Inauguraldissertation

Essays in Financial Macroeconomics: Corporate Debt, Systemic Risk and Macrofinancial Stability

vorgelegt von

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Chapter 1

General Introduction

1.1 Motivational Background

> "*[...] banks got to be too big and overleveraged. [...]. Banks in the United States, even with investment banks now banks, bank assets are about one times GDP of the United States. In many other mature countries–in Europe, for example–they're a multiple of that. So again, around the world, banks got to just be too big, took on too much risk relative to the size of their economies.*"
>
> Timothy Geithner, Charlie Rose Show on PBS, May 2009

One major aspect of the last financial crisis in 2007–2009 that subsequently spilled out and challenged the entire world economy has been the macrofinancial linkages. We observed that vast fluctuations in asset prices as well as asset flows, such as credit and other capital streams, may impact the financial well-being of single households, enterprises and even sovereign nations dramatically. Ample research has been done to study the interplay between the financial sector and the real economy. Recent survey articles regarding the (analytical and empirical) literature on macrofinancial linkages are e.g. Basel Committee on Banking Supervision (2011, 2012), Morley (2016) and Claessens and Kose (2017, 2018) which primarily emphasize the mutual feedback between both spheres. On the one hand, shocks may arise in the real sector, transmit through the financial sector and thereby amplify the business cycle. This financial acceleration effects have been emphasized by numerous papers. The most popular are probably Bernanke and Gertler (1989a) and Kiyotaki and Moore (1997a). These two seminal papers are representing nowadays the classical references and appear very frequently in most of the contributions which have been done in this field of research. On the other hand, the financial sector can be the source of the shocks and may contribute to more pronounced business cycle fluctuations, see e.g. Bernanke et al. (1999) and Brunnermeier and Sannikov (2015), in which pecuniary externalities causes the goods market output to be inefficient due to exogenous credit constraints. Correspondingly, financial shocks propagate to the real economy through the financing structure of companies and households. The financial accelerator is then liable for the amplifications, i.e. small shocks may lead to large changes in business investment and consumption and may thus have tremendous effects on the business cycle.

Regardless of their origin - whether they spill over from the demand or supply side of the financial or the real sectors - financial market imperfections, which are responsible for the propagation of risks between markets, eventually emerge at the microeconomic level. According to the review article of Quadrini (2011), financial frictions arise due to agency problems, such as asymmetric information and limited enforcement. [1] Other forms of incomplete markets are e.g. overlapping generations, cash-in-advance approaches and misaligned incentives. As Quadrini (2011) points out, all theories of financial frictions have something in common, namely, heterogeneous (or at least two groups of) agents. In most of the articles in this field, heterogeneity arises due to different shocks agents experienced at any point in time, no matter whether they are ex-ante identical or not. To put it into a nutshell, the existence of incomplete financial markets implies that the perfect insurance characteristics which are predominant in an Arrow-Debreau world vanish (cf. Freixas and Rochet, 2008). As a result, agents are not capable to hedge risk completely, causing fragility on financial markets.

This thesis shall contribute to the rapidly expanding literature on macrofinancial linkages while a special focus is set on the implications of financial fragility for real macroeconomic outcomes. Each chapter investigates the corporate finance of business investment from a different perspective. Bank lending plays a crucial role as *i)* it represents the direct interface of the financial and the real sphere and *ii)* it is relevant for the transmission of monetary policy. The respective channels that transmits financial frictions into the real economy and eventually translate into systemic risk, are versatile. This work pays special attention to mechanism that contribute to financial acceleration through such channels, which are rarely discussed by the existing literature and aims to advance our understanding of macrofinancial linkages. The contribution of each chapter of this cumulative dissertation to the existing literature is different and introduced separately.

Chapter 2 highlights the dangerous role of the build-up of excess corporate leverage ratios on business cycle fluctuations. A behavioral (and deterministic) macroeconomic model is provided in which financial acceleration takes primarily place through the firm investors' bounded rational expectations about business investment. Financial market imperfections are exogenously given and do not take center stage. Firm investors' sales expectations are (mis-)guided by their subjective beliefs of the economy's prospects. In principle, there are two groups of investors in the economy, some being optimistic, the others pessimistic. Their

[1] These agency problems imply that not all trades of financial assets are feasible due to one major aspect, incomplete (or missing) markets. A world where Arrow-Debreau securities are available, trades are not state-contingent, implying that certain markets for contingencies are missing, leading to a limit of intertemporal trades. As a consequence, agents (intertemporarily) misallocate spending and are unable to insure against uncertain events.

attitude towards the state of the economy is composed in an aggregated business climate or sentiment index which evolves over the business cycle. The index indicates the majority attitude among investors and is evolving from a simple heuristic switching mechanism reminiscent to the discrete choice approach.[2] Since the economy in this chapter evolves in continuous time, the application of the discrete choice approach may turn out to be problematic. Hence, the transition probability approach, first proposed by Weidlich and Haag (1983), helps to govern the changes in the sentiment index.[3] It is assumed that changes in the attitudes are associated through herding behavior and some key economic variables, namely capacity utilization, aggregated corporate profits and the average on-balance sheet corporate leverage ratio. It is shown that under moderate financial acceleration a deleveraging process may set in and force the economy in a recession á la Fisher-Minsky-Koo. This feedback loop may appear recurrently and endogenously. Interestingly, if the impact of the aggregated corporate indebtedness in the economy on the average credit risk premium increases, which is synonymous to a reinforcement of financial acceleration, two deterministic co-existing business cycle regimes emerge. One regime still provides a theoretical explanation of the deleveraging recession mentioned above, the other is characterized by extensive high equilibrium corporate leverages. The proposed model predicts that relatively small shocks in the firms' external finance position may cause a regime switching with permanent high average corporate leverage ratios which partly explains the empirical findings of Graham et al. (2015a) who empirically observed a persistent increase in the average US corporate debt-asset ratio over the last decades. In addition, the simulated economy suffers on less profitability in the firm sector and chronicle pessimism. To summarize, it is emphasized that relatively small changes in the firms' financing position may have tremendous effects on the state of the business cycle through large accelerator effects which are backed up by herding behavior.

Chapter 3 is partly related to the second chapter in the sense that it investigates the securitization of business loans which are to some extend responsible for the build-up of such high levels of corporate debt, as discussed above. In brief, banks, securitize contractual debt

[2]It was first applied in a theoretical economic context by Brock and Hommes (1997). Subsequently, it was elaborated numerous times. Worth mentioning contributions regarding financial economics, where financial market participants predict asset prices and switch between forecast strategies are e.g. Schmitt and Westerhoff (2014, 2015), with regard to exchange rate dynamics see Flaschel et al. (2015), and the real economic sector, with heuristic switching in the sentiment as described in the main body of the text, are e.g. Westerhoff (2006) and Westerhoff and Hohnisch (2007).

