taking to the two shocks. Therein, the previously gathered reduced form evidence serves as a reference.

Overall, the model's responses in output and inflation to the two shocks are qualitatively in line with most medium-scale DSGE models. The incorporation of endogenous bank risk-taking attenuates the otherwise strong influence of financial accelerator effects already embedded into the model. This complies with the expectations since the bank risk-taking channel predicts increasing risk in times of decreasing policy rates, whereas financial accelerator effects generally predict increases in risk once monetary policy tightens. The attenuating effect of bank risk-taking results in responses in output and inflation that are closer to a quasi-New Keynesian style model without financial market frictions. Thus, the direction of influence of the bank risk-taking channel on real economic quantities is correct in the model.

With regards to the endogenous responses of bank risk-taking, the model produces IRFs that closely resemble the reduced form VAR evidence. The responses in bank risk-taking are in line with the predictions of the theoretical considerations (Dell'Ariccia et al. 2014). Bank risk-taking declines initially in response to monetary policy tightening. The effect lasts for a duration of approximately 4 quarters, which complies with the VAR evidence. The subsequent increase in bank risk-taking peaks after seven quarters. This coincides once more with the VAR estimates. In response to a TFP shock, bank risk-taking increases temporarily. This reconfirms the findings of Angeloni, Faia and Lo Duca's (2015) policy experiments. In response to a TFP shock, the increase in bank risk-taking is more persistent.

With regards to the contributions of the three subordinate effects, the model appears to correctly incorporate the individual effects. In response to a monetary policy shock, the pass-through effect promotes bank monitoring. The risk-shifting effect generally reduces bank monitoring and would compensate the pass-through effect. However, the relative influence is shifted in favor of the pass-through effect through an increase in the bank capital-ratio. Based on these insights, the conclusion emerges that the proposed model correctly incorporates the bank risk-taking channel with its three subordinate effects in a general equilibrium context for the first time.

In summary, the model proposed in this paper expands upon a widely known heterogeneous agent DSGE model. I include an endogenous bank risk-taking channel. The microeconomic foundations are close to the theoretical considerations of a bank risk-taking channel (Dell'Ariccia et al. 2014). It is for the first time that all three effect subordinate to the bank risk-taking channel are embedded within a DSGE model. The model produces IRFs that comply with reduced form evidence. The extension of the microeconomic foundations affects the model in a way that is reconcilable with theoretical implications.

Consequently, the model offers central banks in general and the European Central Bank in particular an alternative approach towards incorporating predictions of bank behavior into their analysis. The predictions generated by the model might be particularly helpful for monetary policy makers trying to assess the influence of their decisions on bank risk-taking next to their influence on real economic quantities. It also allows for policy experiments that offer a complementary perspective to reduced form evidence on the internal functioning of the bank risk-taking channel.

In my last contribution, I create an exhibit in which I show how to utilize the model so as to extend the understanding of the pass-through effect through additional policy experiments. In Dell'Arricia, Laeven and Marquez (2014), banking market competition is the determinant of the pass-through effect. Until now, little empirical research has examined the relationship between competition and the pass-through effect. Further, the relatively homogeneous bank risk-taking patterns in my VAR evidence across different Euro area countries call for a further review. The homogeneous patterns emerge despite heterogeneously competitive banking markets.

In the subsequent exhibit, I segregate the influence of competition into the elasticity of substitution, which determines the mark-up in loan markets over the risk-free rate, and interest rate stickiness. This marks an extension of the theoretical foundations of the bank risk-taking channel. I study the respective influences of both characteristics of banking market competition on bank risk-taking in the light of monetary policy shocks. Overall, the influence of changes in both characteristics of competition on bank risk-taking is comparably small. In a general equilibrium context, competition not only influences the pass-through effect, but also changes the relative strength of the risk-shifting effect through loan demand's influence on the optimal leverage effect.

In both cases, the resulting influence on bank risk-taking is stronger for changes in the competitive landscape in markets for loans to entrepreneurs compared to the one in markets for impatient households. The stronger influence is due to the influence of the retail loan's interest rate on the output decision of entrepreneurs. The responses in output and inflation are amplified under these changes and change the endogenous path of monetary policy. This contributes to banks' response in risk-taking. Changes in competition in markets for loans to impatient households change relatively little in terms of output and inflation.

More importantly, the two characteristics result in opposing influences on the pass-through effect. Stronger competition that manifests in a higher elasticity of substitution will amplify the response in bank monitoring to a monetary policy shock. Bank risk-taking decreases through a reinforced pass-through effect. If an increase in competition results primarily in lower interest rate stickiness, this will attenuate the response in bank monitoring. Bank risk-taking increases as the pass-through effect is weakened. How bank risk-taking responds to monetary policy shocks in different banking markets thus depends on how competition influences the elasticity of substitution and interest rate stickiness in the individual market.

These insights considerably enrich the understanding of the pass-through effect (Dell'Ariccia et al. 2014). Furthermore, these insights potentially explain the observation in the narrative VAR evidence. Within the VAR evidence, responses in bank risk-taking were comparably alike in the cross-section of countries, although markets are heterogeneously competitive. The DSGE results provide two aspects that help to explain the observably small differences in bank risk-taking responses. First, there is an endogenous response to competition in the risk-shifting effect. The pass-through effect determines the retail rates. The retail rates in turn influence borrowers' loan demand. If bank capital evolves endogenously and if bank managers can neither raise nor redeem bank equity, then the change in loan volumes will in such a case alter the relative strength of the risk-shifting effect through the optimal leverage effect. This partly offsets the influences of the pass-through effect in a general equilibrium. Second, the two manifestations of competition (interest rate stickiness and the elasticity of substitution) exert opposing influences on the pass-through effect itself. Both aspects contribute to the fact that markets with different levels of competition may exhibit relatively similar bank risk-taking behaviors.

Even though the model performs well, the model reflects only a special case in terms of the more encompassing theoretical considerations. Since this application represents the first step in transferring the partial equilibrium considerations to a general equilibrium context, I imposed the following three simplifications.

First, the bank manager is constrained in the choice of the capital-ratio by the endogenous evolution of bank capital. The bank manager cannot redeem or raise bank capital. It evolves through bank's retained profits and represents a state variable in the bank manager's choice. This reflects a simplification relative to the considerations of Dell'Ariccia, Laeven and Marquez (2014).[2] Nonetheless, endogenizing the wholesale bank's dividend policy[3] could alter the propagation mechanism of the model.

Second, I deviate from the considerations of Dell'Ariccia, Laeven and

[2]There has been little research in terms of endogenous equity premia in DSGE models. This is considered to reflect a promising, but challenging route for future research.

[3]In this case, a negative dividend policy would reflect a seasoned equity offer to a secondary equity market.

Marquez (2014) as follows. I replace the assumptions underlying the optimal leverage effect by an exogenous bank capital-ratio target in combination with quadratic costs. Both considerations result in similar implications for banks. A deposit-ratio that is lower than the optimal choice will result in increasing costs in both cases. The same conclusion arises for either a regulator enforcing the capital-ratio target or through an increasing interest rate on deposits due to information asymmetries. It is mainly a question concerning how to correctly parameterize and how to correctly formulate the cost function. In my application, I have relied on a quadratic specification for deviations from the exogenous capital-ratio target. The parameter values have been kept identical to the estimates of Gerali et al. (2010). Nonetheless, the imposed symmetry and parameter choices can have implications for the endogenous bank risk responses.

Third, within the formulation of my model, I assume that the LTV ratio is constant and is unaffected by banks' risk-taking behavior. Relaxing this assumption by creating an endogenous influence of bank monitoring on the LTV ratio for impatient households and entrepreneurs might alter loan constraints, and hence alter bank risk-taking.

Out of these three simplifications, I consider the first to be most relevant for future research.

From the vantage point of a monetary policy maker interested in safeguarding financial sector stability, two further considerations may be of interest. First, the monetary policy maker might be interested in explicitly incorporating bank risk-taking into the Taylor-rule. For a potential starting point for such an incorporation, Angeloni, Faia and Lo Duca's (2015) approach can be helpful. Second, several policy makers have kept the policy rate at or close to the zero-lower bound (ZLB). How bank risk-taking responds in close proximity to the ZLB has not as yet been studied in my paper. Having a policy rate that is irresponsive to perturbations could be included as an interest rate peg within the Taylor rule. I leave these considerations as potential research venues to extend my work.

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Appendix A

Data Sources

Table A.1: Data Sources Used for VAR Estimations

Variable	**Area**	**Description**	**Source**
Bank margin	Euro area	Lending margin on new business loans to non-financial corporations and households per country	ECB-RAI dataset Codes: RAI,M,LMGBLNFCH,EUR,MIR,Z
Bank Lending Standards	Euro area	Backward looking three months net percentage of banks tightening their lending standards for enterprises	ECB-BLS dataset Codes: BLS.Q.MU.ALL.O.E.Z.B3.ST.S.FNET
Loan volume outstanding	Euro area	Outstanding amounts at the end of the period (stocks) in Euro per country	ECB-BSI dataset Codes: BSI.Q.N.R.A20.A.1.U2.2200.Z01.E, BSI.Q.AT.N.R.A20.A.4.U2.2200.Z01.E, BSI.Q.AT.N.R.A20.A.I.U2.2200.Z01.A, BSI.M.U2.N.A.A21.F.1.U2.2250.Z01.E, BSI.M.U2.N.A.A21.I.1.U2.2250.Z01.E, BSI.M.U2.N.A.A21.J.1.U2.2250.Z01.E
Interest rates on loans	Euro area		ECB-MIR dataset Codes: MIR.M.U2.B.A20.F.R.A.2240.EUR.O
Deposits with agreed maturity, Non-Financial corporations	Euro area	Outstanding amounts at the end of the period (stocks) in Euro	ECB-BSI dataset Codes: BSI.M.U2.N.A.L22.A.1.U2.2240.EUR.E
Deposits with agreed maturity, Households and non-profit institutions serving households	Euro area	Outstanding amounts at the end of the period (stocks) in Euro	ECB-BSI dataset Codes: BSI.M.U2.N.A.L22.A.1.U2.2250.EUR.E

Table A.1: Data Sources Used for VAR Estimations

Variable	**Area**	**Description**	**Source**
Deposits redeemable at notice, Non-Financial corporations	Euro area	Outstanding amounts at the end of the period (stocks) in Euro	ECB-BSI dataset Codes: BSI.M.U2.N.A.L23.A.1.U2.2240.EUR.E
Deposits redeemable at notice, Households and non-profit institutions serving households	Euro area	Outstanding amounts at the end of the period (stocks) in Euro	ECB-BSI dataset Codes: BSI.M.U2.N.A.L23.A.1.U2.2250.EUR.E
Annualized Agreed Rate	Euro area	Outstanding amounts at the end of the period (stocks) in Euro	ECB-BSI dataset Code: MIR.M.U2.B.L22.A.R.A.2230.EUR.O
Deposit rate	Euro area	Weighted average of EONIA and the annualized agreed rate weighted by the sum of deposits redeemable at notice and the sum of deposits with agreed maturity, respectively	
Real GDP	Euro area	Real Gross domestic product, quarterly and seasonally adjusted	Eurostat Eurostat unit ID: CLV10_MEUR Eurostat item ID: B1GQ Eurostat country ID: EA19
EONIA	Euro area	Rate for the overnight maturity calculated as the euro short-term rate plus a spread of 8.5 basis points	ECB-EON dataset Codes: EON,D,EONIA_TO,RATE
Real GDP	Austria, Belgium, Germany, Spain, Finland, Greece, Ireland, Italy, Luxembourg, Portugal	Real Gross domestic product, quarterly and seasonally adjusted	Eurostat Eurostat unit ID: CLVMNACSCA Eurostat item ID: B1GQ Eurostat country ID: AT, BE, DE, ES, FI, GR, IE, IT, LU, PT
Margin on average loan	Austria, Belgium, Germany, Spain, Finland, Greece, Ireland, Italy, Luxembourg, Portugal	Margin on average loan to enterprises, collected at the beginning of the period aggregated at the diffusion index	ECB-BLS dataset Codes: BLS.Q.AT.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.BE.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.DE.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.ES.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.FI.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.GR.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.IE.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.IT.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.LU.ALL.MAL.E.Z.B3.TC.S.DINX BLS.Q.PT.ALL.MAL.E.Z.B3.TC.S.DINX

Table A.1: Data Sources Used for VAR Estimations

Variable	**Area**	**Description**	**Source**
Bank Lending Standards	Austria, Belgium, Germany, Spain, Finland, Greece, Ireland, Italy, Luxembourg, Portugal	Backward looking three months net percentage of banks tightening their lending standards for enterprises	ECB-BLS dataset Codes: BLS.Q.AT.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.BE.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.DE.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.ES.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.FI.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.GR.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.IE.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.It.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.LU.ALL.O.E.Z.B3.ST.S.FNET BLS.Q.PT.ALL.O.E.Z.B3.ST.S.FNET

Note: Table A.1 summarizes the data sources for the respective variables, its geographic coverage and provides a short description. In the last column, the mnemonic used for the respective source is given.

Appendix B

VAR Results

B.1 Spread over EONIA

B.1.1 VAR(1) Results

Table B.1: VAR(1) Results for the Euro Area Including Spread over EONIA as a Profitability Proxy

	LOG_SPREAD	**BLS**	**LOG_REAL_GDP**	**EONIA**
LOG_SPREAD(-1)	−0.032 (0.197)	1.439 (20.328)	−0.007 (0.013)	−1.381 (0.546)**
BLS(-1)	0.001 (0.001)	0.695 (0.110)***	0.000 (0.000)	−0.004 (0.003)
LOG_REAL_GDP(-1)	−5.021 (2.413)**	−184.042 (249.437)	0.553 (0.159)***	7.43 (6.699)
EONIA(-1)	0.007 (0.009)	3.070 (0.919)***	0.000 (0.001)	0.993 (0.025)***
R-squared	0.323	0.787	0.371	0.977
Adj. R-squared	0.283	0.774	0.33	0.976
Sum sq. resids	0.360	3848.787	0.002	2.776
S.E. equation	0.084	8.687	0.006	0.233
F-statistic	8.117	62.802	10.028	731.962
Log likelihood	60.249	−194.867	209.718	4.080
Akaike AIC	−2.045	7.232	−7.481	−0.003
Schwarz SC	−1.899	7.378	−7.335	0.143
Mean dependent	0.001	7.061	0.003	0.977
S.D. dependent	0.099	18.291	0.007	1.505
Determinant Residual Covariance		0		
Log Likelihood		167.314		
Akaike Information Criteria		-6.019		
Schwarz Criteria		-4.840		

Note: Table B.1 presents the estimates for the VAR(1) specification including the LOG_SPREAD over EONIA as a bank profitability proxy, BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.1.2 VAR(2) Results

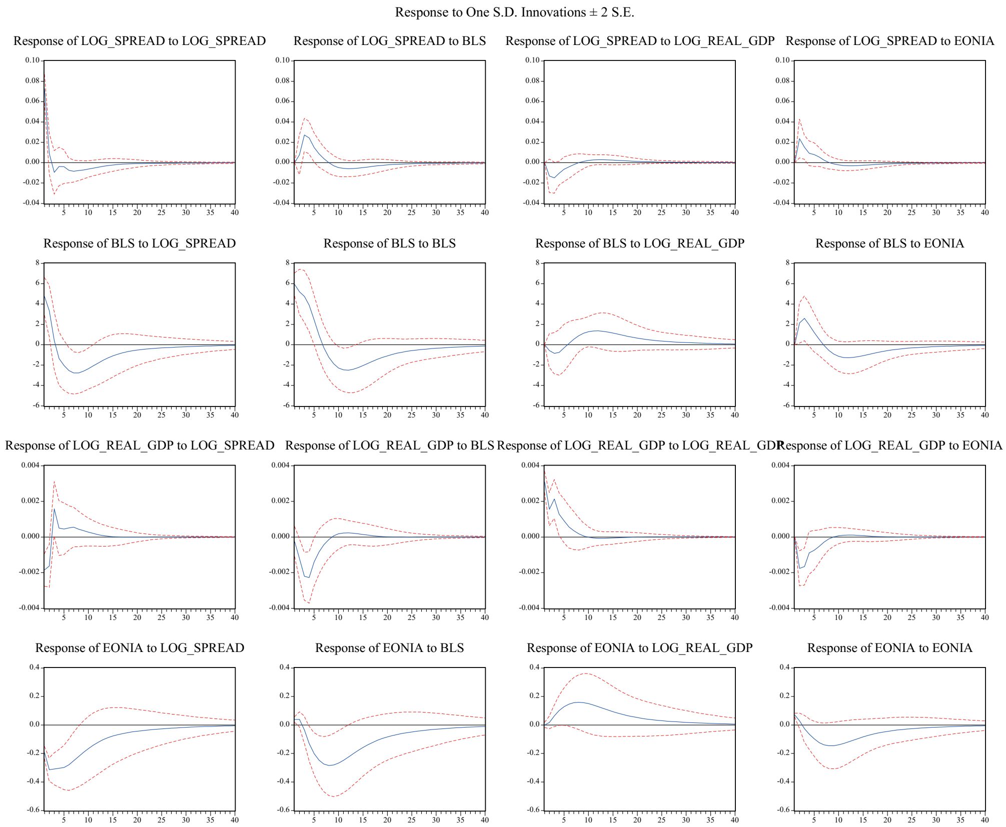
Table B.2: VAR(2) Results for the Euro Area Including Spread over EONIA as a Profitability Proxy

	LOG_SPREAD	**BLS**	**LOG_REAL_GDP**	**EONIA**
LOG_SPREAD(-1)	0.984	78.106	−0.075	−3.306
	(0.489)**	(50.946)	(0.024)***	(1.412)**
LOG_SPREAD(-2)	0.036	17.932	0.019	0.185
	(0.286)	(29.761)	(0.014)	(0.825)
BLS(-1)	−0.001	0.677	0.000	0.004
	(0.002)	(0.200)***	(0.000)	(0.006)
BLS(-2)	0.003	0.048	0.000	−0.010
	(0.002)**	(0.165)	(0.000)*	(0.005)**
LOG_REAL_GDP(-1)	−4.244	−186.514	0.506	5.670
	(2.615)	(272.277)	(0.130)***	(7.548)
LOG_REAL_GDP(-2)	−0.588	107.466	0.254	2.130
	(2.640)	(274.927)	(0.131)*	(7.621)
EONIA(-1)	0.338	30.400	−0.025	0.422
	(0.143)**	(14.868)**	(0.007)***	(0.412)
EONIA(-2)	−0.334	−27.562	0.026	0.574
	(0.142)**	(14.788)*	(0.007)***	(0.410)
R-squared	0.462	0.825	0.717	0.980
Adj. R-squared	0.380	0.799	0.674	0.977
Sum sq. resids	0.286	3101.466	0.001	2.383
S.E. equation	0.079	8.211	0.004	0.228
F-statistic	5.637	30.998	16.620	327.307
Log likelihood	64.873	−185.990	227.030	7.629
Akaike AIC	−2.106	7.185	−8.112	0.014
Schwarz SC	−1.812	7.480	−7.818	0.308
Mean dependent	0.001	7.397	0.003	0.957
S.D. dependent	0.100	18.291	0.007	1.512
Determinant Residual Covariance		0		
Log Likelihood		194.499		
Akaike Information Criteria		-5.502		
Schwarz Criteria		-4.918		

Note: Table B.2 presents the estimates for the VAR(1,2) specification including the LOG_SPREAD over EONIA as a bank profitability proxy, BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.1.3 Complete Set of IRFs of VAR(2)

The subsequent illustration depicts the impulse-responses of all endogenous variables to innovations in the respective variables included in a VAR(2) using LOG_SPREAD_EONIA as a bank profitability proxy.