[3]This methodology was first applied in financial economics by Lux (1995), for macroeconomics by Franke (2012) and extended in a bunch of papers, e.g. Flaschel et al. (2018) and Franke and Westerhoff (2019) where in the latter, a third attitude is introduced, which refers to a neutral state.

in order to enhance its lending capacity, especially when it is approaching its regulatory capacity constraint. The cash flows related to the underlying pool of debt obligations are then carved up to different tranches, i.e. securities with distinct maturity, risk, liquidity etc. and sold as a diversified bundle to passive capital market investors. In principle, banks aim to transform on-balance to off-balance sheet exposures in order to expand their lending capacity to maintain stable and high profits. Hence, the process of securitization enables an economy to reach its risk-bearing capacity to the fullest extent possible (cf. Rajan, 2006). This phenomenon gained importance in the recent decade especially with regarding its possible systemic relevance. In particular, most empirical studies emphasize the important role the process of securitization has played in deepening the last financial crisis in 2007-2009, see e.g. Maddaloni and Peydró (2011), Gorton and Metrick (2012) and Acharya et al. (2013), to name just a few. Overall, these papers have in common that they found evidence that securitization amplifies market imperfections and thus financial acceleration through various channels.

In the European Union a new standardized type of securitization has been recently proposed aiming to increase the volume of cross-border lending and to facilitate the access of bank loans for small- and medium size enterprises. In this chapter of the thesis, it is investigated to evaluate this plan. Special attention is paid to the question to which extent higher levels of securitized business loans might increase the vulnerability of the financial system and the business cycle. For this purpose, a proper agent-based model (ABM) is developed that tries to cover different institutional designs of the banking sector and its connection to a special purpose vehicle (SPV). It includes different features such as a bank rescue mechanism for banks that went bankrupt, a partner-selection process that is responsible for the creation of firm-bank relations. The aggregated dynamics at the macro level are nonlinear and result from the interaction of the heterogeneous agents at the micro level given all the prevailing market frictions in the economy. Numerical simulations are carried out to estimate the effects for increasing securitization intensities which measure the percentage of securitized loans to the total volume of loans.

The results can be summarized as follows. Our results indicate that significant adverse medium- to long-term effects become apparent as soon as the securitization intensity reaches about 10% of the aggregate loan volume in the period of SPV origination. Welfare losses are realized irrespective of whether the collapse of the special purpose vehicle leads to distortions in the banking sector or whether increasing liquidity constraints dampen households' consumption due to their financial investment in the securitized tranches. A more concentrated banking sector reinforces the adverse shock of a liquidation of the SPV whereas a faster and better equipped bank rescue mechanism in the form of levies within the banking sector helps to dampen the consequences of a possible collapse of the securitization market.

Each chapter in this dissertation is focusing on a different aspect that favors financial acceleration. While chapter 2 and chapter 3 are dedicated to the macroeconomic perspective, where financial acceleration finds support at different stages due to several reasons, e.g. herding, cascade failures and sluggish bank bailouts, chapter 4 primarily investigates the risk-taking of an individual (or representative) financial intermediary from the microeconomic perspective. Special attention is paid to the individual risk-taking behavior and its connection to the prevailing monetary policy. Nowadays, it is acknowledged that ongoing phases of loose monetary policy influence the risk management of financial intermediaries, such as banks, which ultimately trigger them to excessive risk-taking. This may cause severe economic damages and the built-up of systemic risk especially in conjunction with weak banking supervision. In this context, ample empirical research has been done, such as Dell'Ariccia and Marquez (2006), Maddaloni and Peydró (2011), Delis and Kouretas (2011) and recently Adrian et al. (2019), among others, who found empirical evidence on this link, especially for the US and Europe. However, little has been done theoretically except of the two notable studies Dell'Ariccia et al. (2014) and Martinez-Miera and Repullo (2017) with the focus on the banks' *search-for-yield* behavior. In both papers, the financial intermediary pays monitoring costs due to asymmetric information to the reduce credit risk and to maintain stable profits. Further, a reduction in the prevailing monetary policy rate lowers banks' monitoring (equivalent to a reduction of the size of the monitoring banking sector) and thus increases risk-taking. In those frameworks, however, the banks' asset portfolio management is designed poorly since the only asset considered are risky loans. Chapter 4 tries to complement these studies. In particular, a partial equilibrium model is introduced based on Greenwald and Stiglitz (1988, 1993a). A representative bank funds (partly) a firm's investment project and pays a kind of bankruptcy costs due to moral hazard. Beside granting loans to the firm, the bank may manage a financial asset portfolio consisting of a risky asset, like a stock and a risk-free asset, like a bond. A credit contract between the firm and the bank is signed where both parties find an agreement about the respective volume of the loan and the repayment rate while the bank reserves the right to ration the credit. Loose monetary policy, a reduction in the policy rate, then triggers the bank managers to re-allocate the asset portfolio towards the risky exposures, i.e. risky bank lending and the risky stock, because the expected return on the risk-free asset cease to be profitable enough. Consequently, the bank is incentivized to *search-for-yield* which leads to higher risk-taking despite of the fact that it pays pecuniary cost due to its risk aversion. The bank's financial position impairs which makes it less resilient against shocks inducing an increase in systemic risk.

1.2 Outline

This dissertation is organized as follows: Chapter 2 introduces a theoretical model in continuous time that primarily focuses on the dynamic interaction of the (corporate) investor sentiment and the general indebtedness in the economy. The herding behavior of bounded rational agents towards excessive leverage ratios turns out to favor financial acceleration and may lead to recessions à la Fisher-Minsky-Koo. Under specific configurations, two co-existing regimes may arise, characterized by recurrent business cycles, fluctuating around distinct trend levels of e.g. leverage ratios. This chapter is already published in Lojak (2018).

Chapter 3 discusses how the intensification of the practice of securitization (of corporate loans) may amplify financial acceleration. For this investigation, a proper stock-flow consistent agent-based model is introduced. As this paper is not published yet, all rights are reserved by the authors.

Chapter 4 investigates contributing factors to financial acceleration, stemming from the risk management of an individual (representative) bank. For this purpose, a partial equilibrium model is provided in which the representative bank determines its optimal asset portfolio. We then analyze its risk-taking behavior for different monetary policy environments using comparative statics. It is shown that, despite of the bank's risk aversion, it chooses riskier financial positions during times of low policy rates. The corresponding article to this chapter is not published in a reviewed scientific journal yet, but as a working paper (see Lojak et al., 2019).

Finally, Chapter 5 clothes the dissertation by summing up the main findings and discusses possible future directions.

Note that variables and parameters are declared newly in each chapter and are supposed to be independent among the chapters of this dissertation. It might therefore occur that a letter or variable specification varies across chapters.

Chapter 2

The Emergence of Co-Existing Debt Cycle Regimes in an Economic Growth Model

This article has already been published in *Metroeconomica* (2018), Vol. 69 (3), https://doi.org/10.1111/meca.12199.