B.2 Spread over Deposits

B.2.1 VAR(1) Results

Table B.3: VAR(1) Results for the Euro Area Including Spread over Deposits as a Profitability Proxy

	LOG_SPREAD_DEP	**BLS**	**LOG_REAL_GDP**	**EONIA**
LOG_SPREAD_DEP(-1)	0.077	−35.338	0.028	−2.166
	(0.188)	(39.340)	(0.025)	(1.088)*
BLS(-1)	0.001	0.754	0.000	−0.005
	(0.001)	(0.112)***	(0.000 1)	(0.003)
LOG_REAL_GDP(-1)	−2.595	−295.209	0.676	9.01
	(1.181)**	(247.241)	(0.158)***	(6.839)
EONIA(-1)	0.000	2.738	0.000	0.986
	(0.005)	(0.961)***	(0.001)	(0.026)***
R-squared	0.432	0.790	0.382	0.976
Adj. R-squared	0.398	0.778	0.346	0.975
Sum sq. resids	0.087	3789.215	0.002	2.900
S.E. equation	0.041	8.620	0.006	0.238
F-statistic	12.908	64.057	10.501	700.130
Log likelihood	99.476	−194.438	210.195	2.886
Akaike AIC	−3.472	7.216	−7.498	0.041
Schwarz SC	−3.326	7.362	−7.352	0.187
Mean dependent	−0.001	7.061	0.003	0.977
S.D. dependent	0.053	18.291	0.007	1.505
Determinant Residual Covariance	0.000			
Log Likelihood	197.491			
Akaike Information Criteria	-7.451			
Schwarz Criteria	-6.272			

Note: Table B.3 presents the estimates for the VAR(1) specification including the LOG_SPREAD over the interest rate on deposits and Repos as a bank profitability proxy, BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.2.2 VAR(2) Results

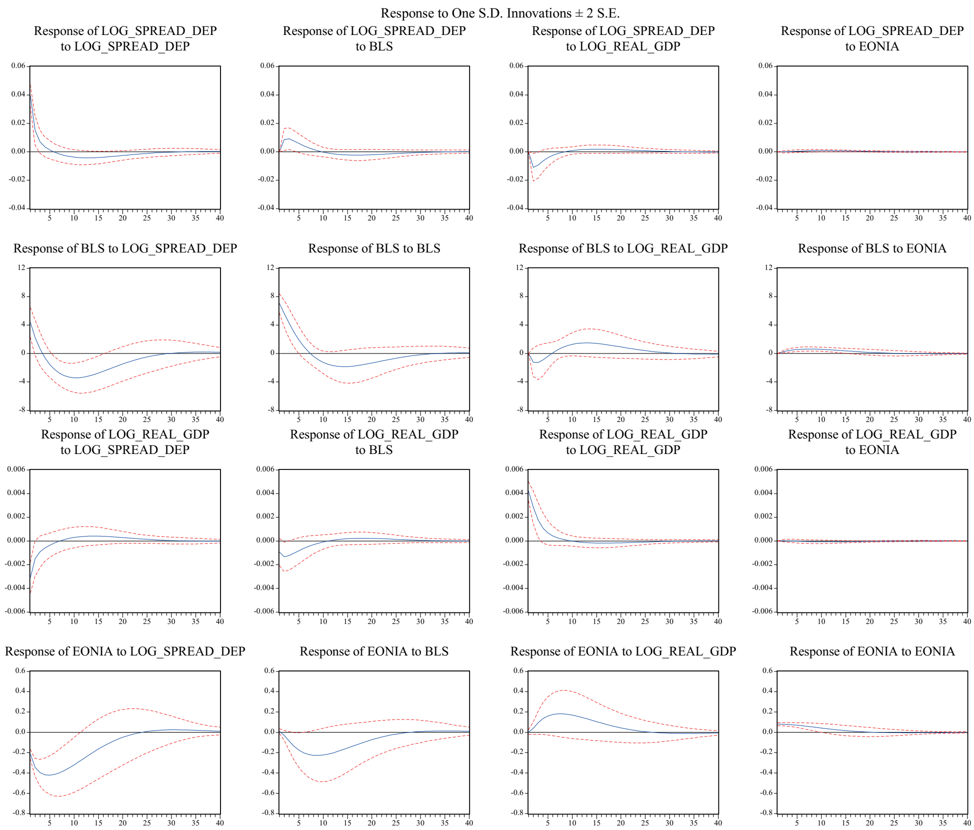
Table B.4: VAR(2) Results for the Euro Area Including Spread over Deposits as a Profitability Proxy

	LOG_SPREAD_DEP	**BLS**	**LOG_REAL_GDP**	**EONIA**
LOG_SPREAD_DEP(-1)	0.937 (0.399)**	41.957 (87.095)	−0.070 (0.043)	−3.924 (2.448)
LOG_SPREAD_DEP(-2)	−0.250 (0.213)	−30.170 (46.443)	0.092 (0.023)***	2.305 (1.305)*
BLS(-1)	0.000 (0.001)	0.838 (0.166)***	0.000 (0.000)*	−0.001 (0.005)
BLS(-2)	0.002 (0.001)**	−0.040 (0.155)	0.000 (0.000)	−0.007 (0.004)
LOG_REAL_GDP(-1)	−1.965 (1.236)	−266.332 (270.205)	0.474 (0.133)***	6.145 (7.595)
LOG_REAL_GDP(-2)	−1.041 (1.336)	−23.878 (291.920)	0.400 (0.144)***	6.133 (8.205)
EONIA(-1)	0.139 (0.065)**	14.728 (14.178)	−0.014 (0.007)*	0.765 (0.399)*
EONIA(-2)	−0.139 (0.063)**	−12.154 (13.929)	0.015 (0.007)**	0.239 (0.392)
R-squared	0.555	0.818	0.687	0.979
Adj. R-squared	0.488	0.791	0.639	0.976
Sum sq. resids	0.067	3221.007	0.001	2.545
S.E. equation	0.038	8.368	0.004	0.235
F-statistic	8.207	29.603	14.421	306.153
Log likelihood	103.895	−187.011	224.341	5.862
Akaike AIC	−3.552	7.223	−8.013	0.079
Schwarz SC	−3.257	7.517	−7.718	0.374
Mean dependent	−0.001	7.397	0.003	0.957
S.D. dependent	0.054	18.291	0.007	1.512
Determinant Residual Covariance		0		
Log Likelihood		233.163		
Akaike Information Criteria		-6.600		
Schwarz Criteria		-6.016		

Note: Table B.4 presents the estimates for the VAR(1,2) specification including the LOG_SPREAD over the interest rate on deposits and Repos as a bank profitability proxy, BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.2.3 Complete Set of IRFs of VAR(1)

The subsequent illustration depicts the impulse-responses of all endogenous variables to innovations in the respective variables included in a VAR(2) using LOG_SPREAD_DEP as a bank profitability proxy.



B.3 Bank Margin

B.3.1 VAR(1) Results

Table B.5: VAR(1) Results for the Euro Area Including New Loan Margin as a Profitability Proxy

	LOG_BANK_MARGIN	**BLS**	**LOG_REAL_GDP**	**EONIA**
LOG_BANK_MARGIN(-1)	−0.209 (0.134)	9.134 (23.598)	−0.003 (0.015)	−0.655 (0.667)
BLS(-1)	0.001 (0.001)**	0.684 (0.102)***	0.000 (0.000)	−0.007 (0.003)**
LOG_REAL_GDP(-1)	−2.815 (1.257)**	−183.327 (221.680)	0.593 (0.142)***	14.679 (6.266)**
EONIA(-1)	−0.007 (0.005)	3.159 (0.936)***	0.000 (0.001)	0.998 (0.027)***
R-squared	0.355	0.788	0.368	0.975
Adj. R-squared	0.317	0.775	0.330	0.974
Sum sq. resids	0.123	3837.892	0.002	3.067
S.E. equation	0.049	8.675	0.006	0.245
F-statistic	9.358	63.028	9.881	661.022
Log likelihood	89.717	−194.789	209.568	1.343
Akaike AIC	−3.117	7.229	−7.475	0.097
Schwarz SC	−2.971	7.375	−7.329	0.243
Mean dependent	−0.004	7.061	0.003	0.977
S.D. dependent	0.060	18.291	0.007	1.505
Determinant Residual Covariance		0.000		
Log Likelihood		122.438		
Akaike Information Criteria		-3.871		
Schwarz Criteria		-3.287		

Note: Table B.5 presents the estimates for the VAR(1) specification including the banks' self-reported margins on new loans as a bank profitability proxy, BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.3.2 VAR(2) Results

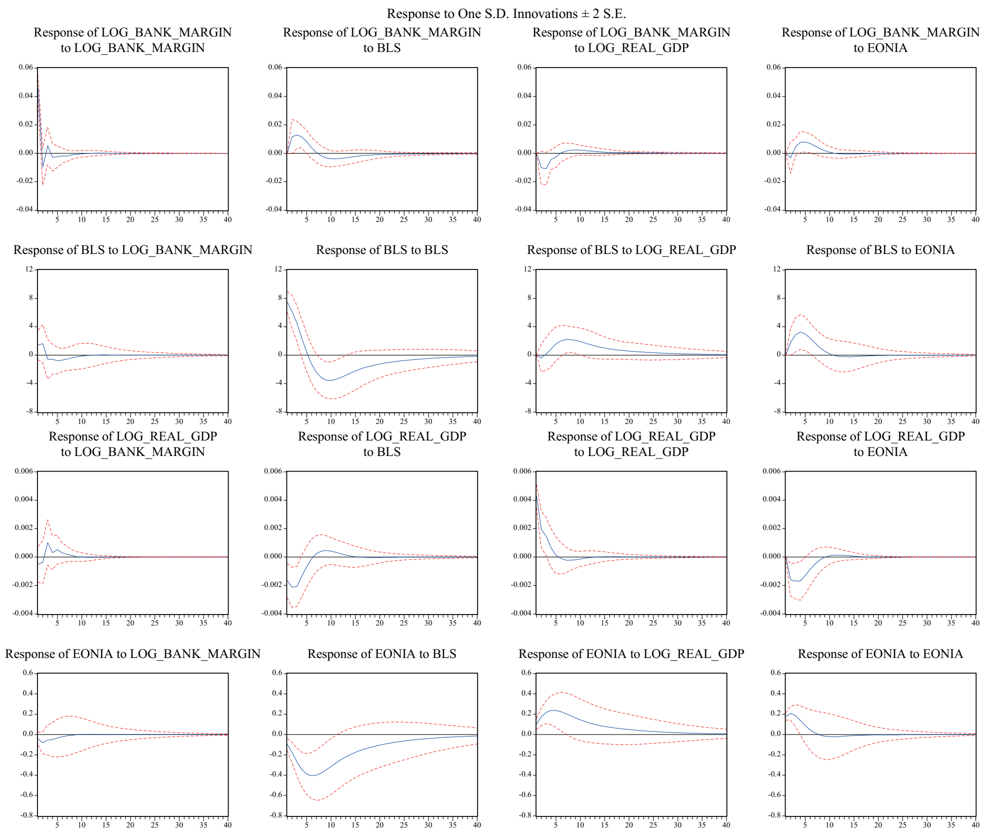
Table B.6: VAR(2) Results for the Euro Area Including New Loan Margin as a Profitability Proxy

	LOG_BANK_MARGIN	**BLS**	**LOG_REAL_GDP**	**EONIA**
LOG_BANK_MARGIN(-1)	−0.273 (0.146)*	13.903 (24.174)	−0.001 (0.015)	−0.375 (0.733)
LOG_BANK_MARGIN(-2)	−0.035 (0.142)	−28.752 (23.393)	0.029 (0.014)**	1.008 (0.710)
BLS(-1)	0.001 (0.001)	0.878 (0.156)***	0.000 (0.000)***	−0.005 (0.005)
BLS(-2)	0.000 (0.001)	−0.083 (0.139)	0.000 (0.000)	−0.002 (0.004)
LOG_REAL_GDP(-1)	−1.977 (1.537)	−339.616 (254.089)	0.674 (0.154)***	12.837 (7.707)
LOG_REAL_GDP(-2)	−1.823 (1.544)	74.352 (255.247)	0.142 (0.155)	−0.599 (7.742)
EONIA(-1)	−0.017 (0.034)	10.268 (5.570)*	−0.009 (0.003)***	1.178 (0.169)***
EONIA(-2)	0.014 (0.035)	−7.814 (5.729)	0.010 (0.004)***	−0.172 (0.174)
R-squared	0.384	0.823	0.538	0.976
Adj. R-squared	0.291	0.796	0.467	0.973
Sum sq. resids	0.115	3137.893	0.001	2.887
S.E. equation	0.050	8.259	0.005	0.251
F-statistic	4.104	30.562	7.646	269.086
Log likelihood	89.504	−186.305	213.817	2.456
Akaike AIC	−3.019	7.197	−7.623	0.205
Schwarz SC	−2.724	7.491	−7.328	0.500
Mean dependent	−0.003	7.397	0.003	0.957
S.D. dependent	0.059	18.291	0.007	1.512
Determinant Residual Covariance		0.000		
Log Likelihood		138.886		
Akaike Information Criteria		-3.959		
Schwarz Criteria		-2.780		

Note: Table B.6 presents the estimates for the VAR(1,2) specification including the banks' self-reported margins on new loans as a bank profitability proxy, BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.3.3 Complete Set of IRFs of VAR(2)

The subsequent illustration depicts the impulse-responses of all endogenous variables to innovations in the respective variables included in a VAR(2) using LOG_BANK_MARGIN as a bank profitability proxy.