2.1 Introduction

The development of the capital structure of US (non-financial) corporations has changed over the previous decades. Empirical evidence displays a steep increase in firms' leverage ratios in the middle of the 20th century. For instance, Graham et al. (2015a) found in an empirical study a cluster in the evolution of corporate leverages (debt-asset ratios). In particular, they identified gradual increases in the trend of aggregate leverages (at least for unregulated companies). To be more precisely, the trend of corporate leverages evolved fairly stable during the periods 1920 and 1945. From 1946 onwards, leverages increased continuously and were more than tripled in the 70th and remained relatively stable thereafter. These prolonged periods of leveraging increased the individual risk of financial corporations which made these regimes more vulnerable to financial shocks. Shortly after the onset of the previous crisis, periods of de-leveraging set in, not just in the US but also in some EU Member States, see also Papanikolaou and Wolff (2014). For some economists, such as Richard Koo, periods of de-leveraging may have important implications for macroeconomic stability, even leading to full-fledged "balance sheet recessions" Koo (2011). Further, Eggertsson and Krugman (2012) and Crowe et al. (2013), among others, consider the rapid reduction in the private sector's debt in the US as one of the key factors responsible for the last economic recession and the following slow recovery.

Focusing on the business sector, the effects of increasing leverages on the state of the economy are one of the main concerns of Minsky's "Financial Instability Hypothesis". He made the point that firms' external financing structure is closely linked to the current state of the business cycle and the investor sentiment. He explicitly stressed this fact when he wrote: "Acceptable financing techniques are not technological constrained; they depend upon the subjective preferences and views of bankers and businessmen about prospects. [...] However, success breeds a disregard of the possibility of failure" (Minsky, 2008, p. 237).

There are various works that elaborate the interdependency of firms financing decisions and the state of confidence formally, e.g. Taylor and O'Connell (1985), Flaschel et al. (1997, ch. 12) and Ryoo (2013a,b), just to name a few. Partly motivated by the aforementioned works, this paper proposes a dynamic macroeconomic framework that incorporates various important features which have not been studied thoroughly by the existing literature. The model considers heterogeneous firms that determine their investment demand by taking into account their subjective beliefs about future sales, i.e. according to recurrent and endogenously determined waves of optimism and pessimism. The evolution of the respective firm shares are then composed into a sentiment index that represents a further non-linear dynamic law which is elaborated formally along the lines of Franke (2012, 2014).

In the proposed theoretical framework, firms finance their investment by means of retained earnings or by taking out loans from commercial banks. Corporate indebtedness or leverage is expressed in terms of the debt-asset ratio and is derived residually from their financing constraint. Commercial banks charge a loan rate on outstanding debt which consists of a mark-up. Since the individual risk of financial intermediaries is closely linked to the firms' degree of leverage (Papanikolaou and Wolff, 2014), we consider that the banking mark-up varies endogenously depending on deviations of firms' leverage ratio. In particular, the loan rate exhibits a financial accelerator term that amplifies destabilizing effects. We show that this feature implies some important consequences for the dynamics of the model framework.

The interaction of firm's leverage ratio and the investor sentiment gives rise to a two-dimensional system of differential equations which is able to produce periodic business cycle fluctuations. It is shown that the resulting dynamics strictly depend on the responsiveness of the endogenous loan rate and on how investors perceive the evolution of debt as potential risk for their future sales and thus growth. In some cases, the model generates co-existing periodic orbits, where sufficiently large disturbances may drive the economy from a "low-" to a "high-indebted" regime where corporate leverages fluctuate around a higher steady state and generate consequently a higher trend ratio. Related to the observations of Graham et al. (2015a), the model is thus flexible enough to mimic the gradual increase in the trend of aggregate leverage ratios, at least in a very stylized manner.

The remainder of the paper is as follows. Section 2.2 introduces the basic model framework where an investment driven IS-relationship expressed in terms of effective demand is derived. A law of motion governing the dynamics of corporate debt by means of firm's debt-asset ratio is then introduced. Section 2.3 extends the basic model framework by the formulation of the sentiment dynamics. Section 2.4 contains the parameter calibration as well as a brief discussion of some shortcomings of the model framework. We provide the numerical simulation of the model and the discussion of the emergence of *i)* an uniquely determined business cycle in section 2.5.1 *ii)* two co-existing business regimes in section 2.5.2. Section 2.6 concludes.

2.2 The Structure of the Real Sector

The following model describes a closed economy without government activity and Harrod-neutral technological progress in a Kaleckian framework. Firms merely produce one type of commodity that can be used for investment as well as consumption. Firms can finance their investment either by internal or by external sources, whereas the only external financing structure is the granting of loans from commercial banks. Firms do not issue new equities or bonds, i.e. portfolio decisions are neglected. Internal finance refers to the firms retained earnings. In this section, we consider that economic activity is supposed to be debt-led, meaning that economy expands when firms' debt ratio increases.

2.2.1 Entrepreneurial Sector

Let us assume that firms' investment decisions (I) are demand driven and related to the capacity of the economy. Accordingly, a common formulation of firms' accumulation rate is given by (see Sasaki and Fujita, 2012; Nishi, 2012)

$$\frac{I}{K} = \underline{\gamma} + \gamma_u u - \gamma_\lambda j\lambda = g \tag{2.1}$$

where $\underline{\gamma}$ is a positive constant representing the trend rate of growth, i.e. the rate at which the sales are expected to grow on average in the near future. This term is also supposed to represent the investor's sentiment or animal spirits which will be endogenized in section 2.3. The variable $u = Y/K$ is the output-capital ratio (assuming that the capacity is represented by the capital stock) or the rate of (capacity) utilization of capital. For the debt-led configuration of economic activity, it is worth to mention that firms' investment decisions (I) depend negatively on the firms' debt service and not merely on the level of debt (Λ) (as it is considered in the debt-burdened formulation of the model in appendix). The term $\lambda = \Lambda/pK$ represents the debt-asset or leverage where p describes the aggregated price level which is assumed to be constant for simplicity (see Franke (2007, 2012) for a related model with a varying price level expressed in terms of a general inflation climate) and j refers to the respective loan rate which is charged by the commercial banks. The coefficients γ_u and γ_λ are both constant and positive.

Consider further a banking system which in turn extends loans (Λ) to firms and collects deposits (Λ_d) from households. For simplicity, let us assume that loans to firms are the only asset of banks, the lending rate is equal to the deposit rate, the public does not hold any cash and commercial banks do not hold reserves. Therefore, the issuance of bank loans generates a corresponding increase in liabilities, i.e. deposits, since $\Lambda = \Lambda_d$.