B.4 Cross-Sectional Evidence for Individual Euro Area Members

B.4.1 VAR(1) Results for Austria

Table B.7: VAR(1) Results for Austria

	AT_MAL	**AT_BLS**	**AT_LOG_GDP**	**EONIA**
AT_MAL(-1)	0.345 (0.126)***	0.317 (0.207)	0.000 (0.000)**	−0.001 (0.002)
AT_BLS(-1)	0.094 (0.082)	0.204 (0.134)	0.000 (0.000)	−0.002 (0.002)
AT_LOG_GDP(-1)	−1153.260 (277.811)***	−570.245 (455.413)	0.408 (0.131)***	27.357 (4.990)***
EONIA(-1)	2.445 (1.075)**	7.218 (1.763)***	0.001 (0.001)	0.945 (0.019)***
R-squared	0.591	0.303	0.239	0.977
Adj. R-squared	0.570	0.267	0.200	0.976
Sum sq. resids	9267.629	24 904.730	0.002	2.989
S.E. equation	12.641	20.722	0.006	0.227
F-statistic	27.940	8.387	6.084	817.812
Log likelihood	−243.196	−273.840	231.801	6.019
Akaike AIC	7.974	8.963	−7.348	−0.065
Schwarz SC	8.111	9.100	−7.211	0.072
Mean dependent	−0.774	13.825	0.004	1.098
S.D. dependent	19.274	24.195	0.007	1.457
Determinant Residual Covariance		0.059		
Log Likelihood		-263.985		
Akaike Information Criteria		9.032		
Schwarz Criteria		9.581		

Note: Table B.7 presents the estimates for the VAR(1) specification for Austria including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.2 VAR(1) Results for Belgium

Table B.8: VAR(1) Results for Belgium

	BE_MAL	BE_BLS	BE_LOG_GDP	EONIA
BE_MAL(-1)	0.743 (0.107)***	0.189 (0.117)	−0.0001 (0.000)*	0.002 (0.002)
BE_BLS(-1)	0.009 (0.115)	0.025 (0.125)	0.000 (0.000)*	−0.002 (0.002)
BE_LOG_GDP(-1)	−697.431 (450.778)	−2090.635 (489.554)***	0.675 (0.115)***	32.756 (6.258)***
EONIA(-1)	1.208 (1.411)	6.100 (1.533)***	0.000 (0.000)	0.935 (0.020)***
R-squared	0.603	0.473	0.300	0.973
Adj. R-squared	0.583	0.446	0.264	0.971
Sum sq. resids	18 495.186	21 813.954	0.001	3.565
S.E. equation	17.857	19.393	0.005	0.248
F-statistic	29.380	17.342	8.296	682.704
Log likelihood	−264.616	−269.733	248.457	0.563
Akaike AIC	8.665	8.830	−7.886	0.111
Schwarz SC	8.802	8.967	−7.749	0.248
Mean dependent	−14.452	−2.823	0.004	1.098
S.D. dependent	27.640	26.046	0.005	1.457
Determinant Residual Covariance		0.071		
Log Likelihood		-270.015		
Akaike Information Criteria		9.226		
Schwarz Criteria		9.775		

Note: Table B.8 presents the estimates for the VAR(1) specification for Belgium including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.3 VAR(1) Results for Germany

Table B.9: VAR(1) Results for Germany

	DE_MAL	**DE_BLS**	**DE_LOG_GDP**	**EONIA**
DE_MAL(-1)	0.460 (0.124)***	0.276 (0.135)**	0.000 (0.000)	0.001 (0.004)
DE_BLS(-1)	0.314 (0.152)**	0.173 (0.165)	0.000 (0.000)	−0.008 (0.005)
DE_LOG_GDP(-1)	−355.428 (117.322)***	−482.996 (127.612)***	0.392 (0.133)***	12.152 (3.849)***
EONIA(-1)	0.335 (0.618)	2.181 (0.672)**	0.000 (0.001)	0.974 (0.020)***
R-squared	0.730	0.573	0.062	0.969
Adj. R-squared	0.716	0.551	0.014	0.968
Sum sq. resids	3713.199	4393.110	0.005	3.996
S.E. equation	8.001	8.703	0.009	0.263
F-statistic	52.240	25.925	1.279	607.022
Log likelihood	−214.842	−220.055	205.764	−2.973
Akaike AIC	7.059	7.228	−6.509	0.225
Schwarz SC	7.197	7.365	−6.371	0.362
Mean dependent	0.081	2.226	0.004	1.098
S.D. dependent	15.012	12.984	0.009	1.457
Determinant Residual Covariance	0.007			
Log Likelihood	-199.743			
Akaike Information Criteria	6.959			
Schwarz Criteria	7.508			

Note: Table B.9 presents the estimates for the VAR(1) specification for Germany including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.4 VAR(1) Results for Spain

Table B.10: VAR(1) Results for Spain

	ES_MAL	**ES_BLS**	**ES_LOG_GDP**	**EONIA**
ES_MAL(-1)	0.561 (0.120)***	−0.197 (0.165)	0.000 (0.000)	0.006 (0.003)*
ES_BLS(-1)	−0.003 (0.068)	0.722 (0.094)***	0.000 (0.000)	−0.007 (0.002)***
ES_LOG_GDP(-1)	−622.063 (250.372)**	−479.120 (345.026)	0.734 (0.125)***	21.828 (6.960)***
EONIA(-1)	3.531 (1.108)***	4.299 (1.527)***	0.000 (0.001)	0.965 (0.031)***
R-squared	0.777	0.729	0.635	0.972
Adj. R-squared	0.766	0.715	0.616	0.971
Sum sq. resids	4671.493	8871.300	0.001	3.610
S.E. equation	8.975	12.367	0.005	0.250
F-statistic	67.523	51.941	33.667	673.897
Log likelihood	−221.959	−241.841	249.509	0.172
Akaike AIC	7.289	7.930	−7.920	0.123
Schwarz SC	7.426	8.068	−7.782	0.261
Mean dependent	2.419	8.226	0.003	1.098
S.D. dependent	18.549	23.155	0.007	1.457
Determinant Residual Covariance		0.007		
Log Likelihood		-195.947		
Akaike Information Criteria		6.837		
Schwarz Criteria		7.386		

Note: Table B.10 presents the estimates for the VAR(1) specification for Spain including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.5 VAR(1) Results for Finland

Table B.11: VAR(1) Results for Finland

	FI_MAL	FI_BLS	FI_LOG_GDP	EONIA
FI_MAL(-1)	0.575 (0.127)***	0.635 (0.155)***	0.000 (0.000)*	−0.001 (0.002)
FI_BLS(-1)	0.140 (0.108)	0.166 (0.132)	0.000 (0.000)	−0.003 (0.002)**
FI_LOG_GDP(-1)	−279.210 (214.061)	−145.794 (261.226)	0.068 (0.142)	5.487 (3.111)*
EONIA(-1)	0.684 (1.553)	8.151 (1.895)***	0.001 (0.001)	0.984 (0.023)***
R-squared	0.619	0.598	0.211	0.970
Adj. R-squared	0.599	0.577	0.170	0.968
Sum sq. resids	18 437.174	27 457.077	0.008	3.893
S.E. equation	17.829	21.758	0.012	0.259
F-statistic	31.373	28.742	5.160	623.450
Log likelihood	−264.519	−276.865	189.197	−2.171
Akaike AIC	8.662	9.060	−5.974	0.199
Schwarz SC	8.799	9.197	−5.837	0.336
Mean dependent	−2.065	10.887	0.003	1.098
S.D. dependent	28.155	33.456	0.013	1.457
Determinant Residual Covariance		0.594		
Log Likelihood		-335.738		
Akaike Information Criteria		11.346		
Schwarz Criteria		11.895		

Note: Table B.11 presents the estimates for the VAR(1) specification for Finland including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.6 VAR(1) Results for Greece

Table B.12: VAR(1) Results for Greece

	GR_MAL	**GR_BLS**	**GR_LOG_GDP**	**EONIA**
GR_MAL(-1)	0.766 (0.124)***	0.800 (0.214)***	−0.001 (0.000)***	−0.007 (0.003)**
GR_BLS(-1)	−0.062 (0.074)	0.158 (0.127)	0.000 (0.000)***	0.000 (0.002)
GR_LOG_GDP(-1)	−334.456 (115.283)***	−356.184 (199.000)*	−0.104 (0.127)	−1.227 (2.695)
EONIA(-1)	2.699 (1.004)***	8.248 (1.732)***	−0.001 (0.001)	0.995 (0.024)***
R-squared	0.708	0.559	0.353	0.965
Adj. R-squared	0.693	0.536	0.319	0.963
Sum sq. resids	8287.022	24 693.263	0.010	4.529
S.E. equation	11.953	20.634	0.013	0.279
F-statistic	46.811	24.505	10.537	533.277
Log likelihood	−239.729	−273.576	182.779	−6.856
Akaike AIC	7.862	8.954	−5.767	0.350
Schwarz SC	7.999	9.091	−5.630	0.487
Mean dependent	10.887	26.586	−0.002	1.098
S.D. dependent	21.559	30.297	0.016	1.457
Determinant Residual Covariance		0.472		
Log Likelihood		-328.620		
Akaike Information Criteria		11.117		
Schwarz Criteria		11.666		

Note: Table B.12 presents the estimates for the VAR(1) specification for Greece including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.7 VAR(1) Results for Ireland

Table B.13: VAR(1) Results for Ireland

	IE_MAL	**IE_BLS**	**IE_LOG_GDP**	**EONIA**
IE_MAL(-1)	0.601 (0.115)***	0.099 (0.171)	0.000 (0.000)	0.000 (0.003)
IE_BLS(-1)	0.238 (0.090)**	0.660 (0.134)***	−0.001 (0.000)***	−0.006 (0.002)***
IE_LOG_GDP(-1)	126.317 (80.266)	−60.784 (119.979)	−0.244 (0.144)*	2.448 (2.098)
EONIA(-1)	0.256 (1.015)	4.062 (1.517)***	0.006 (0.002)***	1.033 (0.027)***
R-squared	0.732	0.736	0.125	0.961
Adj. R-squared	0.715	0.719	0.068	0.959
Sum sq. resids	5591.652	12 493.720	0.018	3.821
S.E. equation	11.025	16.480	0.020	0.288
F-statistic	41.893	42.794	2.198	379.694
Log likelihood	−188.872	−208.971	127.364	−6.656
Akaike AIC	7.715	8.519	−4.935	0.426
Schwarz SC	7.868	8.672	−4.782	0.579
Mean dependent	12.840	15.500	0.007	1.444
S.D. dependent	20.637	31.090	0.021	1.417
Determinant Residual Covariance	0.565			
Log Likelihood	-269.500			
Akaike Information Criteria	11.420			
Schwarz Criteria	12.032			

Note: Table B.13 presents the estimates for the VAR(1) specification for Ireland including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.8 VAR(1) Results for Italy

Table B.14: VAR(1) Results for Italy

	IT_MAL	IT_BLS	IT_LOG_GDP	EONIA
IT_MAL(-1)	0.579 (0.134)***	0.330 (0.191)*	0.000 (0.000)**	0.002 (0.003)
IT_BLS(-1)	0.041 (0.100)	0.351 (0.143)**	0.000 (0.000)	−0.003 (0.002)
IT_LOG_GDP(-1)	−415.618 (294.761)	−618.105 (418.678)	0.568 (0.130)***	26.077 (5.806)***
EONIA(-1)	1.236 (1.020)	4.932 (1.448)***	−0.001 (0.000)	0.992 (0.020)***
R-squared	0.622	0.624	0.452	0.974
Adj. R-squared	0.602	0.605	0.423	0.973
Sum sq. resids	8570.943	17 292.166	0.002	3.326
S.E. equation	12.156	17.267	0.005	0.240
F-statistic	31.792	32.140	15.930	733.138
Log likelihood	−240.773	−262.531	238.297	2.714
Akaike AIC	7.896	8.598	−7.558	0.042
Schwarz SC	8.033	8.740	−7.421	0.179
Mean dependent	0.581	11.352	0.000	1.098
S.D. dependent	19.276	27.473	0.007	1.457
Determinant Residual Covariance	0.020			
Log Likelihood	-230.810			
Akaike Information Criteria	7.962			
Schwarz Criteria	8.511			

Note: Table B.14 presents the estimates for the VAR(1) specification for Italy including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.9 VAR(1) Results for Luxembourg

Table B.15: VAR(1) Results for Luxembourg

	LU_MAL	**LU_BLS**	**LU_LOG_GDP**	**EONIA**
LU_MAL(-1)	0.381 (0.132)***	0.292 (0.153)*	0.000 (0.000)	−0.003 (0.003)
LU_BLS(-1)	0.205 (0.108)*	0.337 (0.125)***	0.000 (0.000)	−0.003 (0.003)
LU_LOG_GDP(-1)	−179.834 (95.851)*	−148.076 (110.773)	0.155 (0.129)	7.052 (2.281)***
EONIA(-1)	−0.459 (1.048)	3.946 (1.212)***	0.000 (0.001)	0.975 (0.025)***
R-squared	0.396	0.470	−0.147	0.965
Adj. R-squared	0.364	0.443	−0.206	0.963
Sum sq. resids	8095.220	10 811.954	0.015	4.582
S.E. equation	11.814	13.653	0.016	0.281
F-statistic	12.652	17.145	−2.478	526.818
Log likelihood	−239.003	−247.974	170.698	−7.221
Akaike AIC	7.839	8.128	−5.377	0.362
Schwarz SC	7.976	8.265	−5.240	0.499
Mean dependent	−0.129	6.644	0.007	1.098
S.D. dependent	14.818	18.287	0.015	1.457
Determinant Residual Covariance		0.279		
Log Likelihood		-312.333		
Akaike Information Criteria		10.591		
Schwarz Criteria		11.140		

Note: Table B.15 presents the estimates for the VAR(1) specification for Luxembourg including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

B.4.10 VAR(1) Results for Portugal

Table B.16: VAR(1) Results for Portugal

	PT_MAL	**PT_BLS**	**PT_LOG_GDP**	**EONIA**
PT_MAL(-1)	0.790 (0.113)***	0.180 (0.129)	0.000 (0.000)	0.003 (0.002)
PT_BLS(-1)	0.092 (0.106)	0.693 (0.121)***	0.000 (0.000)	−0.004 (0.002)**
PT_LOG_GDP(-1)	−83.733 (321.403)	132.287 (367.048)	0.353 (0.122)***	13.576 (5.074)***
EONIA(-1)	1.040 (1.541)	4.065 (1.760)**	0.000 (0.001)	1.004 (0.024)***
R-squared	0.821	0.782	0.277	0.965
Adj. R-squared	0.811	0.771	0.240	0.963
Sum sq. resids	18 266.603	23 823.426	0.003	4.553
S.E. equation	17.747	20.267	0.007	0.280
F-statistic	88.432	69.275	7.409	530.342
Log likelihood	−264.231	−272.464	224.197	−7.021
Akaike AIC	8.653	8.918	−7.103	0.356
Schwarz SC	8.790	9.055	−6.966	0.493
Mean dependent	6.452	22.581	0.002	1.098
S.D. dependent	40.856	42.308	0.008	1.457
Determinant Residual Covariance		0.215		
Log Likelihood		-304.190		
Akaike Information Criteria		10.329		
Schwarz Criteria		10.878		

Note: Table B.16 presents the estimates for the VAR(1) specification for Portugal including the banks' self-reported margins on average loans as a bank profitability proxy, the net change in national BLS, the growth rate in real GDP, and EONIA. Standard errors of the respective estimates are given in the parentheses below. The stars indicate the significance level as follows: *, **, *** represent 10%, 5%, 1% significance levels, respectively.

Appendix C

Full Set of Equilibrium Conditions

My model as it has been estimated and is replicated in Appendix E consists of 87 endogenous variables and 13 exogenous variables in 87 equations.[1] Subsequently, I drop the indices distinguishing between the different economic agents. The model's full set of equilibrium conditions can be separated into blocks – patient households, impatient households, entrepreneurs, retailers, capital producers, wholesale bank, retail banks, bank capital, public sector, market clearing conditions, and shocks.

Patient household. From the patient household, I have the intertemporal consumption Euler equation

$$\lambda_t^P = \left(1 - a^P\right) \varepsilon_t^C \left(C_t^P - a^P C_{t-1}^P\right)^{-1}, \tag{C.1}$$

the demand for housing

$$\lambda_t^P q_t^H = \varepsilon_t^H \frac{j}{H_t^P} + \lambda_{t+1}^P \beta_p q_{t+1}^H, \tag{C.2}$$

the deposit demand equation

$$\lambda_t^P = \beta_P \lambda_{t+1}^P \frac{1 + r_t^d}{\pi_{t+1}}, \tag{C.3}$$

and the patient households' budget constraint

$$C_t^P + q_t^H \left(H_t^P - H_{t-1}^P\right) + d_t = w_t^P N_t^P + \left(1 + r_{t-1}^d\right) d_{t-1} \pi_t^{-1} + T_t^P. \tag{C.4}$$

[1] There are some additional variables included in the source code used primarily for the replication of the IRF. Moreover, Dynare adds 4 auxiliary variables to estimate the model.

In combination with the labor market dynamics, I derive the wage inflation for patient households

$$\pi_t^{w^P} = \frac{w_t^P}{w_{t-1}^P}\pi_t \tag{C.5}$$

in combination with the labor supply to the union

$$\begin{aligned} &\kappa^w\left(\pi_t^{w^P} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)\pi_t^{w^P} = \\ &\beta_P E_t\left[\tfrac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^w\left(\pi_{t+1}^{w^P} - \pi_t^{\iota_w}\pi^{1-\iota_w}\right)\tfrac{\pi_{t+1}^{w^P\,2}}{\pi_{t+1}}\right] + \left(1-\varepsilon_t^N\right)N_t^P + \tfrac{\varepsilon_t^N N_t^{P\,1+\phi}}{w_t^P\lambda_t^P}. \end{aligned} \tag{C.6}$$

Impatient household. Likewise, I have an intertemporal consumption Euler for the impatient households

$$\lambda_t^I = \left(1-a^I\right)\varepsilon_t^C\left(C_t^I - a^I C_{t-1}^I\right)^{-1}, \tag{C.7}$$

housing demand

$$\lambda_t^I q_t^H = \varepsilon_t^H \frac{j}{H_t^I} + \lambda_{t+1}^I \beta_I q_{t+1}^H + s_t^I m_t^I q_{t+1}^H \pi_{t+1}, \tag{C.8}$$

loan demand

$$\lambda_t^I = \beta_I \lambda_t^I \frac{1+r_t^{LH}}{\pi_{t+1}} + s_t^I\left(1+r_t^{LH}\right), \tag{C.9}$$

the impatient households' budget constraint

$$C_t^I + q_t^H\left(H_t^I - H_{t-1}^I\right) + \left(1+r_{t-1}^{LH}\right)l_{t-1}^{I,d}\pi_t^{-1} = w_t^I N_t^I + l_t^{I,d} + T_t^I, \tag{C.10}$$

and loan constraint

$$\left(1+r_t^{LH}\right)l_t^I \le m_t^I E_t\left[q_{t+1}^H H_t^I \pi_{t+1}\right]. \tag{C.11}$$

Parallel to the patient household, I also obtain a wage inflation from the labor market conditions

$$\pi_t^{w^I} = \frac{w_t^I}{w_{t-1}^I}\pi_t \tag{C.12}$$

and the labor supply to the union

$$\begin{aligned} &\kappa^w\left(\pi_t^{w^I} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)\pi_t^{w^I} = \\ &\beta_I E_t\left[\tfrac{\lambda_{t+1}^I}{\lambda_t^I}\kappa^w\left(\pi_{t+1}^{w^I} - \pi_t^{\iota_w}\pi^{1-\iota_w}\right)\tfrac{\pi_{t+1}^{w^I\,2}}{\pi_{t+1}}\right] + \left(1-\varepsilon_t^N\right)N_t^I + \tfrac{\varepsilon_t^N N_t^{I\,1+\phi}}{w_t^I\lambda_t^I}, \end{aligned} \tag{C.13}$$

Entrepreneur. The review of the entrepreneurs within my model has depicted that the intertemporal consumption Euler equation is given by

$$\lambda_t^E = \left(1 - a^E\right) \left[C_t^E - a_t^E C_{t-1}\right]^{-1}. \tag{C.14}$$

The FOCs of the entrepreneur yielded optimality conditions for labor demanded from patient households

$$w_t^P = \mu \left(1 - \alpha\right) \frac{Y_t^E}{x_t N_t^{E,P}}, \tag{C.15}$$

for labor demanded from impatient households

$$w_t^I = \left(1 - \mu\right) \left(1 - \alpha\right) \frac{Y_t^E}{x_t N_t^{E,I}}, \tag{C.16}$$

for loans

$$\lambda_t^E = \beta_E \lambda_{t+1}^E \frac{1 + r_t^{LE}}{\pi_{t+1}} - s_t^E \left(1 + r_t^{LE}\right), \tag{C.17}$$

and finally for capital

$$\begin{aligned} \lambda_t^E q_t^k &= s_t^E m_t^E q_{t+1}^k \pi_{t+1} \left(1 - \delta\right) \\ &+ \beta_E \lambda_{t+1}^E \left\{ q_{t+1}^k \left(1 - \delta\right) + u_{t+1} r_{t+1}^k \right. \\ &- \left. \left[\chi_1 \left(u_{t+1} - 1\right) + \tfrac{\chi_2}{2} \left(u_{t+1} - 1\right)^2\right] \right\}. \end{aligned} \tag{C.18}$$

Similarly, the optimality condition for capital utilization resulted in

$$r_t^k = \chi_1 + \chi_2 \left(u_t - 1\right), \tag{C.19}$$

where the return on capital is given by

$$r_t^k = \alpha A_t^E x^{-1} \left(K_{t-1}^E u_t\right)^{\alpha - 1} \left(N_t^{E,P\mu} N_t^{E,I 1-\mu}\right)^{1-\alpha}. \tag{C.20}$$

The entrepreneur is also bound by the budget constraints

$$\begin{aligned} C_t^E + w_t^P N_t^{E,P} + w_t^I N_t^{E,I} + \tfrac{1 + r_{t-1}^{LE}}{\pi_t} l_{t-1}^E + q_t^k K_t^E \\ + \psi\left(u_t\right) K_{t-1}^E = \tfrac{Y_t^E}{x_t} + l_t^E + q_t^k \left(1 - \delta\right) K_{t-1}^E. \end{aligned} \tag{C.21}$$

and loan acquisition

$$\left(1 + r_t^{LE}\right) l_t^E = m_t^E E_t \left[q_{t+1}^k \pi_{t+1} \left(1 - \delta\right) K_t^E\right] \tag{C.22}$$

as well as by the Cobb-Douglass production function

$$Y_t^E = A_t^E \left[K_{t-1}^E u_t\right]^\alpha \left(N_t^{E,P^\mu} N_t^{E,I^{(1-\mu)}}\right)^{1-\alpha}. \tag{C.23}$$

Capital Producer. The capital production sector has resulted in two equations, one on the evolution of capital

$$K_{t+1} = (1-\delta) K_t + \left[1 - \frac{\kappa^i}{2}\left(\frac{I_t \varepsilon_t^{qk}}{I_{t-1}} - 1\right)^2\right] I_t, \tag{C.24}$$

and one yielding the real price of capital

$$\begin{aligned} 1 = q_t^k &\left[1 - \tfrac{\kappa_i}{2}\left(\tfrac{I_t \varepsilon_t^{qk}}{I_{t-1}} - 1\right)^2 - \kappa^i \left(\tfrac{I_t \varepsilon_t^{qk}}{I_{t-1}} - 1\right) \tfrac{I_t \varepsilon_t^{qk}}{I_{t-1}}\right] \\ &+ \beta_E \tfrac{\lambda_{t+1}^e}{\lambda_t^e} q_{t+1}^k \kappa^i \left(\tfrac{I_{t+1}\varepsilon_{t+1}^{qk}}{I_t} - 1\right)\left(\tfrac{\varepsilon_{t+1}^{qk} I_{t+1}}{I_t}\right)^2. \end{aligned} \tag{C.25}$$

Retailer. I derive a New Keynesian Phillips curve and an expression for aggregate profits from the retailing sector, which read as

$$\begin{aligned} &1 - \varepsilon_t^Y + \tfrac{\varepsilon_t^Y}{x_t} - \kappa^P \left(\pi_t - \pi_{t-1}^{\iota_P} \pi^{1-\iota_p}\right) \pi_t \\ &+ \beta_P \tfrac{\lambda_{t+1}^P}{\lambda_t^P} \kappa^P \left(\pi_{t+1} - \pi_t^{\iota_P} \pi^{1-\iota_p}\right) \pi_{t+1} \tfrac{Y_{t+1}}{Y_t} = 0 \end{aligned} \tag{C.26}$$

and

$$\Pi_t^R = Y_t \left[1 - \frac{1}{x_t} - \frac{\kappa^P}{2}\left(\pi_t - \pi_{t-1}^{\iota_P} \pi^{1-\iota_p}\right)^2\right], \tag{C.27}$$

respectively.

Wholesale bank. The banking sector is extended relative to Gerali et al. (2010) and now comprises an evolution of bank capital

$$K_t^B \pi_t = K_{t-1}^B + \omega^B \Pi_{t-1}^B, \tag{C.28}$$

in combination with the balance sheet identity

$$l_t^I + l_t^E = K_t^B + D_t^B, \tag{C.29}$$

a FOC for monitoring

$$m_t = \min\left\{\frac{1+R_t^L}{2\kappa^m} + \sqrt{\left(\frac{1+R_t^L}{2\kappa^m}\right)^2 - \frac{(1+r_t)(1-k_t)}{\kappa^m}}, 1\right\}, \tag{C.30}$$

and for the wholesale branch's spread

$$m_t R_t^L = r_t + 1 - m_t - \kappa^{KB}\left(\frac{K_t^B}{L_t} - \upsilon^B\right)^2\left(\frac{K_t^B}{L_t}\right)^2 + \frac{\kappa^m}{2}\left(m_t^2 - \frac{m^2}{\varepsilon_t^m}\right) \quad \text{(C.31)}$$

Retail banks. Moreover, there are three optimality conditions of the two retail bank units. These are the two optimality conditions for loans granted to impatient households,

$$\begin{aligned} 0 = \left(1 - \varepsilon_t^{LH}\right) - \tfrac{\varepsilon_t^{LH}}{r_t^{LH}}\left[m_t R_t^L + (1 - m_t)\right] - \kappa^{LH}\left(\tfrac{r_t^{LH}}{r_{t-1}^{LH}} - 1\right)\tfrac{r_t^{LH}}{r_{t-1}^{LH}} \\ +\beta_P E_0 \tfrac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^{LH}\left(\tfrac{r_{t+1}^{LH}}{r_t^{LH}} - 1\right)\left(\tfrac{r_{t+1}^{LH}}{r_t^{LH}}\right)^2 \tfrac{l_{t+1}^I}{l_t^I}, \end{aligned} \quad \text{(C.32)}$$

and entrepreneurs

$$\begin{aligned} 0 = \left(1 - \varepsilon_t^{LE}\right) - \tfrac{\varepsilon_t^{LE}}{r_t^{LE}}\left[m_t R_t^L + (1 - m_t)\right] - \kappa^{LE}\left(\tfrac{r_t^{LE}}{r_{t-1}^{LE}} - 1\right)\tfrac{r_t^{LE}}{r_{t-1}^{LE}} \\ +\beta_P E_0 \tfrac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^{LE}\left(\tfrac{r_{t+1}^{LE}}{r_t^{LE}} - 1\right)\left(\tfrac{r_{t+1}^{LE}}{r_t^{LE}}\right)^2 \tfrac{l_{t+1}^E}{l_t^E}, \end{aligned} \quad \text{(C.33)}$$

and the optimality condition for deposits raised from patient households

$$\begin{aligned} 0 = -\tfrac{\varepsilon_t^d}{r_t^d} r_t + \left(\varepsilon_t^d - 1\right) - \kappa^d\left(\tfrac{r_t^d}{r_{t-1}^d} - 1\right)\left(\tfrac{r_t^d}{r_{t-1}^d}\right) \\ +\beta_P E_t \tfrac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^d\left(\tfrac{r_{t+1}^d}{r_t^d} - 1\right)\left(\tfrac{r_{t+1}^d}{r_t^d}\right)^2 \tfrac{d_{t+1}}{d_t} \end{aligned}. \quad \text{(C.34)}$$

Bank profit. Eventually, this provides an aggregate bank profit of

$$\begin{aligned} \Pi_t^B = r_t^{LH} l_t^H + r_t^{LE} l_t^E - r_t^d d_t - \tfrac{\kappa^{KB}}{2}\left(\tfrac{K_t^B}{l_t^H + l_t^E} - \upsilon^b\right)^2 K_t^b - \tfrac{\kappa^m}{2}\left(m_t^2 - \tfrac{m^2}{\varepsilon_t^m}\right) L_t \\ -\xi \tfrac{m^2}{\varepsilon_t^m} K_t^B - \tfrac{\kappa^{LH}}{2}\left(\tfrac{r_t^{LH}}{r_{t-1}^{LH}} - 1\right)^2 r_t^{LH} l_t^I - \tfrac{\kappa^{LE}}{2}\left(\tfrac{r_t^{LE}}{r_{t-1}^{LE}} - 1\right)^2 r_t^{LE} l_t^E - \tfrac{\kappa^d}{2}\left(\tfrac{r_t^d}{r_{t-1}^d} - 1\right)^2 r_t^d d_t \end{aligned} \quad \text{(C.35)}$$

Public Sector. The monetary policy maker's Taylor rule is given by

$$1 + r_t = (1 + r)^{1-\phi_R}(1 + r_{t-1})^{\phi_R}\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi(1-\phi_R)}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_y(1-\phi_R)}\varepsilon_t^r. \quad \text{(C.36)}$$

Shocks. Additionally, I have 12 shock processes

$$\varepsilon_t^C = 1 - \rho_{\varepsilon^C} + \rho_{\varepsilon^C}\varepsilon_{t-1}^C + e_t^C \quad \text{(C.37)}$$

$$A_t = 1 - \rho_A + \rho_A A_{t-1} + e_t^A \quad \text{(C.38)}$$

$$\varepsilon_t^H = 1 - \rho_{\varepsilon^H} + \rho_{\varepsilon^H}\varepsilon_{t-1}^H + e_t^H \quad \text{(C.39)}$$

$$m_t^I = (1 - \rho_{m^I})\, m^I + \rho_{m^I}\left(m_{t-1}^I\right) + e_t^{m^I} \quad \text{(C.40)}$$

$$m_t^E = (1-\rho_{m^E})\, m^E + \rho_{m^E}\left(m_{t-1}^E\right) + e_t^{m^E} \tag{C.41}$$

$$\varepsilon_t^{LE} = (1-\rho_{\varepsilon^{LE}})\, \varepsilon^{LE} + \rho_{\varepsilon^{LE}} \varepsilon_{t-1}^{LE} + e_t^{\varepsilon^{LE}} \tag{C.42}$$

$$\varepsilon_t^{LH} = (1-\rho_{\varepsilon^{LH}})\, \varepsilon^{LH} + \rho_{\varepsilon^{LH}} \varepsilon_{t-1}^{LH} + e_t^{\varepsilon^{LH}} \tag{C.43}$$

$$\varepsilon_t^{D} = (1-\rho_{\varepsilon^{D}})\, \varepsilon^{D} + \rho_{\varepsilon^{D}} \varepsilon_{t-1}^{D} + e_t^{\varepsilon^{D}} \tag{C.44}$$

$$\varepsilon_t^{Y} = (1-\rho_{\varepsilon^{Y}})\, \varepsilon^{Y} + \rho_{\varepsilon^{Y}} \varepsilon_{t-1}^{Y} + e_t^{\varepsilon^{Y}} \tag{C.45}$$

$$\varepsilon_t^{N} = (1-\rho_{\varepsilon^{N}})\, \varepsilon^{N} + \rho_{\varepsilon^{N}} \varepsilon_{t-1}^{N} + e_t^{\varepsilon^{N}} \tag{C.46}$$

$$\varepsilon_t^{m} = (1-\rho_{\varepsilon^{m}})\, \varepsilon^{m} + \rho_{\varepsilon^{m}} \varepsilon_{t-1}^{m} + e_t^{\varepsilon^{m}} \tag{C.47}$$

Market clearing. In writing the final model, I assume constant rescaling among household types and entrepreneurs within the economy. This gives rise to $a^P = a^I = a^E$ and to additional simplifications in the clearing conditions, where γ_P, γ_I, γ_E, and γ_B mark the shares of patient households, impatient households, entrepreneurs and banks in the economy

$$C_t = C_t^P \gamma^p + C_t^I \gamma^I + C_t^E \gamma^E$$

$$L_t^H = \gamma^B l_t^H$$

$$L_t^E = \gamma^B l_t^E$$

$$L_t = l_t^E + l_t^H$$

$$D_t = \gamma^P d_t^P$$

$$Y_t = Y_t^E \gamma^E$$

$$\Pi_t^{TB} = \gamma^B \Pi_t^B$$

$$N_t^{E,P} \gamma^E = N_t^P \gamma^P$$

$$N_t^{E,I} \gamma^E = N_t^I \gamma^I$$

$$H_t = H_t^P \gamma^P + H_t^I \gamma^I$$

$$K_t = K_t^E \gamma^E$$

$$\pi_t^w = \pi_t \frac{w_t^P + w_t^I}{w_{t-1}^P + w_{t-1}^I}$$

In writing the source code, I draw on the convention of writing the model in exponential form and I compute a fully flexible model to derive the output gap.

Appendix D

The Non-Stochastic Steady State

Subsequently, I depict how to calculate the steady state conditions for the model by assuming that $\pi = 1$, all shock processes and variables are at their steady state values. Therefore, I follow the convention that variables without time-subscripts represent the steady state values.

The patient households' equations simplify to a reduced form consumption Euler equation

$$\frac{1}{C^P} = \lambda^P,$$

housing demand

$$(1 - \beta_P)\, \lambda^P q^H = \frac{j}{H^P},$$

and deposit demand

$$\frac{1}{\beta_P} = 1 + r^d.$$

The budget constraint simplifies to

$$\frac{C^P - w^P N^P - T^P}{r^d} = D.$$

From the labor market, it becomes apparent that

$$\pi^{w^p} = \pi$$

and

$$-\frac{1}{\lambda^P} = \frac{1 - \varepsilon^N}{\varepsilon^N} w^P N^{-\phi}.$$

In a similar way, I obtain the steady state conditions for the impatient household. The consumption Euler equation becomes

$$\frac{1}{C^I} = \lambda^I.$$

The housing demand and loan demand are given by

$$\frac{q^H H}{j} = \left(\lambda^I (1-\beta_I) - s^I m^I\right)^{-1}$$

and

$$\frac{\lambda^I}{\beta\lambda^I + s^I} = 1 + r^{LH},$$

respectively. While the wage inflation for impatient households, $\pi^{w^I} = \pi$, and the labor supply

$$-\frac{1}{\lambda^I} = \frac{1-\varepsilon^I}{\varepsilon^I} w^I N^{-\phi}$$

are similar to the one for patient households, the budget constraint now depicts that

$$\frac{w^I N^I + T^I - C^i}{r^{LH}} = l^{I,d}.$$

The loan constraint for impatient households becomes

$$l^I = \frac{m^I q^H H^I}{1 + r^{LH}}.$$

For the entrepreneur, the intertemporal consumption Euler equation equally becomes

$$\frac{1}{C^E} = \lambda^E.$$

From the two labor demand equations, it becomes apparent that labor hours of patient and impatient households are hired in accordance to

$$\frac{(1-\mu)}{\mu}\frac{w^p}{w^I} = \frac{N^{E,I}}{N^{E,P}}.$$

Analogue to the loan demand of the impatient household, the entrepreneurs' becomes

$$\frac{\lambda^E}{\beta\lambda^E + s^E} = 1 + r^{LE}$$

and the budget constraint is given by

$$\lambda^E = \left(s^E m^E + \beta_E \lambda^E\right)(1-\delta) + \beta_E \lambda^E r^k,$$

which incorporates that

$$q^k = 1,$$

which in turn originates from the capital producers' optimality condition for the real price of capital. I also obtain from the capital utilization rate and the return on capital that

$$r^k = \chi_1 = \alpha x^{-1} K^{E\alpha-1} \left(N^{E,P\mu} N^{E,I1-\mu} \right)^{1-\alpha}.$$

From the Cobb-Douglas production function, I obtain

$$Y^E = K^\alpha \left(N^{E,P\mu} N^{E,I1-\mu} \right)^{1-\alpha}$$

so that the previous equation also becomes

$$r^k = \alpha x^{-1} \frac{Y^E}{K^E}.$$

The entrepreneurs' budget constraint depicts

$$C^E + w^P N^{E,P} + w^I N^{E,I} + r^{LE} l^E + \delta K^E = \frac{Y^E}{x}$$

and from the evolution of capital, I also know that

$$I = \delta K^E.$$

Likewise, I take from the New Keynesian Phillips Curve that

$$x = \frac{\varepsilon^Y}{\varepsilon^Y - 1}.$$

The loan acquisition constraint reduces to

$$l^E = \frac{m^E (1-\delta) K^E}{1 + r^{LE}}.$$

The retail sector generates profits equal to

$$\Pi^P = Y \left[1 - \frac{1}{x} \right].$$

For the financial sector, I obtain that

$$1 = \omega^B \Pi^B$$

in combination with the balance sheet condition that also needs to hold in the steady state

$$L^I + L^E = K^B + D^B.$$

The FOC for the wholesale branch becomes

$$mR^L = r + 1 - m$$

and the optimality condition for monitoring is

$$m = \frac{R^L L - \frac{1+r}{m} D + K}{\kappa^m L},$$

or drawing on the explicit FOC (cf. Eq. 4.23)

$$m = \frac{1 + R^L}{2\kappa^m} \pm \sqrt{\left(\frac{1 + R^L}{2\kappa^m}\right)^2 - \frac{(1+r)\left(1 - \upsilon^B\right)}{\kappa^m}},$$

as $R^D = \frac{1+r}{m} - 1$ and $r = \frac{\pi}{\beta_p} - \frac{\varepsilon^d - 1}{\varepsilon^d}$. From here, it is straightforward to recover everything else by solving backwards.