2.2.2 Household's Sector

Turning to the households, their consumption is determined along the lines of Flaschel et al. (1997, ch. 12), that is

$$pC = wL + (1 - s_c)[(1 - s_f)(\Pi - \delta - j\Lambda) + j\Lambda] \tag{2.2}$$

where C is real consumption; δ is the capital depreciation rate, w and L are the nominal wage rate and the number of the employees; s_c is the capitalists propensity to save; s_f is the firms retention rate; $(1 - s_f)(\Pi - \delta - j\Lambda)$ are firms net profits or dividend income (Π are the gross profits, and $j\Lambda$ are firms' interest payments to the commercial banks). While the bank's lending rate (j) is often considered to be fixed at a certain value, e.g. Hein (2007), Sasaki and Fujita (2012), Nishi (2012) and Ryoo (2013b), here it is set by the commercial banks as an endogenously evolving banking mark-up over the base rate similarly to Lima and Meirelles (2007). Moreover, Lima and Meirelles (2007) assume that the mark-up varies either pro- or anticyclically with the rate of capacity utilization, we instead suppose that it depends positively and linearly on the firms' leverage ratio.[1] In contrast, we measure it in terms of deviations from a target debt ratio. However, it is given by

$$j = j(\lambda) = i + \iota_\lambda(\lambda - \lambda^d). \tag{2.3}$$

The parameter ι_λ measures the sensitivity with which banks update their mark-up w.r.t. changes in firms' indebtedness. We assume that $\iota_\lambda > 0$ to ensure that the dynamic mark-up adjusts in a pro-cyclical manner. When the firms' leverage ratio exceeds the benchmark value λ^d, banks interpret it as a deterioration of firms' solvency and thus charge a higher mark-up over the base rate i. Consequently, if banks perceive a declining credit risk by a shrinking spread, they will reduce their loan rate in response. Although this specification is not widely used in the literature, we endogenize j as a plausible configuration of a financial accelerator,

[1] The idea, that the banking loan rate varies positively with firms' indebtedness, was already proposed in Keen (1995) for instance.

not just to spice up the dynamics of the model, but to emphasize that bank's lending behavior has important effects on the economy's (in-)stability and to illustrate the flexibility of the underlying theoretical model. As it turns out, the arising non-linear features of the model are worth studying.

Expressing real consumption (2.2) as proportion of the capital stock (K) yields

$$\frac{C}{K} = (1-\sigma\pi)u - (1-s_f)(1-s_c)\delta + s_f(1-s_c)j(\lambda)\lambda = c(\lambda, \lambda^2) \tag{2.4}$$

where $\omega = wL/pY = 1-\pi$ is the wage share, $\pi = \Pi/pY$ the profit share and $\sigma = s_c+(1-s_c)s_f$ is a composite parameter. Correspondingly, the profit rate can be decomposed into the profit share, determined by unit costs times the utilization rate, reflecting the development of effective demand. According to equation (2.4), aggregate consumption as a proportion of the capital stock is determined by firms' debt ratio. It is linear in the leverage ratio $c(\lambda)$ for $\iota_\lambda = 0$ and becomes non-linear $c(\lambda^2)$ for all $\iota_\lambda > 0$ due to the multiplicative combination of λ and $j(\lambda)$. Correspondingly, we denote this feature by $F(\lambda, \lambda^2)$, where F refers to an arbitrary function.

2.2.3 Market Clearing

The goods market equilibrium is given by

$$u = \frac{C}{K} + \frac{I}{K} + \delta. \tag{2.5}$$

In the Kaleckian literature it is common to use capacity utilization as a measure of economic activity. For simplicity, we use the output-capital ratio (u) instead. Accordingly, the utilization rate adjusts to establish goods market equilibrium. Replacing C/K by (2.4), net investment, i.e. investment less capital depreciation, I/K by (2.1) and solving for u gives

$$u = \frac{\underline{\gamma} + \sigma\delta + [s_f(1-s_c) - \gamma_\lambda]\, j(\lambda)\lambda}{\sigma\pi - \gamma_u} = u(\lambda, \lambda^2) \tag{2.6}$$

which roughly corresponds to the resulting equilibrium utilization rate of Sasaki and Fujita (2012, eq. 6) and Nishi (2012, eq. 5). According to the "Keynesian stability condition", a stable adjustment process requires that the denominator of (2.6) is positive, which means that investment reacts less sensitive to changes of utilization than saving (see Bhaduri and

Marglin, 1990)

$$\sigma\pi > \gamma_u.$$

Regardless of whether the interest rate changes over time or not, equilibrium utilization is an increasing function of the debt ratio, i.e. debt-led capacity utilization, given that the reaction coefficient of investment (γ_λ) to interest payments as well as the capitalists' propensity to consume (s_c) is very weak. Formally, whenever $s_f(1-s_c)-\gamma_\lambda > 0$ is satisfied.

In order to get the short-run capital accumulation rate, we substitute equation (2.6) in (2.1), obtaining

$$g = \bar{\underline{\gamma}} + \frac{[\gamma_u(s_f(1-s_c)-\gamma_\lambda)-(\sigma\pi-\gamma_u)\gamma_\lambda]j(\lambda)\lambda}{\sigma\pi-\gamma_u} = g(\lambda,\lambda^2) \tag{2.7}$$

where $\bar{\underline{\gamma}} = \underline{\gamma}+\gamma_u(\underline{\gamma}+\sigma\delta)/(\sigma\pi-\gamma_u)$ is a composite parameter that determines the location of the function. Following the same methodology, the growth rate of the capital stock is debt-led for $\gamma_u(s_f(1-s_c)-\gamma_\lambda) > (\sigma\pi-\gamma_u)\gamma_\lambda$. Hence, it depends on the value of the profit share, the coefficients in the accumulation rate and on the retention rate and the capitalists' propensity to consume. Further, note that capital accumulation gives rise to be a quadratic function of the debt ratio for each nonzero banking mark-up. Given that equilibrium utilization rate is quadratic in λ, the non-linear nature applies also for the profit rate net of interest payments

$$f = \pi u(\lambda^2) - \delta - j(\lambda)\lambda = f(\lambda,\lambda^2). \tag{2.8}$$

Accordingly, changes in the financial position of firms affects the utilization rate, the capital accumulation rate and net profits in a non-linear manner. Whether an increase in λ may or may not raise effective demand depends on the specific parameter values of equation (2.6)-(2.8).

2.2.4 Debt Dynamics

The interaction between the financial and the real sector is linked through the financing of firms investment projects. Firms can either finance their investment by retained earnings or by taking out loans. Accordingly, the level of firms' indebtedness is assumed to be residually determined. Debt financing becomes the closure of the spread between firm's planned level of investment and their accumulated retained earnings. It should be noted that banks are always ready to provide firms the required amount of loans that is needed. Hence, "credit rationing" does not play any crucial role. The only restriction on credit supply is the varying mark-up on the lending rate (2.3). The finance identity is

$$pI = s_f(\Pi - \delta - j(\lambda)\Lambda) + \dot{\Lambda}$$

where $\dot{\Lambda}$ is the increment of debt (where the dot above a variable indicates its time derivative). Then, the law of motion of the leverage is obtained by normalizing the financing constraint by the value of the capital stock and by a logarithmic differentiation of the resulting expression. Its evolution is governed by

$$\dot{\lambda} = (1 - \lambda)g(\lambda^2) - s_f f(\lambda^2) - \hat{p}\lambda = \dot{\lambda}(\lambda, \lambda^2, \lambda^3) \tag{2.9}$$

where $\hat{p}$ is the inflation rate which is assumed to be constant over time. Ryoo (2013b) already pointed out the non-linear nature of the law of motion for the debt-asset ratio which in turn may result in multiple equilibria. In our investigation, the differential equation for the dynamics of firms debt ratio may be shaped like a cubical function, at least for high values of the parameter linking firms' leverage to the accumulation rate γ_λ or/and the financial accelerator ι_λ. It possesses those properties due to the leverage depending banking mark-up in the loan rate.