Appendix E

Dynare Source Code

```
/* ----------------------------------------------------------------------
This file implements the medium-scale DSGE model developed in this paper.
It takes the model published in Gerali et al. (2010) as a backbone.

For comments and questions, please contact Matthias Eschweiler.
Email: matt.eschweiler@gmail.com
---------------------------------------------------------------------------
*/

//-------------------------------------------------------------------------
// 1. Definition of endogenous variables
//-------------------------------------------------------------------------
var

//Patient households
v_C_p       ${C_p}$
(long_name='Consumption of patient households') //Variable 1

v_H_p ${H_p}$
(long_name='Housing consumption of patient households') //Variable 2

v_D_p ${D_p}$
(long_name='Deposits of patient households') //Variable 3

v_N_p ${N_p}$
(long_name='Labor hours supplied by patient households') //Variable 4

v_lambda_p ${\lambda_p}$
(long_name='Lagrange multiplier on budget constraint of patient households')
//Variable 5

v_Pi_R ${t_p}$
(long_name='Lumpsum transfer to/from patient households') //Variable 6
```

```
v_piw_p ${\pi^w_p}$
(long_name='reset wage inflation for patient households') //Variable 7


//Impatient households
v_C_i       ${C_i}$
(long_name='Consumption of impatient households') //Variable 8

v_H_i ${H_i}$
(long_name='Housing consumption of impatient households') //Variable 9

v_L_di ${L^{d,i}}$
(long_name='Loans demand by impatient households') //Variable 10

v_N_i ${N_i}$
(long_name='Labor hours supplied by impatient households') //Variable 11

v_lambda_i ${\lambda_i}$
(long_name='Lagrange multiplier on budget constraint of impatient households')
//Variable 12

v_s_i ${s_i}$
(long_name='Lagrange multiplier on debt constraint of impatient households')
//Variable 13

v_piw_i ${\pi^w_i}$
(long_name='reset wage inflation for impatient households') //Variable 14

//Capital producers
v_I ${I}$        (long_name='Investment') //Variable 15

v_Q       ${Q}$
(long_name='Tobins Q') //Variable 16


//Entrepreneurs
v_C_e       ${C_e}$
(long_name='Consumption of entrepreneurs') //Variable 17

v_K_e ${K_e}$
(long_name='Physical capital') //Variable 18

v_N_di ${N^{d,i}}$
(long_name='Labor hours demanded from impatient households') //Variable 19

v_N_dp ${N^{d,p}}$
(long_name='Labor hours demanded from patient households') //Variable 20

v_u ${u}$
```

```
(long_name='capital utilization rate') //Variable 21

v_lambda_e ${\lambda_e}$
(long_name='Lagrange multiplier on budget constraint of entrepreneurs') //Variable 22


v_s_e ${s_e}$
(long_name='Lagrange multiplier on debt constraint of entrepreneurs') //Variable 23


v_Y_e ${Y_e}$
(long_name='output of entrepreneurs') //Variable 24

v_L_de ${L^d_e}$
(long_name='Loans to entrepreneurs') //Variable 25


//Retailers
v_pi ${\pi}$
(long_name='inflation rate') //Variable 26

v_x ${x}$
(long_name='relative compeititve price of wholesale goods') //Variable 27


//Banking sector
v_D_b ${D_p}$
(long_name='Deposit demand of banking sector') //Variable 28

v_L_e ${L_e}$
(long_name='Loans supplied by banking sector to entrepreneurs')
//Variable 29

v_L_i ${L_i}$
(long_name='Loans supplied by banking sector to impatient households') //Variable 30


v_r_d ${r_d}$
(long_name='Interest rate on deposits') //Variable 31

v_r_lh ${r_{lh}}$
(long_name='Interest rate on loans granted to impatient households') //Variable 32


v_r_le ${r_{le}}$
(long_name='Interest rate on loans granted to entrepreneurs') //Variable 33


v_R_L ${R_L}$
```

```
(long_name='net wholesale loan rate') //Variable 34

v_K_b ${K_b}$
(long_name='Bank capital') //Variable 35

v_bm_b ${bm_b}$
(long_name='Bank intermediation margin') //Variable 36

v_spread_b ${S_b}$
(long_name='Bank Spread') //Variable 37

v_Pi_B   ${\Pi_B}$
(long_name='bank dividends to patient households') //Variable 38

v_m            ${m}$
(long_name='bank monitoring effort')                        //Variable 39

v_R_D          ${R_D}$
(long_name='net wholesale loan rate') //Variable 40


//Monetary Policy
v_r_ib ${r_{ib}}$
(long_name='monetary policy rate') //Variable 41


//Auxiliary variables
v_r_k ${r_k}$
(long_name='real return on capital') //Variable 42

v_rr_e ${r_ee}$
(long_name='real return to entrepreneur') //Variable 43

v_BKR ${BKR}$
(long_name='bank capital to loan ratio') //Variable 44

v_Y_ss ${Y_{ss}}$
(long_name='Output measured at steady state prices') //Variable 45


//Aggregation and Market Clearing
v_C ${C}$
(long_name='Aggregate consumption') //Variable 46

v_Y ${Y}$
(long_name='Aggregate Output') //Variable 47

v_D ${D}$
(long_name='Aggregate Deposits') //Variable 48
```

```
v_LE ${LE}$
(long_name='Aggregate loans to entrepreneurs') //Variable 49

v_LH ${LH}$
(long_name='Aggregate loans to households') //Variable 50

v_L ${L}$
(long_name='Aggregate loan volume') //Variable 51

v_w_p ${w_p}$
(long_name='hourly real wage for patient households') //Variable 52

v_w_i ${w_i}$
(long_name='hourly real wage for impatient households') //Variable 53

v_Pi_AB ${\Pi_AB}$
(long_name='Aggregate bank profits') //Variable 54

v_q_h ${q_H}$
(long_name='real house prices') //Variable 55

v_K ${K}$
(long_name='Aggregate capital') //Variable 56

v_pi_w ${\pi_w}$
(long_name='Aggregate wage inflation') //Variable 57


//Variables determined by exogenous processes
v_A ${A}$
(long_name='Total Factor Productivity') //Variable 58

v_eps_c ${\epsilon_C}$
(long_name='intratemporal substitution shock to consumption')
//Variable 59

v_eps_h ${\epsilon_H}$
(long_name='intratemporal substitution shock to housing') //Variable 60

v_mk_d ${mk_d}$
(long_name='markup on deposits') //Variable 61

v_mk_LH ${mk_{LH}}$
(long_name='markup on loans to households') //Variable 62

v_mk_LE ${mk_{LE}}$
(long_name='markup on loans to entrepreneurs') //Variable 63
```

```
v_eps_q         ${\epsilon_{q}}$
(long_name='shock to the productivity of investment goods') //Variable 64

//v_m_i ${\m_i}$
(long_name='stochastic LTV of impatient HH (deactivated)') //Variable 65

//v_m_e ${\m_e}$
(long_name='stochastic LTV of Entrepreneur' (deactivated)) //Variable 66

v_eps_y ${\epsilon_y}$
(long_name='stochastic elasticity for products (CES)') //Variable 67

v_eps_n ${\epsilon_n}$
(long_name='stochastic elasticity for labor (CES)') //Variable 68

v_eps_m  ${\epsilon_{Kb}}$
(long_name='variable driving steady state monitoring') //Variable 69


//Replicated and graphed variables
v_IntRatePol ${PolicyRate}$
(long_name='Annualized Policy Rate') //Variable 70

v_IntRateHH ${HouseholdRate}$
(long_name='Annualized Interest Rate on Loans to Households') //Variable 71


v_IntRateEnt ${EntreprenRate}$
(long_name='Annualized Interest Rate on Loans to Entrepreneurs')
//Variable 72

v_IntRateDep ${DepositRate}$
(long_name='Annualized Interest Rate on Deposits') //Variable 73

v_Inflation ${InfRate}$
(long_name='Annualized Inflation Rate') //Variable 74

v_LoansHH ${LoantoHouse}$
(long_name='Loan Volume to Households') //Variable 75

v_LoansEnt ${LoantoEntre}$
(long_name='Loan Volume to Entrepreneurs') //Variable 76

v_Output ${Output}$
(long_name='Output') //Variable 77

v_Consumption ${Consumption}$
(long_name='Consumption') //Variable 78
```

```
v_Investment ${Investment}$
(long_name='Investment') //Variable 79

v_Deposits ${Deposits}$
(long_name='Deposits') //Variable 80

v_BankCap ${BankCapital}$
(long_name='Bank Capital') //Variable 81

v_Spread        ${Spread}$
(long_name='Bank spread') //Variable 82

v_CapRatio      ${CapitalRatio}$
(long_name='Bank Capital Ratio') //Variable 83

v_Monitoring    ${BankMonitoring}$
(long_name='Bank Capital') //Variable 84

v_Summand1      ${Auxiliary1}$
(long_name='Auxiliary variable 1') //Variable 85

v_Summand2      ${Auxiliary2}$
(long_name='Auxiliary variable 2') //Variable 86

v_WSSpread      ${WholesaleSpread}$
(long_name='Wholesale Spread') //Variable 87
;



//----------------------------------------------------------------------------
// 2. Exogenous Variable definition
//----------------------------------------------------------------------------
varexo

e_A ${\varepsilon_A}$
(long_name='Innovation to Total Factor Productivity') //Exovar 1

e_eps_c ${\varepsilon_c}$
(long_name='Innovation to intratemporal substitution shock to consumption')
//Exovar 2

e_eps_h ${\varepsilon_h}$
(long_name='Innovation to intratemporal substitution shock to housing')
//Exovar 3

e_eps_d ${\varepsilon_d}$
(long_name='Innovation to markup on deposits') //Exovar 4
```

```
e_eps_LH ${\varepsilon_{LH}}$
(long_name='Innovation to markup on loans to households') //Exovar 5

e_eps_LE ${\varepsilon_{LE}}$
(long_name='Innovation to markup on loans to entrepreneurs') //Exovar 6

e_eps_q  ${\varepsilon_K}$
(long_name='Innovation to shock to the productivity of investment goods')
//Exovar 7

//e_m_i ${\varepsilon_m_i}$
(long_name='Innovation to stochastic LTV of impatient household deactivated')
//Exovar 8

//e_m_e ${\varepsilon_m_e}$
(long_name='Innovation to stochastic LTV of entrepreneurs (deactivated)') //Exovar 9

e_eps_y ${\varepsilon_y}$
(long_name='Innovation to stochastic elasticity for products (CES)')

//Exovar 10

e_eps_n ${\varepsilon_n}$
(long_name='Innovation to stochastic elasticity for labor (CES)')
//Exovar 11

e_eps_m     ${\varepsilon_{m}}$
(long_name='Innovation to monitoring') //Exovar 12

e_r_ib      ${\varepsilon_r_{ib}}$
(long_name='Innovation to monetary policy') //Exovar 13
;

//----------------------------------------------------------------------------
// 3. Definition of parameters
//----------------------------------------------------------------------------
parameters

//Patient Households
p_beta_p ${\beta_p}$
(long_name='Utility discount factor of patient households') //Parameter 1

p_j   ${j}$
(long_name='housing weighting in households utility function') //Parameter 2

p_phi  ${\phi}$
(long_name='Inverse Frisch elasticity of labor supply') //Parameter 3

p_a_p  ${a_p}$
```

```
(long_name='habit persistance of consumption of patient households')
//Parameter 4

p_h    ${h}$
(long_name='fixed housing supply') //Parameter 5

p_gamma_p  ${\gamma_p}$
(long_name='share of patient households') //Parameter 6

p_ni   ${\nu}$
(long_name='wage share of patient households') //Parameter 7

p_iota_w      ${\iota_w}$
(long_name='indexation of wages') //Parameter 8


// Impatient Households
p_beta_i  ${\beta_i}$
(long_name='Utility discount factor of impatient households') //Parameter 9

p_m_i_ss  ${m_i^{ss}}}$
(long_name='Loan-to-Value ratio of impatient households in the steady state')

//Parameter 10

p_a_i  ${a_i}$
(long_name='habit persistance of consumption of impatient households')
//Parameter 11

p_gamma_i  ${\gamma_i}$
(long_name='share of impatient households') //Parameter 12


// Entrepreneurs
p_beta_e  ${\beta_e}$
(long_name='Utility discount factor of entrepreneurs') //Parameter 13

p_alpha  ${\alpha}$
(long_name='Capital share in production function') //Parameter 14

p_chi_1  ${\chi_1}$
(long_name='Parameter 1 governing utilization costs') //Parameter 15

p_chi_2     ${\chi_2}$
(long_name='Parameter 2 governing utilization costs') //Parameter 16

p_m_e_ss  ${m_e^{ss}}}$
(long_name='Loan-to-Value ratio of entrepreneurs in the steady state')
//Parameter 17
```

```
p_a_e  ${a_e}$
(long_name='habit persistance of consumption of entrepreneurs') //Parameter 18

p_gamma_e     ${\gamma_e}$
(long_name='share of entrepreneurs') //Parameter 19

p_delta_k ${\delta_K}$
(long_name='depriciation rate of capital') //Parameter 20

p_kappa_i  ${\kappa_i}$
(long_name='Rotemberg costs for investment') //Parameter 21


//Labor packer
p_eps_n_ss ${\epsilon_n^{ss}}$
(long_name='Steady state elasticity of labor') //Parameter 22

p_kappa_w ${\kappa_w}$
(long_name='wage adjustment cost') //Parameter 23


//Retailers
p_eps_y_ss  ${\varepsilon_y^{ss}}$
(long_name='steady state level of price elasticity of demand')  //Parameter 24

p_kappa_p  ${\kappa_p}$
(long_name='Rotemberg costs for price adjustment') //Parameter 25

p_iota_p  ${\iota_p}$
(long_name='indexation of prices') //Parameter 26


//Banks
p_beta_b  ${\beta_b}$
(long_name='Utility discount factor banks') //Parameter 27

p_gamma_b  ${\gamma_b}$
(long_name='share of bankers') //Parameter 28

p_eps_d  ${\varepsilon_d}$
(long_name='elasticity of substitution between deposits') //Parameter 29

p_eps_lh  ${\varepsilon_{lh}}$
(long_name='elasticity of substitution between loans to households')
//Parameter 30

p_eps_le ${\varepsilon_{le}}$
(long_name='elasticity of substitution between loans to entrepreneurs')
```

```
//Parameter 31

p_mk_d_ss  ${mk_d^{ss}}$
(long_name='steady state deposit rate markup') //Parameter 32

p_mk_lh_ss  ${mk_{LH}^{ss}}}$
(long_name='steady state loan rate for households markup') //Parameter 33

p_mk_le_ss  ${mk_{LE}^{ss}}}$
(long_name='steady state loan rate for entrepreneurs markup') //Parameter 34

p_r_le_ss   ${r_{LE}^{ss}}$
(long_name='steady state interest rate on loans to entrpreneurs')
//Parameter 35

p_r_lh_ss  ${r_{LH}^{ss}}$
(long_name='steady state interest rate on loans to household') //Parameter 36

p_r_k_ss   ${r_k^{ss}}$
(long_name='steady state real return on capital') //Parameter 37

p_vi   ${vi}$
(long_name='Banking Capital ratio over Loans (Basel II)') //Parameter 38

p_kappa_kb ${\kappa_{KB}}$
(long_name='Rotemberg costs for deviations from optimal bank capital')
//Parameter 39

p_kappa_m ${\kappa_{m}}$
(long_name='Rotemberg costs for bank monitoring') //Parameter 40

p_xi   ${xi}$
(long_name='Steady state cost component for monitoring') //Parameter 41

p_m_ss   ${m_{ss}}$
(long_name='steady state bank monitoring level') //Parameter 42

p_kappa_d  ${\kappa_d}$
(long_name='Rotemberg costs for deposit interest rate adjustment')
//Parameter 43

p_kappa_le  ${\kappa_{le}}$
(long_name='Rotemberg costs for entrepreneurial loan interest rate adjustment')

//Parameter 44

p_kappa_lh  ${\kappa_{lh}}$
(long_name='Rotemberg costs for household loan interest rate adjustment')
//Parameter 45
```

```
p_iota_d ${\iota_d}$
(long_name='indexation of deposit rates') //Parameter 46

p_iota_le  ${\iota_{le}}$
(long_name='indexation of loans to entrepreneurs') //Parameter 47

p_iota_lh ${\iota_{lh}}$
(long_name='indexation of loans to households') //Parameter 48

p_omega         ${\omega}$
(long_name='dividend policy of banks') //Parameter 49


//Public Sector
p_rho_ib ${\rho_{ib}}$
(long_name='AR parameter in Taylor rule') //Parameter 50

p_phi_pi ${\phi_{\pi}}$
(long_name='Weight attached to inflation in Taylor rule') //Parameter 51

p_phi_y ${\phi_y}$
(long_name='Weight attached to output in Taylor rule') //Parameter 52

p_pi_ss ${\pi_{ss}}$
(long_name='Steady State inflation') //Parameter 53

p_r_ib_ss ${\r_ib^{ss}}$
(long_name='Steady State policy rate') //Parameter 54


//Shocks
p_rho_eps_c  ${\rho^{\epsilon_c}}$
(long_name='shock to consumption') //Parameter 55

p_rho_A  ${\rho^{A}}$
(long_name='shock to TFP') //Parameter 56

p_rho_eps_h  ${\rho^{\epsilon_h}}$
(long_name='housing shock') //Parameter 57

p_rho_mi  ${\rho^{m_i}}$
(long_name='LTV impatient households') //Parameter 58

p_rho_me  ${\rho^{m_e}}$
(long_name='LTV entrepreneurs') //Parameter 59

p_rho_eps_y ${\rho^{\epsilon_y}}$
(long_name='good elasticity') //Parameter 60
```

```
p_rho_mk_d  ${\rho^{mk_d}}$
(long_name='mark down for deposits') //Parameter 61

p_rho_mk_le  ${\rho^{mk_{le}}}$
(long_name='mark up for entrepreneurial loans') //Parameter 62

p_rho_mk_lh  ${\rho^{mk_{lh}}}$
(long_name='mark up for houshold loans') //Parameter 63

p_rho_eps_q     ${\rho^{\epsilon_{q}}}$
(long_name='Tobins Q') //Parameter 64

p_rho_eps_n  ${\rho^{\epsilon_l}}$
(long_name='labor elasticity') //Parameter 65

p_rho_eps_m  ${\rho^{\epsilon_m}$
(long_name='monitoring') //Parameter 66
;

//--------------------------------------------------------------------------
// 4. Parameters calibration
//--------------------------------------------------------------------------

//Patient Households
p_beta_p =   0.9943;
p_j   =   0.2;
p_phi  =   1.0;
p_a_p  =   0.8670;
p_h    =   1;
p_gamma_p  =   1;
p_ni   =   0.8;
p_iota_w      =   0.3002;

//Impatient Households
p_beta_i  =   0.975;
p_m_i_ss  =   0.7;
p_a_i  =   p_a_p;
p_gamma_i  =   1;

//Entrepreneurs
p_beta_e  =   p_beta_i;
p_alpha  =   0.250;
p_m_e_ss  =   0.35;
p_a_e  =   p_a_i;
p_gamma_e     =   1;
p_delta_k =   0.025;
p_kappa_i  =   10.0306;
```

```
//Labor packer
p_eps_n_ss =   5;
p_kappa_w       =   107.35205;

//Retailers
p_eps_y_ss  =   6;
p_kappa_p  =   33.7705;
p_iota_p  =   0.1581;

//Banks
p_beta_b  =   p_beta_p;
p_gamma_b  =   1;
p_eps_d  =   -1.4603;
p_eps_lh  =   2.9328;
p_eps_le =   2.9328;
p_mk_d_ss  =   p_eps_d / (p_eps_d -1);
p_mk_lh_ss  =   p_eps_lh / (p_eps_lh - 1);
p_mk_le_ss  =   p_eps_le / (p_eps_le - 1);
p_pi_ss =   1;
p_m_ss   =   0.997;
p_r_ib_ss =   (p_pi_ss / p_beta_p - 1) * (p_eps_d - 1) / p_eps_d;
p_r_le_ss   =   (p_r_ib_ss + 2 - 2 * p_m_ss) * p_eps_le / (p_eps_le -1);
p_r_lh_ss  =   (p_r_ib_ss + 2 - 2 * p_m_ss) * p_eps_le / (p_eps_le -1);
p_r_k_ss   =   -(1 - p_delta_k) - p_m_e_ss * (1 - p_delta_k) * p_pi_ss
/ p_beta_e * (1 / (1 + p_r_le_ss) - p_beta_e / p_pi_ss) + 1 / p_beta_e;
p_vi   =   0.09;
p_kappa_kb =   8.9148;
p_kappa_m =   (p_r_ib_ss + 3 - 3 * p_m_ss - ((1 + p_r_ib_ss) - 1) *
(1 - p_vi) + p_vi) / (p_m_ss);
p_xi   =   ((p_r_le_ss + p_r_lh_ss) / 2 - p_r_ib_ss * (1 - p_vi))
/ (p_m_ss^2 * p_vi);
p_kappa_d  =   2.7754;
p_kappa_le  =   7.9801;
p_kappa_lh  =   9.0443;
//p_kappa_d  =   0;
//p_kappa_le  =   0;
//p_kappa_lh  =   0;
p_iota_d =   0;
p_iota_le  =   0;
p_iota_lh =   0;
p_omega         =   1;
p_chi_1  =   p_r_k_ss;
p_chi_2     =   0.1 * p_r_k_ss;

//Public Sector
p_rho_ib =   0.7505;
p_phi_pi =   2.0038;
p_phi_y =   0.3033;
```

```
//Shocks
p_rho_eps_c  =   0.3860;
p_rho_A  =   0.9382;
p_rho_eps_h  =   0.9219;
p_rho_mi  =   0.9224;
p_rho_me  =   0.9013;
p_rho_eps_y =   0.2942;
p_rho_mk_d  =   0.8927;
p_rho_mk_le  =   0.8739;
p_rho_mk_lh  =   0.8512;
p_rho_eps_q  =   0.5717;
p_rho_eps_n  =   0.5962;
p_rho_eps_m  =   0.8130;


//---------------------------------------------------------------------------
// 5. Model Block
//---------------------------------------------------------------------------
model;

//Patient Household

//1 Intertemporal Consumption Euler Equation
exp(v_lambda_p) = (1 - p_a_p) * exp(v_eps_c) * (exp(v_C_p)
- p_a_p * exp(v_C_p(-1)))^(-1);

//2 Housing demand
exp(v_lambda_p) * exp(v_q_h) = exp(v_eps_h) * p_j / exp(v_H_p)
+ exp(v_lambda_p(+1)) * p_beta_p * exp(v_q_h(+1));

//3 Deposit demand
exp(v_lambda_p) = p_beta_p * exp(v_lambda_p(+1)) *
(1 + exp(v_r_d)) / exp(v_pi(+1));

//4 Budget constraint of patient households
exp(v_C_p) + exp(v_q_h) * (exp(v_H_p) - exp(v_H_p(-1))) + exp(v_D_p)
= exp(v_w_p) * exp(v_N_p) + (1 + exp(v_r_d(-1))) * exp(v_D_p(-1)) / exp(v_pi)
+ exp(v_Pi_R) / p_gamma_p;

//5 Reset wage inflation patient households
exp(v_piw_p) = exp(v_w_p) / exp(v_w_p(-1)) * exp(v_pi);

//6 Labor supply to union
p_kappa_w * (exp(v_piw_p) - exp(v_pi(-1)) ^ p_iota_w * p_pi_ss ^ (1 - p_iota_w)) *
exp(v_piw_p) = p_beta_p * exp(v_lambda_p(+1)) / exp(v_lambda_p) * p_kappa_w *
(exp(v_piw_p(+1)) - exp(v_pi)^p_iota_w * p_pi_ss ^ (1 - p_iota_w)) *
exp(v_piw_p(+1))^2 / exp(v_pi(+1)) + (1 - exp(v_eps_n)) * exp(v_N_p) +
exp(v_eps_n) * exp(v_N_p)^(1 + p_phi) / (exp(v_w_p) * exp(v_lambda_p));
```

```
//Impatient Household

//7 Intertemporal Consumption Euler Equation
exp(v_lambda_i) = (1 - p_a_i) * exp(v_eps_c) * (exp(v_C_i) - p_a_i * exp(v_C_i(-1)))^(-1);

//8 Housing demand
//exp(v_lambda_i) * exp(v_q_h) = exp(v_eps_h) * p_j / exp(v_H_i)
+ exp(v_lambda_i(+1)) * p_beta_i * exp(v_q_h(+1))
+ exp(v_s_i) * exp(v_m_i) * exp(v_q_h(+1)) * exp(v_pi(+1));

exp(v_lambda_i) * exp(v_q_h) = exp(v_eps_h) * p_j / exp(v_H_i)
 + exp(v_lambda_i(+1)) * p_beta_i * exp(v_q_h(+1))
 + exp(v_s_i) * p_m_i_ss * exp(v_q_h(+1)) * exp(v_pi(+1));

//9 Loan demand
exp(v_lambda_i) = p_beta_i * exp(v_lambda_i(+1)) * (1 + exp(v_r_lh))
/ exp(v_pi(+1)) + exp(v_s_i) * (1 + exp(v_r_lh));

//10 Budget constraint of impatient households
exp(v_C_i) + exp(v_q_h) * (exp(v_H_i) - exp(v_H_i(-1)))
+ (1 + exp(v_r_lh(-1))) * exp(v_L_di(-1)) / exp(v_pi)
= exp(v_w_i) * exp(v_N_i) + exp(v_L_di);

//11 Loan constraint of impatient households
//(1 + exp(v_r_lh)) * exp(v_L_di) = exp(v_m_i) * exp(v_q_h(+1))
* exp(v_H_i) * exp(v_pi(+1));
(1 + exp(v_r_lh)) * exp(v_L_di) = p_m_i_ss * exp(v_q_h(+1)) * exp(v_H_i) * exp(v_pi(+1));

//12 Reset wage inflaton impatient households
exp(v_piw_i) = exp(v_w_i) / exp(v_w_i(-1)) * exp(v_pi);

//13 Labor supply to union
p_kappa_w * (exp(v_piw_i) - exp(v_pi(-1)) ^ p_iota_w *
p_pi_ss ^ (1 - p_iota_w)) * exp(v_piw_i) = p_beta_i *
(exp(v_lambda_i(+1)) / exp(v_lambda_i) * p_kappa_w * (exp(v_piw_i(+1)) -
exp(v_pi)^p_iota_w * p_pi_ss ^ (1 - p_iota_w)) * exp(v_piw_i(+1))^2 /
exp(v_pi(+1))) + (1 - exp(v_eps_n)) * exp(v_N_i)
+ exp(v_eps_n) * exp(v_N_i)^(1 + p_phi) / (exp(v_w_i) * exp(v_lambda_i));


//Entrepreneur

//14 Intertemporal Consumption Euler Equation
exp(v_lambda_e) = (1 - p_a_e) * (exp(v_C_e) - p_a_e * exp(v_C_e(-1)))^(-1);

//15 Labor demand from patient households
exp(v_w_p) = p_ni * (1 - p_alpha) * exp(v_Y_e) / (exp(v_N_dp) * exp(v_x));
```

```
//16 Labor demand from impatient households
exp(v_w_i) = (1 - p_ni) * (1 - p_alpha) * exp(v_Y_e) / (exp(v_N_di)
* exp(v_x));

//17 Loan demand
exp(v_lambda_e) = p_beta_e * exp(v_lambda_e(+1)) *
(1 + exp(v_r_le))/exp(v_pi(+1)) + exp(v_s_e) * (1 + exp(v_r_le));

//18 Capital demand
//exp(v_lambda_e) * exp(v_Q) = exp(v_s_e) * exp(v_m_e) * exp(v_Q(+1))
* exp(v_pi(+1)) * (1 - p_delta_k) + p_beta_e * exp(v_lambda_e(+1))
* (exp(v_Q(+1)) * (1 - p_delta_k) + exp(v_u(+1)) * exp(v_r_k(+1))
- (p_chi_1 * (exp(v_u(+1)) - 1) + p_chi_2 / 2 * ((exp(v_u(+1)) - 1)^2)));
exp(v_lambda_e) * exp(v_Q) = exp(v_s_e)  * p_m_e_ss * exp(v_Q(+1))
* exp(v_pi(+1)) * (1 - p_delta_k) + p_beta_e * exp(v_lambda_e(+1))
* (exp(v_Q(+1)) * (1 - p_delta_k) + exp(v_u(+1)) * exp(v_r_k(+1))
- (p_chi_1 * (exp(v_u(+1)) - 1) + p_chi_2 / 2 * ((exp(v_u(+1)) - 1)^2)));

//19 Capital utilization
exp(v_r_k) = p_chi_1 + p_chi_2 * (exp(v_u) - 1);

//20 Return on capital
exp(v_r_k) = p_alpha * exp(v_A) * exp(v_x)^(-1) * (exp(v_K_e(-1))
* exp(v_u))^(p_alpha - 1) * (exp(v_N_dp)^p_ni
* exp(v_N_di)^(1 - p_ni))^(1 - p_alpha);

//21 Budget constraint of entrepreneurs
exp(v_C_e) + exp(v_w_p) * exp(v_N_dp) + exp(v_w_i) * exp(v_N_di)
+ (1 + exp(v_r_le(-1))) / exp(v_pi) * exp(v_L_de(-1))
+ exp(v_Q) * exp(v_K_e) + (p_chi_1 * (exp(v_u) - 1)
+ p_chi_2 / 2 * ((exp(v_u) - 1)^2)) * exp(v_K_e(-1))
= exp(v_Y_e) / exp(v_x) + exp(v_L_de)
+ exp(v_Q) * (1 - p_delta_k) * exp(v_K_e(-1));

//22 Loan constraint of entrepreneurs
//(1 + exp(v_r_le)) * exp(v_L_de)
= exp(v_m_e) * (exp(v_Q(+1)) * exp(v_pi(+1)) * (1 - p_delta_k) * exp(v_K_e));
(1 + exp(v_r_le)) * exp(v_L_de)
= p_m_e_ss * (exp(v_Q(+1)) * exp(v_pi(+1)) * (1 - p_delta_k) * exp(v_K_e));

//23 Cobb-Douglas Production function
exp(v_Y_e) = exp(v_A) * (exp(v_K_e(-1)) * exp(v_u))^p_alpha *
(exp(v_N_dp)^p_ni * exp(v_N_di)^(1 - p_ni))^(1 - p_alpha);


//Capital Producer

//24 Capital evolution
exp(v_K) = (1 - p_delta_k) * exp(v_K(-1))
```

```
+ (1 - p_kappa_i / 2 * (exp(v_I(-1)) * exp(v_eps_q(-1))
/ exp(v_I(-2)) - 1)^2) * exp(v_I(1-1));

//25 Real Price of Capital
1 = exp(v_Q) * (1 - p_kappa_i / 2 * (exp(v_I) * exp(v_eps_q)
/ exp(v_I(-1)) - 1)^2 - p_kappa_i * (exp(v_I) * exp(v_eps_q)
/ exp(v_I(-1)) - 1) * exp(v_I) * exp(v_eps_q) / exp(v_I(-1)))
+ p_beta_e * exp(v_lambda_e(+1)) / exp(v_lambda_e) * exp(v_Q(+1))
* exp(v_eps_q(+1))^2 * p_kappa_i * (exp(v_I(+1)) * exp(v_eps_q(+1))
/ exp(v_I) - 1) * (exp(v_I(+1)) / exp(v_I))^2;


//Retailers

//26 NK Phillips curve
0 = 1 - exp(v_eps_y) + exp(v_eps_y) / exp(v_x)
- p_kappa_p * (exp(v_pi) - exp(v_pi(-1)) ^ p_iota_p * p_pi_ss ^ (1 - p_iota_p))
* exp(v_pi) + p_beta_p * exp(v_lambda_p(+1)) / exp(v_lambda_p) * p_kappa_p *
(exp(v_pi(+1)) - exp(v_pi)^p_iota_p * p_pi_ss^(1-p_iota_p))
* exp(v_pi(+1)) * exp(v_Y(+1)) / exp(v_Y);

//27 Retail profits
exp(v_Pi_R) = exp(v_Y) * (1 - 1 / exp(v_x) - p_kappa_p / 2 * (exp(v_pi)
- exp(v_pi(-1)) ^ p_iota_p * p_pi_ss^(1 - p_iota_p))^2);


//Wholesale bank

//28 Bank capital evolution
exp(v_K_b) * exp(v_pi) = exp(v_K_b(-1)) + exp(v_Pi_B(-1));

//29 Balance sheet identity
exp(v_L_i) + exp(v_L_e) = exp(v_K_b) + exp(v_D_b);

//30 FOC for monitoring
exp(v_m) = min((1 + exp(v_R_L))/(2*p_kappa_m)
+ (((1 + exp(v_R_L))/(2 * p_kappa_m))^2 - (1 + exp(v_r_ib)) *
(1 - exp(v_K_b)/exp(v_L))/p_kappa_m)^(1/2),1);

//31 FOC for wholesale branch
exp(v_m) * exp(v_R_L) + p_kappa_kb * (exp(v_K_b) / exp(v_L) - p_vi)
* (exp(v_K_b) / exp(v_L))^2 - p_kappa_m / 2 * (exp(v_m)^2
- p_m_ss^2 / exp(v_eps_m)) + exp(v_m) - 1 = exp(v_r_ib);

//32 Arbitrage Condition
exp(v_m) * (1 + exp(v_R_D)) = (1 + exp(v_r_ib));


//Retail bank
```

```
//33 FOC household's loans
0 = 1 - exp(v_mk_LH) / (exp(v_mk_LH) - 1) + exp(v_mk_LH) / (exp(v_mk_LH) - 1)
* (exp(v_R_L) * exp(v_m) - exp(v_m) + 1) / exp(v_r_lh)
- p_kappa_lh * (exp(v_r_lh) / exp(v_r_lh(-1))
- (exp(v_r_lh(-1)) / exp(v_r_lh(-2)))^p_iota_lh) * exp(v_r_lh) / exp(v_r_lh(-1))
+ p_beta_p * (exp(v_lambda_p(+1)) / exp(v_lambda_p)) * p_kappa_lh *
(exp(v_r_lh(+1)) / exp(v_r_lh) - (exp(v_r_lh) / exp(v_r_lh(-1)))^p_iota_lh) *
((exp(v_r_lh(+1)) / exp(v_r_lh))^2) * (exp(v_L_i(+1)) / exp(v_L_i));

//34 FOC entrepreneur's loans
0 = 1 - exp(v_mk_LE) / (exp(v_mk_LE) - 1) + exp(v_mk_LE) / (exp(v_mk_LE) - 1) *
(exp(v_R_L) * exp(v_m) - exp(v_m) + 1) / exp(v_r_le)
- p_kappa_le * (exp(v_r_le) / exp(v_r_le(-1))
- (exp(v_r_le(-1)) / exp(v_r_le(-2)))^p_iota_le) * exp(v_r_le) / exp(v_r_le(-1))
+ p_beta_p * (exp(v_lambda_p(+1)) / exp(v_lambda_p)) * p_kappa_le *
(exp(v_r_le(+1)) / exp(v_r_le) - (exp(v_r_le) / exp(v_r_le(-1)))^p_iota_le) *
((exp(v_r_le(+1)) / exp(v_r_le))^2) * (exp(v_L_e(+1)) / exp(v_L_e));

//35 FOC deposits
0 = - 1 + exp(v_mk_d) / (exp(v_mk_d) - 1) - exp(v_mk_d) / (exp(v_mk_d) - 1) *
(exp(v_m) * exp(v_R_D) + exp(v_m) - 1) / exp(v_r_d)
- p_kappa_d * (exp(v_r_d) / exp(v_r_d(-1))
- (exp(v_r_d(-1)) / exp(v_r_d(-2))) ^ p_iota_d) * exp(v_r_d) / exp(v_r_d(-1))
+ p_beta_p * (exp(v_lambda_p(+1)) / exp(v_lambda_p)) * p_kappa_d *
(exp(v_r_d(+1)) / exp(v_r_d) - (exp(v_r_d)/exp(v_r_d(-1)))^p_iota_d) *
((exp(v_r_d(+1))/exp(v_r_d))^2) * (exp(v_D_b(+1))/exp(v_D_b));

//Bank Profits

//36 Profit function
exp(v_Pi_B) = exp(v_r_lh) * exp(v_L_i) + exp(v_r_le) * exp(v_L_e)
- exp(v_r_d) * exp(v_D_b)
- p_kappa_d/2 * ((exp(v_r_d) / exp(v_r_d(-1)) - 1)^2) * exp(v_r_d) * exp(v_D_b)
- p_kappa_le / 2 * ((exp(v_r_le) / exp(v_r_le(-1)) - 1)^2) * exp(v_r_le) * exp(v_L_e)
- p_kappa_lh / 2 * ((exp(v_r_lh) / exp(v_r_lh(-1)) - 1)^2) * exp(v_r_lh) * exp(v_L_i)
- p_kappa_kb / 2 * ((exp(v_K_b) / exp(v_L)  - p_vi)^2) * exp(v_K_b)
- p_kappa_m / 2 * (exp(v_m)^2 - p_m_ss^2 / exp(v_eps_m)) * exp(v_L)
- p_xi * p_m_ss^2 / exp(v_eps_m) * exp(v_K_b);


//Public Sector

//37 Taylor rule
1 + exp(v_r_ib) = (1 + p_r_ib_ss)^(1 - p_rho_ib) * (1 + exp(v_r_ib(-1)))^p_rho_ib
* ((exp(v_pi) / p_pi_ss)^p_phi_pi * (exp(v_Y_ss) / exp(v_Y_ss(-1)))^p_phi_y) ^
(1 - p_rho_ib) * (1 + e_r_ib);
```

```
//Market Clearing conditions

//38 For deposit market
p_gamma_b * exp(v_D_b) = p_gamma_p * exp(v_D_p);

//39 For loans to impatient households
p_gamma_b * exp(v_L_i) = p_gamma_i * exp(v_L_di);

//40 For loans to entrepreneurs
p_gamma_b * exp(v_L_e) = p_gamma_e * exp(v_L_de);

//41 For consumption
exp(v_C) = p_gamma_p * exp(v_C_p)
+ p_gamma_i * exp(v_C_i) + p_gamma_e * exp(v_C_e);

//42 For loans supplied to households
exp(v_LH) = p_gamma_b * exp(v_L_i);

//43 For loans supplied to entrepreneurs
exp(v_LE) = p_gamma_b * exp(v_L_e);

//44 For total loans supplied
exp(v_L) = (exp(v_LH) + exp(v_LE));

//45 For deposits demanded
exp(v_D) = p_gamma_p * exp(v_D_p);

//46 For Output
exp(v_Y) = p_gamma_e * exp(v_Y_e);

//47 For aggregate bank profits
exp(v_Pi_AB) = p_gamma_b * exp(v_Pi_B);

//48 For labor from patient households
p_gamma_e * exp(v_N_dp) = p_gamma_p * exp(v_N_p);

//49 For labor from impatient households
p_gamma_e * exp(v_N_di) = p_gamma_i * exp(v_N_i);

//50 For housing
p_h = p_gamma_p * exp(v_H_p) + p_gamma_i * exp(v_H_i);

//51 For capital
exp(v_K) = p_gamma_e * exp(v_K_e);

//52 For steady state output
exp(v_Y_ss) = exp(v_C) + 1 * (exp(v_K) - (1-p_delta_k) * exp(v_K(-1)));

//53 For aggregate wage inflation
```

```
exp(v_pi_w) = ( exp(v_piw_p) + exp(v_piw_i) )
/ ( exp(v_piw_p(-1)) + exp(v_piw_i(-1)) ) * exp(v_pi);


//Exogenous Processes

//54 Shocks to consumption
exp(v_eps_c) = 1 - p_rho_eps_c * 1 + p_rho_eps_c * exp(v_eps_c(-1)) + e_eps_c;

//55 Shocks to TFP
exp(v_A) = 1 - p_rho_A * 1 + p_rho_A * exp(v_A(-1)) + e_A;

//56 Housing
exp(v_eps_h) = 1 - p_rho_eps_h * 1 + p_rho_eps_h * exp(v_eps_h(-1)) - e_eps_h;

//57 LTV ratio of impatient household
exp(v_m_i) = (1 - p_rho_mi) * p_m_i_ss + p_rho_mi * exp(v_m_i(-1)) + e_m_i;

//58 LTV ratio of entrepreneurs
exp(v_m_e) = (1 - p_rho_me) * p_m_e_ss + p_rho_me * exp(v_m_e(-1)) + e_m_e;

//59 Mark down on deposits
exp(v_mk_d) = (1 - p_rho_mk_d) * p_mk_d_ss
+ p_rho_mk_d * exp(v_mk_d(-1)) + e_eps_d;

//60 Mark up on loans to entrepreneus
exp(v_mk_LE) = (1 - p_rho_mk_le) * p_mk_le_ss
+ p_rho_mk_le * exp(v_mk_LE(-1)) + e_eps_LE;

//61 Mark up on loans to households
exp(v_mk_LH) = (1 - p_rho_mk_lh) * p_mk_lh_ss
+ p_rho_mk_lh * exp(v_mk_LH(-1)) + e_eps_LH;

//62 Tobins Q
exp(v_eps_q) = 1 - p_rho_eps_q * 1 + p_rho_eps_q * exp(v_eps_q(-1)) + e_eps_q;

//63 Elasticity of demand for products
exp(v_eps_y) = (1 - p_rho_eps_y) * p_eps_y_ss
+ p_rho_eps_y * exp(v_eps_y(-1)) + e_eps_y;

//64 Elasticity of demand for labor
exp(v_eps_n) = (1 - p_rho_eps_n) * p_eps_n_ss
+ p_rho_eps_n * exp(v_eps_n(-1)) + e_eps_n;

//65 Monitoring
exp(v_eps_m) = (1 - p_rho_eps_m) * 1
+ p_rho_eps_m * exp(v_eps_m(-1)) + e_eps_m;
```

```
//Auxiliary varibales

//66 Real return to entrepreneurs
v_rr_e = exp(v_lambda_e) - p_beta_e * exp(v_lambda_e(+1)) *
(1 + exp(v_r_le)) / exp(v_pi(+1));

//67 Banks capital ratio
v_BKR = exp(v_K_b) / exp(v_L);

//68 Bank margin
exp(v_bm_b) = (exp(v_L_i(-1)) / (exp(v_L_i(-1))
+ exp(v_L_e(-1))) * exp(v_r_lh(-1))
+ exp(v_L_e(-1)) / (exp(v_L_i(-1))
+ exp(v_L_e(-1))) * exp(v_r_le(-1)))
- exp(v_r_d(-1));

//69 Bank spread
exp(v_spread_b) = (exp(v_r_lh) + exp(v_r_le)) / 2 - exp(v_r_d);


//Replicated Variables

v_IntRatePol = 400 * exp(v_r_ib);
v_IntRateHH = 400 * exp(v_r_lh);
v_IntRateEnt = 400 * exp(v_r_le);
v_IntRateDep = 400 * (exp(v_r_d));
v_Spread = 400 * exp(v_spread_b);
v_CapRatio = 100 * v_BKR;
v_Inflation  = v_pi * 100;
v_LoansHH = v_LH * 100;
v_LoansEnt = v_LE * 100;
v_Output = v_Y_ss * 100;
v_Consumption = v_C * 100;
v_Investment = v_I * 100;
v_Deposits = v_D * 100;
v_BankCap = 100 * v_K_b;
v_Summand1 = (1 + exp(v_R_L))/(2*p_kappa_m);
v_Summand2 = (((1 + exp(v_R_L))/(2 * p_kappa_m))^2 + (1 + exp(v_r_ib))
* (1 - exp(v_K_b)/exp(v_L))/p_kappa_m)^(1/2);
v_Monitoring = (v_Summand1 + v_Summand2);
v_WSSpread = 400 * (exp(v_R_L) - exp(v_r_ib));

end;

//--------------------------------------------------------------------------
// 6. Initial Values
//--------------------------------------------------------------------------
initval;
```

```
v_C_p       = -0.122029;
v_H_p       = -0.0535366;
v_D_p       = 0.840797;
v_N_p       = -0.262977;
v_lambda_p  = 0.122029;
v_Pi_R      = -1.52345;
v_Pi_B      = 0;
v_C_i       = -1.91801;
v_H_i       = -2.95404;
v_L_di      = 0.164689;
v_N_i       = -0.0581332;
v_lambda_i  = 1.91801;
v_s_i       = -2.57912;
v_I         = -1.94962;
v_C_e       = -2.19923;
v_K_e       = 1.73925;
v_N_dp      = -0.262977;
v_N_di      = -0.0581332;
v_L_de      = 0.313687;
v_Y_e       = 0.26830;
v_lambda_e  = 2.19923;
v_s_e       = -2.29789;
v_D_b       = 0.940797;
v_L_i       = 0.164689;
v_L_e       = 0.313687;
v_r_d       = -5.16157;
v_r_lh      = -3.51225893;
v_r_le      = -3.51225893;
v_R_L       = -4.60243;
v_K_b       = -1.57284;
v_pi       = 1.16E-14;
v_x         = 0.182322;
v_C         = 0.133577;
v_Y         = 0.268308;
v_D         = 0.840797;
v_LE        = 0.313687;
v_LH        = 0.164689;
v_L         = 0.935107;
v_w_p       = -0.161863;
v_w_i       = -1.753;
v_Pi_AB     = 0;
v_q_h       = 3.48936;
v_K         = 1.73925;
v_r_ib      = -4.63991748;
v_r_k       = -2.95595543;
v_R_D       =   -4.3664223;
v_mk_d     = log(p_mk_d_ss);
v_mk_LE    = log(p_mk_le_ss);
v_mk_LH    = log(p_mk_lh_ss);
```

```
v_m_i      = log(p_m_i_ss);
v_m_e      = log(p_m_e_ss);
v_m         =   log(0.997);
v_Y_ss      = v_Y ;
v_rr_e      = exp(v_s_e);
v_BKR      = exp(v_s_i);
v_bm_b      = -4.88329;
v_spread_b  = -4.99645;
v_eps_y     = log(p_eps_y_ss);
v_eps_n   =   log(p_eps_n_ss);
end;


//---------------------------------------------------------------------------
// 7. Steady State
//---------------------------------------------------------------------------
steady;
check;
model_diagnostics;
resid;


//---------------------------------------------------------------------------
// 8. Shocks
//---------------------------------------------------------------------------
shocks;
var e_eps_c     = 0.0144^2;
var e_A         = 0.0062^2;
var e_eps_h     = 0.0658^2;
var e_m_e       = 0.0034^2;
var e_m_i       = 0.0023^2;
var e_eps_d     = 0.0488^2;
var e_eps_LH    = 0.0051^2;
var e_eps_LE    = 0.1454^2;
var e_eps_q     = 0.0128^2;
var e_r_ib      = 0.0018^2;
var e_eps_y     = 1.0099^2;
var e_eps_n     = 0.3721^2;
var e_eps_m     = 0.050^2;
end;


//---------------------------------------------------------------------------
// 9. Simulation of IRFs
//---------------------------------------------------------------------------
stoch_simul(order=1, irf=40, irf_shocks=(e_r_ib));


//---------------------------------------------------------------------------
```

```
// 10. Latex Code Construction
//-------------------------------------------------------------------------
write_latex_original_model;
```