2.3 Endogenous Sentiment Dynamics

The present paper aims to provide a stylized model which is able to generate a type of endogenous long-term "Minsky cycles" from the interaction of corporate debt and the investors sentiment. Therefore, it remains outstanding to provide a law governing the dynamics of the firms business sentiment. In this section, we introduce a mechanism that enables us to differentiate between two types of firms which differ in their perceptions of future sales.

Let us turn back to the assumptions concerning firms investment decisions. The constant term in equation (2.1) $\underline{\gamma}$, firms capital stock growth expectations, often refers to being animal spirits or even to a general business sentiment (Skott and Zipperer, 2012; Franke, 2012). The assumption that this term may increase (decrease) in a case of over-(under-)utilization leads to the *Harrodian* destabilizing mechanism which was first raised by Skott (2012). The consequences of permanent deviations of actual from desired utilization were often discussed and many authors argued that it refers rather to a temporary phenomenon and cannot persist systematically. Amadeo (1986) and Lavoie (1995), among others, raise the issue whether it seems to be convincing to assume that utilization may probably differ from the desired or targeted utilization rate. They argue that the variability of utilization can reconcile actual and desired utilization if the desired rate itself varies endogenously. Harrodian instability, in contrast, is a process of cumulative causation. In the case of a permanent mismatch of actual and desired utilization of productive capacity, entrepreneurs would eventually revise their investment plans and respond with adjustments of their expected secular rate of sales ($\underline{\gamma}$), which in turn raises investment and thus utilization again. This unstable process leads to ever rising rates of capacity utilization.

In order to cope with that instability problem, some authors have introduced endogenous adjustment processes for $\underline{\gamma}$ and the normal or desired utilization rate u^d (Schoder, 2012; Franke, 2015). Correspondingly, in a case of rising sales expectations, firms reduce their target rate in order to respond more spontaneously to demand fluctuations. However, this part of the present paper aims to endogenize the business sentiment term in a convenient manner. The formalization of the dynamic law governing the adjustments of the animal spirits are in the line of Franke (2012) who provided a behavioral foundation for the agent's attitudes.

Following Franke (2012), aggregate sales expectation can be written as

$$\underline{\gamma} = g^{\star} + \beta a = \underline{\gamma}(a) \tag{2.10}$$

where $g^{\star}$ is the trend capital stock accumulation rate and a refers to the sentiment term (which law of motion should be defined below). Firms determine their investment by taking into account their beliefs about the future prospects of the economy, whereas they can either be optimistic or pessimistic. The sentiment index a can be understood as an average among the shares of firms with the respective attitude. It is bounded at $a = -1$, the state where all investors are pessimistic about the return of an investment, and $a = +1$, the state where firms are optimistic. In a balanced state $\underline{a} = 0$, the share of optimistic firms corresponds exactly to the share of pessimistic firms which in turn indicates a steady state environment.

Using such a sentiment dependent investment function, the associated utilization rate becomes

$$u = \frac{g^\star + \sigma\delta + \beta a + [s_f(1-s_c) - \gamma_\lambda]\, j(\lambda)\lambda}{\sigma\pi - \gamma_u} = u(a, \lambda, \lambda^2). \tag{2.11}$$

Note that the introduction of the sentiment variable does not influence the condition in which debt regime the economy is actually located, i.e. whether $s_f(1-s_c) - \gamma_\lambda$ is positive or negative. Assuming that the investor sentiment influences firms' investment decisions positively, i.e. that $\beta > 0$, equilibrium utilization will also increase in it ($\partial u/\partial a > 0$).

Changes in the sentiment index can be formalized using the "transition probability approach" which has its origin in statistical mechanics and was first published in social sciences by Weidlich and Haag (1983). The first contribution adapting this approach in the context of financial markets is Lux (1995). Franke (2012) put it forward into a business cycle model and derived a differential equation for the evolution of the sentiment index without having invoked the statistical mechanics apparatus, namely

$$\dot{a} = \nu[(1-a)\exp(s) - (1+a)\exp(-s)]. \tag{2.12}$$

The parameter ν measures the adjustment speed and $\exp(\cdot)$ is the exponential function.[2] The variable $s = s(\cdot)$ represents a switching index function that captures the key variables which are responsible for the firms' subjective evaluation of the current state of the business cycle. It is given by

$$s = \phi_a a + \phi_u(u - u^d) + \phi_r(f(u, j, \lambda) - i - \rho^\star) - \phi_\lambda \iota_\lambda(\lambda - \lambda^d) \tag{2.13}$$

where ϕ_a, ϕ_u, ϕ_r and ϕ_λ are sensitivity parameter.

An increase of s indicates a rise in the general business sentiment. More specifically, the switching index function is assumed to be determined as follows: According to equation (2.13), the switching index depends on *self-reference* and *hetero-reference* terms. The former represents a positive feedback of the sentiment a on itself. In particular, it constitutes a concept of contagion or herding where the parameter ϕ_a measures the degree of group pressure and can therefore be understood as a "herding parameter". The remaining terms within the function refer to *hetero-reference* effects, i.e. the feedback of external norms or more objective

[2]Note that this formula can be reformulated by using hyperbolic functions. Accordingly, it can be illustrated as $\dot{a} = 2\nu[\tanh(s) - a]\cosh(s)$.

factors that induce firms to change their attitude. The *first* external norm is the current state of the business cycle expressed in terms of deviations of utilization from firm's desired benchmark rate. It is assumed to have a positive impact on the general sentiment which is quite intuitive since if firms observe an increase in effective demand, they believe that their sales will increase as well. The *second* component refers to the return differential $f - i - \rho^\star$ where i is the real rate of interest which is supposed to be exogenous. Specifically, firms (or their entrepreneurs) compare their (net) profits with the returns from the safer investment in government bonds (whose return is assumed to be constant within the present framework). Accordingly, they match the spread between the return on profits and the real interest rate against a desired return differential $\rho^\star$ that in turn reflects what they think would be a suitable benchmark measure. Hence, the sentiment index increases if $f - i$ exceeds $\rho^\star$. In contrast, it decreases if the spread falls short of $\rho^\star$, indicating that the return on investment is no longer profitable enough (Franke, 2015). The *third* building block consists of the banking mark-up, i.e. the spread commercial banks impose on the lending rate to cover potential losses. In particular, consider that higher corporate leverages indicate greater future "default risk" which in turn exerts a downward pressure on the state of confidence. Therefore, the last term enters negatively.

2.4 Calibration, Accounting Consistency and its Shortcomings

The equilibrium position of the utilization rate and the debt-asset ratio can be explicitly determined. For this purpose, we will assume that utilization as well as the debt-asset ratio are at their respective target rate in steady state. Accordingly, we will derive possible restrictions on specific parameters which permit utilization and the debt ratio to reach fully adjusted positions in the long-run, i.e. the realized rates (u, λ) adjust to the exogenous given desired rates (u^d, λ^d) (Amadeo, 1986; Duménil and Lévy, 1999). Taking the dynamic equilibrium condition $\dot{\lambda} = 0$ into account, the parameter values can be determined from those steady state values.

Proposition 1 *Let a steady state position of the model framework be determined by the desired or target values, i.e.* $\underline{u} = u^d$ *and* $\underline{\lambda} = \lambda^d$*, where line below the variable indicates the steady state. A fully adjusted position in the long-run can* *be thus reached with*

$$s_f = \frac{(1-\underline{\lambda})\underline{g} - \hat{p}\underline{\lambda}}{\underline{f}} \tag{2.14}$$

and

$$s_c = \frac{g^\star + \gamma_u \underline{u} - \gamma_\lambda \underline{j}\underline{\lambda} - s_f \underline{f}}{(1-s_f)\underline{f} + \underline{j}\underline{\lambda}} \tag{2.15}$$

with

$$\begin{aligned}
\underline{g} &= g^\star + \gamma_u \underline{u} - \gamma_\lambda \underline{j}\underline{\lambda} \\
\underline{u} &= \frac{g^\star + \sigma\delta + [s_f(1-s_c) - \gamma_\lambda]\underline{j}\underline{\lambda}}{\sigma\pi - \gamma_u} \\
\rho^\star &= \underline{f} - i \\
\underline{j} &= i.
\end{aligned}$$

For the calibration and the numerical simulations, we employ the parameter values depicted in table 2.1 (column for Scenario 2). The depreciation rate δ and the profit share π are broadly compatible with the values in Franke (2016). Following the detailed discussion of Franke (2017) we adopt a steady state utilization rate of $u^d = 0.9$ for both scenarios. The parameter value for γ_u and the steady state utilization rate are from the empirical estimates of Skott (2012) and the target debt-asset ratio λ^d of the firms is taken from Flaschel et al. (1997).[3] The values of $\underline{\gamma}$, γ_λ, and i are arbitrarily but plausibly chosen.[4]

Under the numerical parameter values depicted in column Sc. 1 (Scenario 1) of table 2.1, we obtain values for the retention rate $s_f = 25,40\%$, for the capitalist's marginal propensity to save out of income $s_c = 23.53\%$, for the reference value in the return differential $\rho^\star = 13.10\%$, for the steady state profit and accumulation rate $\underline{f} = 16.10\%$ and $\underline{g} = 7.13\%$. Without putting too much emphasis on these particular magnitudes, despite of the high value of the

[3]Note that the value is also compatible with the findings of Graham et al. (2015a). They identified a corporate leverage ratio, expressed as debt to capital ratio, of 31% at least for unregulated corporations in the US between the years 1970 and 2010.

[4]Note that the numerical value of γ_λ has been reduced in scenario 2 since the effect of the debt-asset ratio on investment is highlighted trough the sentiment channel and accelerator channel. Notice further that the values of the behavioral parameters in the switching index are chosen to ensure persistent fluctuations. Since the debt ratio fluctuates merely in a small vicinity around its desired level, the parameter ϕ_λ is chosen very high in order to maintain a significant impact of the debt-asset ratio, expressed as deviation from its long-term counterpart, on the sentiment variable. Unfortunately, the high value of ϕ_λ as well as the other behavioural parameters lack on any empirical validation. Since an estimation would exceed the scope of this paper by far we leave it for future work on this model.

Table 2.1: Numerical parameter values

Parameter	Description	Sc. 1	Sc. 2
u^d	Desired and steady state utilization rate	0.900	0.900
λ^d	Desired and steady state debt-asset ratio	0.300	0.300
$\underline{\gamma}$	Constant sales expectations	0.000	0.000
γ_u	Sensitivity investment react to changes in the utilization rate	0.080	0.080
γ_λ	Sensitivity investment react to changes in the debt-asset ratio	0.080	0.010
ι_λ	Financial accelerator	1.000	3.000
π	Profit share	0.300	0.300
ω	Wage share	0.700	0.700
δ	Depreciation rate	0.100	0.100
$\hat{p}$	Inflation rate	0.030	0.030
i	Average loan rate or base rate	0.030	0.030
β	Parameter linking the sentiment index to accumulation	0.055	0.062
ϕ_a	Herding parameter in $s(\cdot)$	0.440	0.220
ϕ_u	Sensitivity parameter in $s(\cdot)$	0.500	0.630
ϕ_r	Sensitivity parameter in $s(\cdot)$	0.350	0.200
ϕ_λ	Sensitivity parameter in $s(\cdot)$	8.000	1.800
ν	Adjustment speed parameter in sentiment index	3.000	3.000

The table displays the numerical parameter values for the scenarios: *i)* the occurence of the unique Minsky cycle *ii)* the emergence of two co-existing business regimes

steady state accumulation rate $\underline{g}$, most of the above listed values are convincing and broadly compatible with those of the literature. Unfortunately, the model lacks on the calibration of a convenient short-run investment multiplier. It amounts to $\partial u/\partial g = 20.46$ which does not coincide with any plausible value the multiplier may take on. This specific shortcoming concerns not just the present model set-up, instead, it afflicts many models with IS market clearing which consists of feedbacks of the residually determined debt-asset ratio.[5]

[5]This specific insufficiency was already pointed out by Flaschel et al. (1997, ch. 12). For an elaborated and detailed discussion see Franke (2016). He also provides a way to cope with the problem by incorporating an active government which levies taxes (automatic stabilizers). This solution requires to add a further dimension, i.e. the issuing of sovereign debt. The large multiplier often leads to the phenomenon that the amplitudes of the debt-asset ratio in models of this type may be unrealistically low compared to those of the utilization rate. The impact of firms' leverage on investment is especially low when we express it as the margin $\lambda - \lambda^d$ as done in the banking mark-up specification in equation (2.3). Due to this fact, a large value of the financial accelerator is required to increase the impact of firms' external capital structure on IS-utilization and to unfold the accelerators amplification effects. Hence, it is fixed at $\iota_\lambda = 1$ for all scenarios that are recorded in table 2.1. For the following discussion on this model, we will accept the disproportions which are coming from the multiplier and merely focus on the resulting dynamic features without spending too much emphasis on particular magnitudes.

2.5 Persistent Fluctuations

In this section, we identify and explain the scope for persistent cyclical behavior which emerges intrinsically without imposing the assumption of repeated random shocks. By doing so, the resulting bounded and self-sustaining oscillations embody the properties of limit cycles which may be interpreted as the business cycle. Interestingly, we show that the non-linear dynamic framework can generate various kinds of dynamic behavior, namely, the emergence of *i)* an attractive and unique closed orbit displaying periodic solutions reminiscent of Minsky cycles and *ii)* the emergence of two contemporaneous existing business regimes, a “low-” and a “high-” indebted regime.

2.5.1 The Existence of an Uniquely Determined Limit Cycle

The long-term dynamics of two or more variables can be decently analyzed in a phase diagram. In this case, we are interested in the dynamic interaction between the sentiment index, whose changes are determined by the law of motion given by equation (2.12), and firms' debt-asset ratio which evolves according to equation (2.9). The local stability properties of the dynamic system can be studied by using the Jacobian matrix (represented by equations (A.1.2)-(A.1.5) in the appendix). Since the Jacobian matrix, evaluated at the steady state, is analytically no longer tractable, instead we use the numerical values of the particular entries (equation (A.1.6) in appendix). Its sign pattern is given by

$$J_{UC} = \begin{pmatrix} + & - \\ + & - \end{pmatrix} \tag{2.16}$$

where the subindex UC stands for unique cycle.