Appendix F

Adapted Model with Backward Indexation

In order to introduce backward indexation, which alleviates the costs of the retail banks attached to changing the interest rates, I introduce three new parameters into the model.[1] These parameters govern the percentage of loans or deposits in the respective retail bank's portfolio, which benefit from an indexation to lagged adjustments in the respective retail rates.
For the retail bank for loans, these new parameters are ι_{LH} and ι_{LE} for loans to impatient households and entrepreneurs, respectively. The introduction calls for a modification of the retail bank's objective function, previously given by Eq. 4.27, to

$$\max_{r_t^{LH}(j),r_t^{LE}(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{P} \Big[\left(1+r_t^{LH}(j)\right) l_t^I(j) + \left(1+r_t^{LE}(j)\right) l_t^E(j) - m_t \left(1+R_t^L\right) L_t(j) \\ - \frac{\kappa_{LH}}{2} \left(\frac{r_t^{LH}(j)}{r_{t-1}^{LH}(j)} - \left(\frac{r_{t-1}^{LH}(j)}{r_{t-2}^{LH}(j)} \right)^{\iota_{LH}} \right)^2 r_t^{LH} l_t^I - \frac{\kappa_{LE}}{2} \left(\frac{r_t^{LE}(j)}{r_{t-1}^{LE}(j)} - \left(\frac{r_{t-1}^{LE}(j)}{r_{t-2}^{LE}(j)} \right)^{\iota_{LE}} \right)^2 r_t^{LE} l_t^E \Big] \tag{F.1}$$

which is still subject to the identity $L_t(j) = l_t(j) = l_t^I(j) + l_t^E(j)$ and demand constraints for the two loan types given by Eqs. 4.17 and 4.16. Analogue to the discussion in chapter 4.6, formulating an unconstrained version of the objective function, imposing a symmetric equilibrium, and differentiating towards the two choice variables of the retail bank yields the optimality

[1] The model code presented in appendix E already comprises the adapted version, but in the appendix the shares of the respective portfolios that are subject to backward indexation of interest rates are forced to zero.

conditions. This becomes for the retail rate on loans to impatient households

$$0=\left(1-\varepsilon_t^{LH}\right)+\frac{\varepsilon_t^{LH}}{r_t^{LH}}\left[m_tR_t^L-(1-m_t)\right]-\kappa_{LH}\left(\frac{r_t^{LH}}{r_{t-1}^{LH}}-\left(\frac{r_{t-1}^{LH}(j)}{r_{t-2}^{LH}(j)}\right)^{\iota_{LH}}\right)\frac{r_t^{LH}}{r_{t-1}^{LH}}$$
$$+\beta_PE_0\frac{\lambda_{t+1}^P}{\lambda_{t+1}^P}\kappa_{LH}\left(\frac{r_{t+1}^{LH}}{r_t^{LH}}-\left(\frac{r_t^{LH}(j)}{r_{t-1}^{LH}(j)}\right)^{\iota_{LH}}\right)\left(\frac{r_{t+1}^{LH}}{r_t^{LH}}\right)^2\frac{l_{t+1}^I}{l_t^I}$$

and for loans to entrepreneurs

$$0=\left(1-\varepsilon_t^{LE}\right)+\frac{\varepsilon_t^{LE}}{r_t^{LE}}\left[m_tR_t^L-(1-m_t)\right]-\kappa_{LE}\left(\frac{r_t^{LE}}{r_{t-1}^{LE}}-\left(\frac{r_{t-1}^{LE}(j)}{r_{t-2}^{LE}(j)}\right)^{\iota_{LE}}\right)\frac{r_t^{LE}}{r_{t-1}^{LE}}$$
$$+\beta_PE_0\frac{\lambda_{t+1}^P}{\lambda_{t+1}^P}\kappa_{LE}\left(\frac{r_{t+1}^{LE}}{r_t^{LE}}-\left(\frac{r_{t-1}^{LE}(j)}{r_{t-2}^{LE}(j)}\right)^{\iota_{LE}}\right)\left(\frac{r_{t+1}^{LE}}{r_t^{LE}}\right)^2\frac{l_{t+1}^E}{l_t^E}.$$