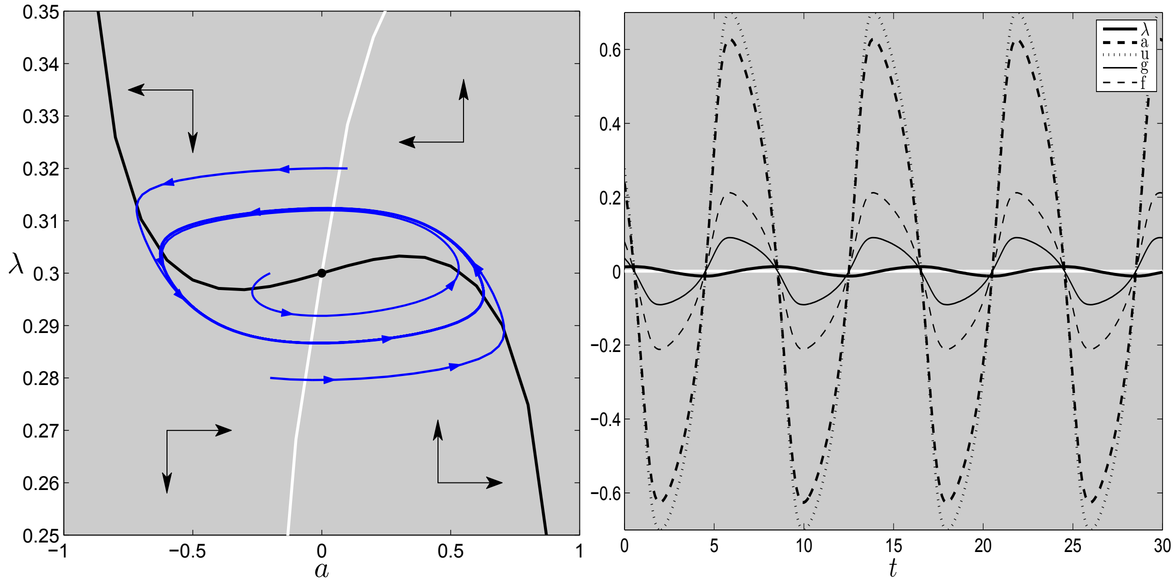
While the elements on the main diagonal of the Jacobian matrix (2.16) display the respective auto-feedback, the elements in the off-diagonal indicate the mutual feedback of a and λ. Accordingly, the signs in the main diagonal indicate destabilizing sentiment and stabilizing debt dynamics. Even though the determinant of (2.16) is positive, which is required for local stability, the equilibrium point is repelling due to the positive trace of the Jacobian. As the numerical values suggest (see equation (A.1.6) in appendix), local instability stems from the destabilizing sentiment dynamics which are relatively strong in contrast to the self-stabilizing feedback of the debt dynamics. Given the repelling steady state, the dynamics of the system are illustrated in the phase diagram in figure 2.1a. The left panel of figure 2.1 illustrates the dynamic interaction of firms' debt ratio and the sentiment index. A constituent part of the phase diagram are the isoclines, that are, the geometrical locus of all pairs of (a, λ) that give rise to $\dot{a} = 0$, the bold black line, and to $\dot{\lambda} = 0$, the bold white line. Since the explicit analytical solution of both isoclines is not transparent enough to directly draw any conclusion from it due to the non-linearities within both dynamic laws, we instead employ the contour plots of the reduced form which exhibit a height of zero to illustrate our results. The resulting curves are equivalent to plots of the analytical solution of the isoclines. The point where both isoclines intersect refers to the equilibrium point $E_{UC} = \{0, \underline{\lambda}\}$.[6] Arrows in the plane indicate the off-equilibrium dynamics.

The dynamic interaction of the sentiment index and firms' leverage ratio gives rise to the existence of an uniquely determined limit cycle that exhibits a cycle length of 8.0 periods. The time unit refers to years that can be attributed to the calibration depicted in table 2.1. Different starting points of the trajectories (in blue) indicate that the closed orbit is stable and attractive, i.e. that they can neither spiral outwards nor converge to the point of rest E_{UC}. The blue arrowheads on the trajectories (as well as the black arrows) point out that the trajectories move counterclockwise. This can be seen on the off-diagonal entries of the Jacobian (2.16). The mutual effect of λ on a is negative. An increase in the debt ratio pushes up consumption since the capitalist household's income has been increased. Firm's investment and thus utilization is also increasing due to the debt-led properties discussed previously. Even though the effect of λ on real economic activity is stimulating, the impact on the investor sentiment is negative due to increasing debt default perceptions. The huge value of ϕ_λ in the switching index ensures that the direct effect of the debt ratio on the sentiment index is predominant and outweighs the formerly discussed positive effects.

The sign pattern of the Jacobian matrix also suggests that firms' leverage ratio increases in the sentiment index a. This effect is more obvious. Consider a positive swing of optimism which increases firms' planned investment and thus capital accumulation. Then, the economy works over its capacity (u^d) which in turn increases firms' profits. Firms need to invest more to cope with the additional demand (and thus the increase in firms' sales). They realize it by

[6] Notice that global stability can be ruled out due to the emergence of two additional fixed points which are lying in an unrealistic locus. The second equilibrium point is located at $E_2 = (-0.965, 0.445)$ and refers to a saddle point. The third fixed point appears at $E_3 = (-1.00, 1.873)$ and is locally stable. Each trajectory that starts above the stable branch of E_2 converges to E_3. Due to the fact that the stable point of rest is located in an economically unrealistic area, a detailed analysis of it becomes redundant.

taking out further loans from commercial banks due to the fact that firms' internal funds are insufficient and exhausted. The right panel in figure 2.1 illustrates the cyclical motions of all



(a) Phase diagram: (a, λ)-interaction

(b) Cyclical motions of the model

Figure 2.1: The dynamics of the non-linear economy for the numerical parameter values depicted in table 2.1 in column Sc. 1. Note that the thick blue line in subfigure 2.1a displays the trajectories, the bold black line illustrates the $(\dot{a} = 0)$ - and the bold white line the $\dot{\lambda} = 0$ isocline. The cyclical motions in subfigure 2.1b are detrended by the respective steady states.

variables. Before going into detail, note that the time series in figure 2.1b are detrended due to illustrative purposes. The emergence of limit cycles in the aforementioned deterministic economic system is merely a very general objective of the current work. A more specific aim is to analyze whether the self-sustaining periodic solutions make any economic sense. In particular, we are interested in the co-movements, i.e. the qualitative lead-and lag-behavior of the variables. We will not spend too much emphasis on the particular order of magnitudes since, as already pointed out in section 2.4, the motions are biased due to the large investment multiplier.