Likewise, the introduction of backward indexation for deposit-issuing retail banks, ι_D, changes the objective function from Eq. 4.34 to

$$\max_{r_t^d(j)}E_0\sum_{t=0}^{\infty}\Lambda_{0,1}^P\left[m_t\left(1+R_t^D\right)D_t\left(j\right)-\left(1+r_t^d\left(j\right)\right)d_t^P\left(j\right)\right.$$
$$\left.-\frac{\kappa^d}{2}\left(\frac{r_t^d(j)}{r_{t-1}^d(j)}-\left(\frac{r_{t-1}^d(j)}{r_{t-2}^d(j)}\right)^{\iota_D}\right)^2r_t^dd_t\right], \tag{F.2}$$

which is subject to the demand for deposits given by Eq. 4.18 and the identity $D_t\left(j\right)=d_t^P\left(j\right)=d_t\left(j\right)$. Reformulating Eq. F.2 to an unconstrained problem, imposing a symmetric equilibrium, and differentiating to r_t^d provides the modified optimality condition of the loan retail branch

$$0=-\frac{\varepsilon_t^d}{r_t^d}\left(m_tR_t^D+(m_t-1)\right)+\left(\varepsilon_t^d-1\right)-\kappa^d\left(\frac{r_t^d}{r_{t-1}^d}-\left(\frac{r_{t-1}^d(j)}{r_{t-2}^d(j)}\right)^{\iota_D}\right)\left(\frac{r_t^d}{r_{t-1}^d}\right)$$
$$+\beta_PE_t\frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa^d\left(\frac{r_{t+1}^d}{r_t^d}-\left(\frac{r_t^d(j)}{r_{t-1}^d(j)}\right)^{\iota_D}\right)\left(\frac{r_{t+1}^d}{r_t^d}\right)^2\frac{d_{t+1}}{d_t}.$$

From the three modified optimality conditions, it becomes visible that the revised model encompasses the previous formulation of the model as a special case, where $\iota_D=\iota_{LH}=\iota_{LE}=0$. The introduction of the new parameters gives additional freedom in adjusting the pass-through effect, while leaving the steady state values unaffected.

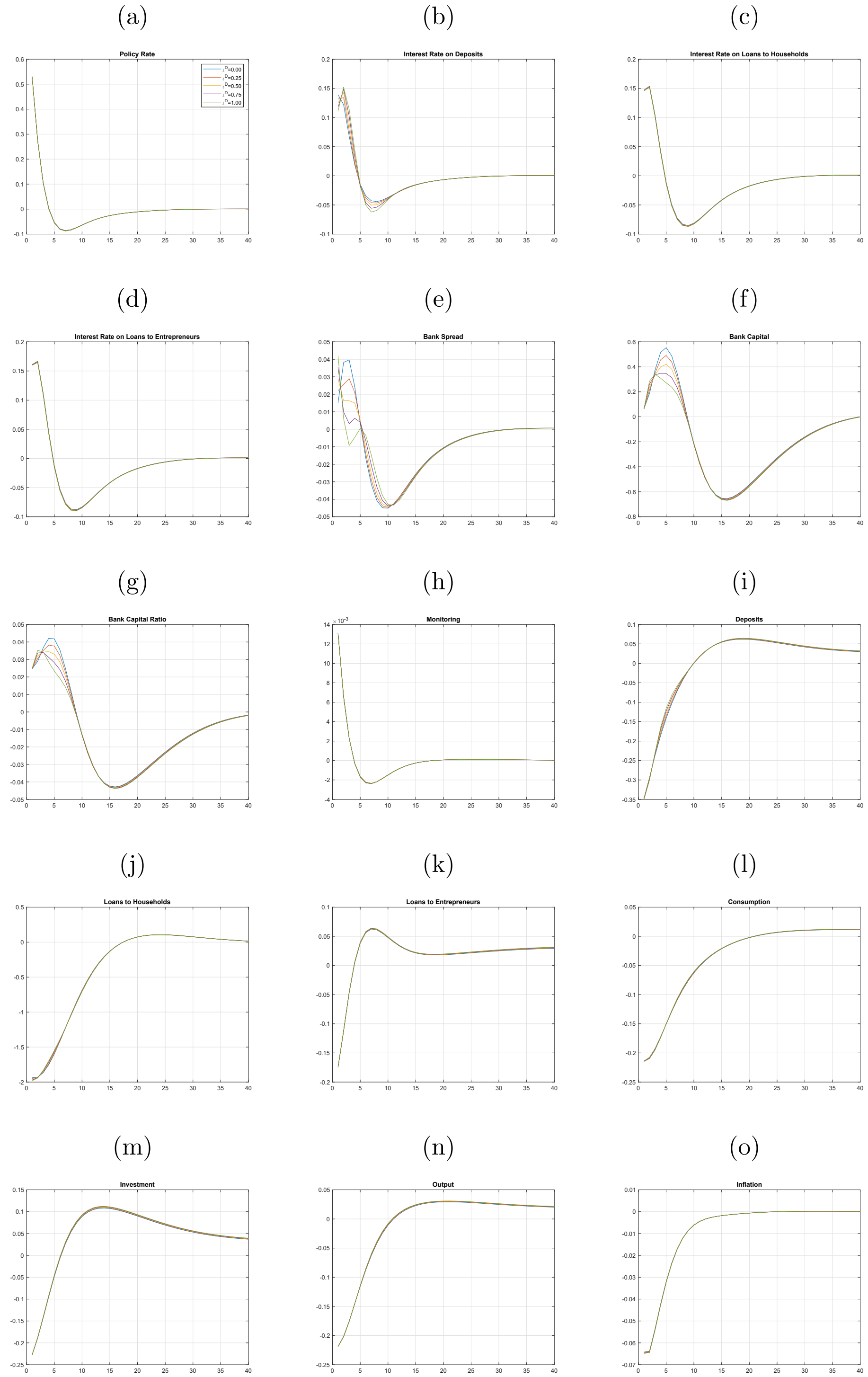
In the subsequent discussion, I adapt the backward indexation parameters to take on values of 0, 0.25, 0.50, 0.75, and 1.0. The results are discussed individually per parameter to provide clear insights. The parameter value of 0 reflects the specification of chapter 5.2.1. Note, however, that backward-indexation introduces a lagging effect relative to the specifications of chapter 6.

Appendix G

Estimations with Backward Indexation

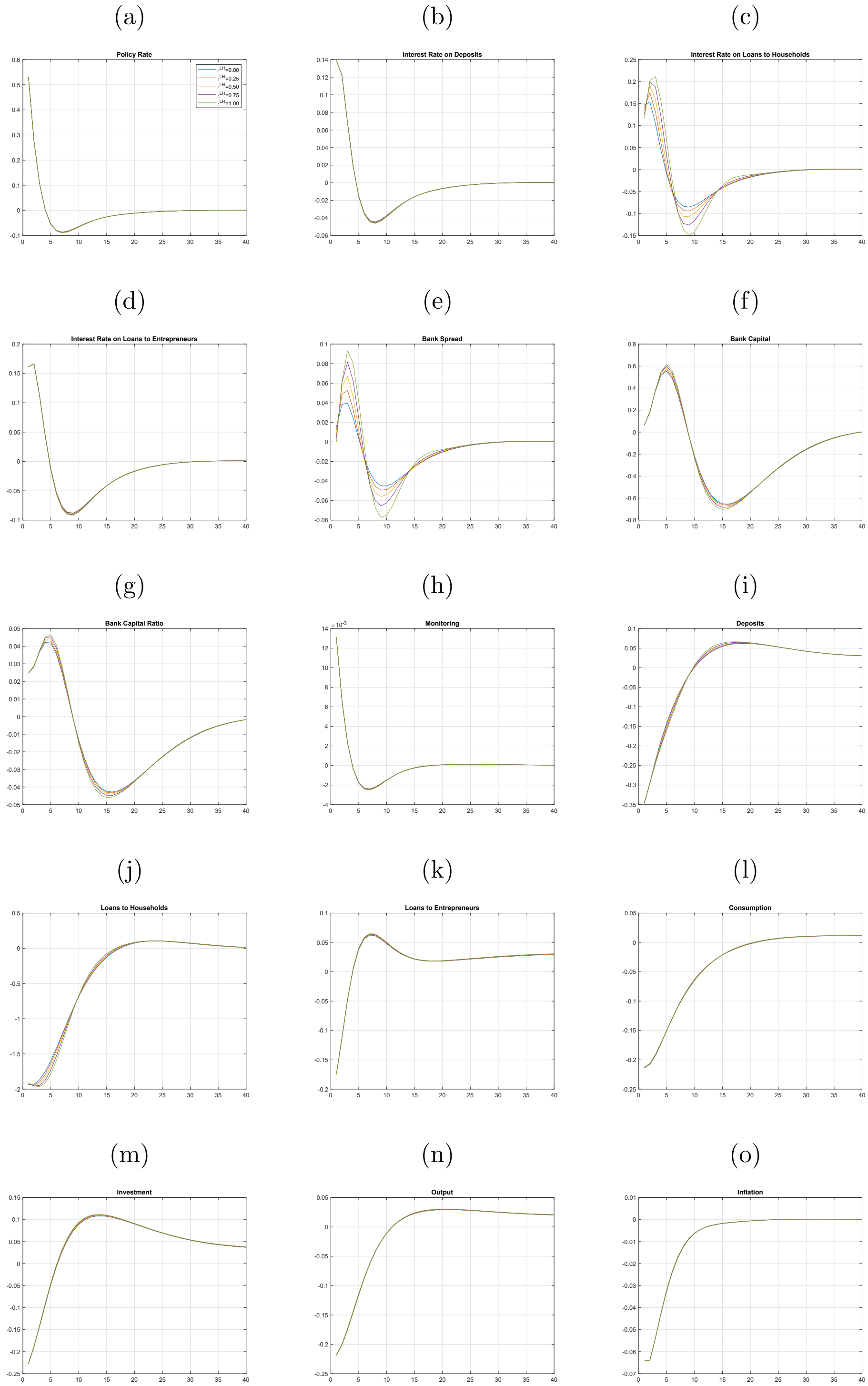
The subsequent three figures G.1 through G.3 provide the IRFs obtained by using the parameter values for κ^d, κ^{LH}, and κ^{LE} as discussed in chapter four of the main text and increasing the backward-indexation parameters ι_D, ι_{LH}, and ι_{LE} from 0 to 1 in 0.25-steps, respectively. Within each illustration, one of the three backward-indexation parameters is changed, while the others are being kept constant at zero. For reference purposes, I also provide the estimates presented in chapter 5.2.1, where no backward-indexation has been applied, i.e $\iota_D = \iota_{LH} = \iota_{LE} = 0$.
With regards to the other parameter calibrations, the values used in the previous exercise have been applied for this exercise as well. Also in terms of the estimation procedure comparability is warranted.
The adaptations for backward indexation do not demand any changes in terms of starting values.
Within each of the three figures G.1 through G.3, I provide the IRFs to a 50bp monetary policy shock for the policy rate (panel a), the interest rate on deposits (panel b), the interest rates applicable to loans granted to either impatient households (panel c) or entrepreneurs (panel d), the resulting bank spread (panel e), which is the difference between a weighted average of the two interest rates on loans and the interest rate on deposits, the bank capital (panel f), the bank capital ratio (panel g), banks' monitoring activity (panel h), the volume of deposits accepted (panel i), the volumes of loans granted to impatient households (panel j) and entrepreneurs (panel k), as well as the four economic variables, consumption (panel l), investment (panel m), total real output (panel n), and inflation (panel o).

Figure G.1: The Role of Interest Rate Stickiness in Deposit Markets on Monetary Policy Transmission



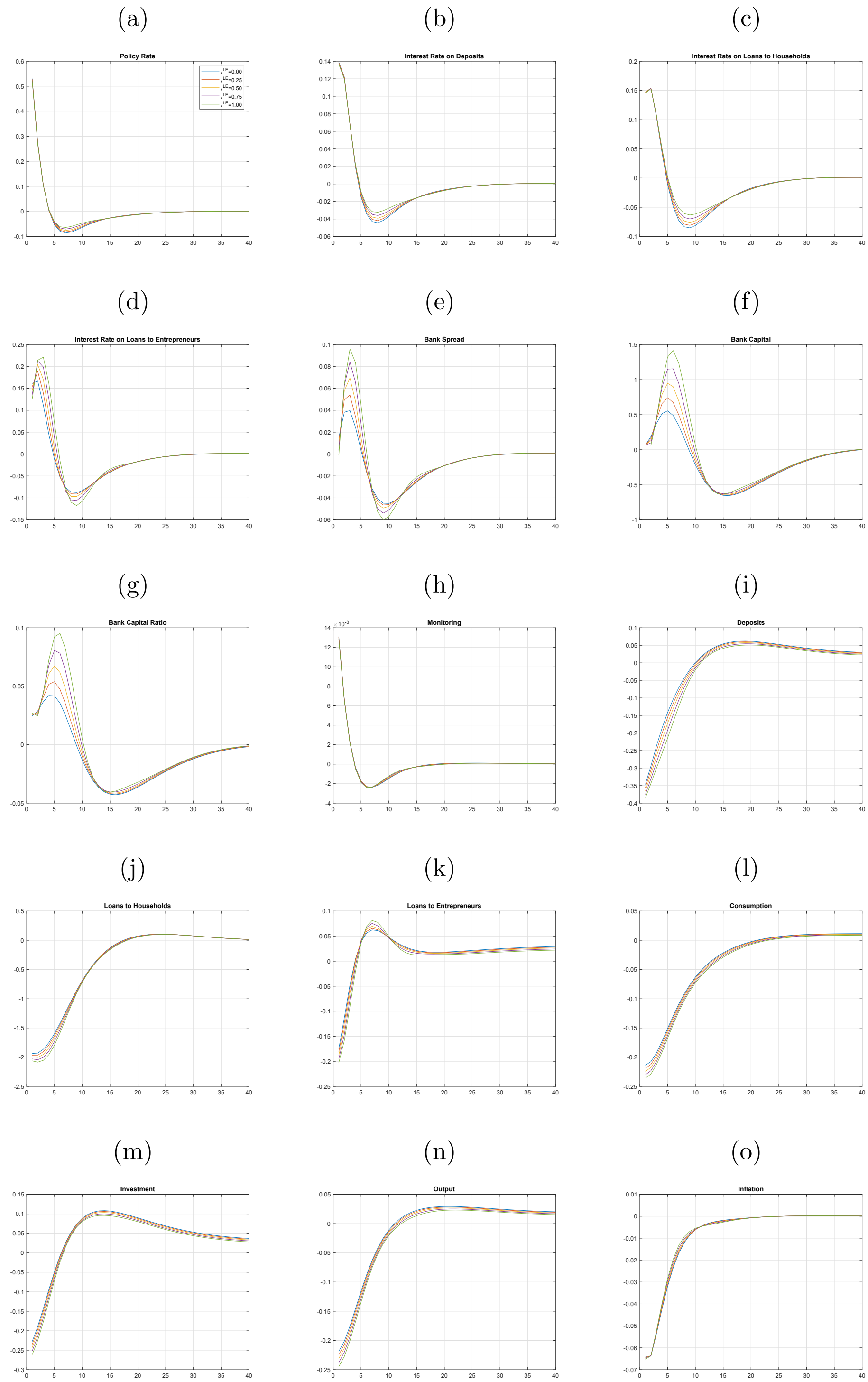
Note: Figure G.1 depicts responses to a monetary policy shock for a model with bank risk-taking, where ι_d takes on values of 0 (blue), 0.25 (red), 0.50 (yellow), 0.75 (violet), and 1.00 (green). All other parameter values are similar to table 4.1. The time is in quarters and values represent percentage deviations.

Figure G.2: The Role of Interest Rate Stickiness in Markets for Loans to Households on Monetary Policy Transmission



Note: Figure G.2 depicts responses to a monetary policy shock for a model with bank risk-taking, where ι_{LH} takes on values of 0 (blue), 0.25 (red), 0.50 (yellow), 0.75 (violet), and 1.00 (green). All other parameter values are similar to table 4.1. The time is in quarters and values represent percentage deviations.

Figure G.3: The Role of Interest Rate Stickiness in Markets for Loans to Entrepreneurs on Monetary Policy Transmission



Note: Figure G.3 depicts responses to a monetary policy shock for a model with bank risk-taking, where ι_{Le} takes on values of 0 (blue), 0.25 (red), 0.50 (yellow), 0.75 (violet), and 1.00 (green). All other parameter values are similar to table 4.1. The time is in quarters and values represent percentage deviations.

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