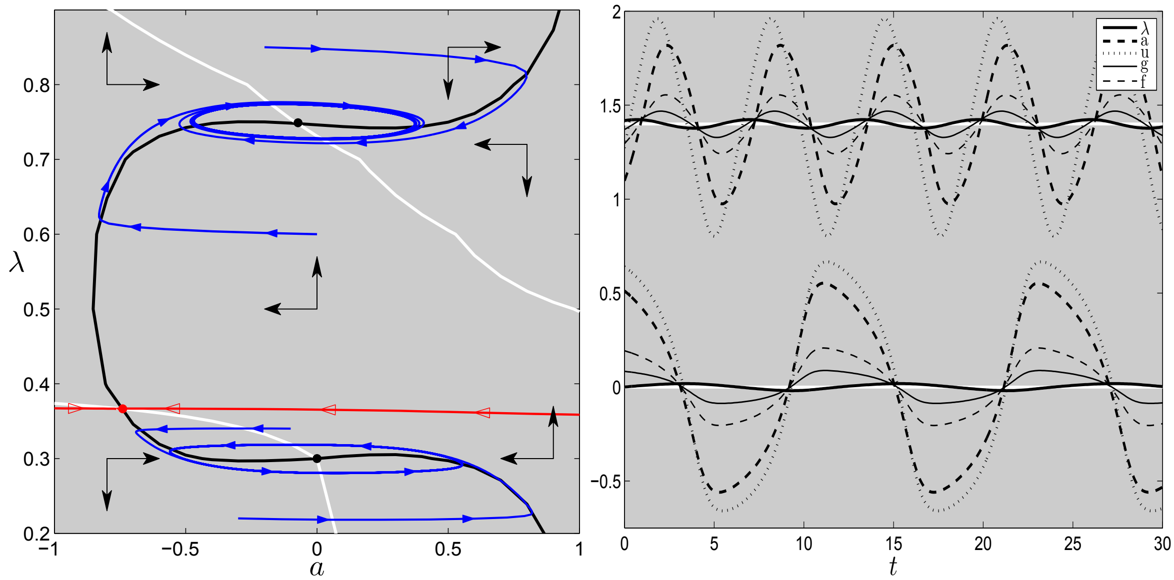
The analysis starts at the first trough of firms' profit rate (thin dashed line). The increase of firms' profitability contemporaneously increases firms' internal funds and reduces thus their credit needs. Once the profit rate begins to increase, firms, or their entrepreneurs, expect that the profit rate will also rise in the near future so that the general sentiment index starts to increase as well. Formally, this effect occurs due to the increase in the switching index function given by equation (2.13) and the inherent mean-reverting tendency of the sentiment index specification in equation (2.12). Due to the fact that the share of firms which are optimistic about their future sales enlarged to a certain amount, they will be engaged in investment projects that promise a higher accumulation rate. Consequently, the accumulation rate starts to increase. The positive impulse in firms investment stimulates capacity utilization so that the utilization rate begins to increase immediately. The expanding economy, the positive state of confidence and the consequent increasing capital accumulation also tends to ever rising liabilities up to a point where firms start to increase the loan demand from commercial banks since their retained earnings are exhausted earlier.[7] As the debt ratio begins to increase, firms' profits still increase as well, but at a diminishing rate. Since the accumulation rate and capacity utilization is debt-led, the general economic performance still improves. At some point, firms' profitability shrinks which triggers investors to believe that risk free assets are the safer investment opportunity (see the return differential within the switching index function, equation (2.13)). The business climate decreases again and so does aggregate economic activity. Firms start to de-leverage by reducing their investment since they expect lower sales in the near future which in turn depresses the economy. This effect is reinforced by a swing of pessimism that drives the economy into a Minsky-Koo kind recession.

2.5.2 Long-Term Fluctuations and the Emergence of Co-Existing Limit Cycles

The traditional view of corporate finance does not provide any long-term interdependence between firms' financial side and real economic activity. In a simple "Modigliani-Miller" world, the valuation of a firm, and thus investment, is independent of its financial structure. Accordingly, changes in firms' risk and financial disturbances are primarily result of real shocks coming from some exogenous perturbations. In this section, in contrast, we show that firms' choice of financing instrument in fact matters. While doing so, we will not primarily question the validation of the aforementioned theorem, we would rather illustrate that the non-linear economy may behave differently if we increase the financial acceleration (ι_λ) indicating that relatively small changes on the financial markets may produce large changes in economic conditions. Since a rise in the accelerator increases the mutual feedback of the debt ratio on the sentiment index, we can reduce the indirect effect of the leverage ratio on the accumulation rate by lowering the behavioral parameter ϕ_λ in the switching index.

[7]Note that the magnitudes and the timing points of the debt-asset ratio may be biased due to the aforementioned huge multiplier effect.

The following numerical simulation of the model was carried out with the parameter values recorded in column Sc. 2 (Scenario 2) of table 2.1. Taking Proposition 1 into consideration, the economy may reach a fully adjusted position for the numerical values of the capitalist's marginal propensity to consume $s_c = 23.76\%$, the retention rate $s_f = 25.68\%$, the steady state profit rate $\underline{f} = 16.10\%$, the equilibrium accumulation rate $\underline{g} = 7.19\%$, the composite parameter $\sigma = 0.4334$ and the benchmark value in the return differential $\rho^{\star} = 13.1\%$. Again, we will not give too much attention to the particular numerical magnitudes and accounting consistency, we will rather focus on the resulting dynamic properties and co-movements of the cyclical motions.



(a) Phase diagram: (a, λ)-interaction

(b) Cyclical motions of the model

Figure 2.2: The dynamics of the non-linear economy for the numerical parameter values depicted in table 2.1 in column Sc. 2. Note that the thick blue line in subfigure 2.1a displays the trajectories, the bold black line illustrates the $\dot{a} = 0$ and the bold white line the $\dot{\lambda} = 0$ isocline. The red line illustrates the separatrix. The cyclical motions in subfigure 2.1b are adjusted to assort them around a certain value. The pattern which swing around the trend value *a)* zero refer to the low-indebted regime and *b)* 1.4 to those of the high-indebted regime.

Figure 2.2 displays the arising dynamics under the numerical values in column Sc. 2 of table 2.1, where the panel 2.2a illustrates the dynamic interaction between a and λ in a phase plane and the right panel 2.2b the associated cyclical pattern of key economic variables. The blue bold lines within the phase diagram are again the trajectories, the white line the $\dot{\lambda} = 0$ and the black bold line the $\dot{a} = 0$ isocline(s). Of particular note is that $\dot{\lambda} = 0$ does not correspond to a continuous line, it rather appears to be a pole. This property, however, indicates that in a certain range of a there exists multiple values of λ that comply with $\dot{\lambda} = 0$. The higher value of the financial accelerator ι_λ adds an additional non-linearity to the model which is reflected by the unconventional "cone-shaped" $\dot{a} = 0$ isocline. The curve also gives rise to multiple equilibria since the condition $\dot{a} = 0$ is satisfied for a certain range of λ. Usually, compared to Franke (2012, 2014) or/and figure 2.1a, the shape of $\dot{a} = 0$ takes on an inverse S-shaped form which is reminiscent to the famous Kaldor model. In particular, the variable measured on the y-axis tends to ∞ when the sentiment index gets close to -1 while it becomes $-\infty$ for a being very close to 1. In the present case, the $\dot{a} = 0$ line can approach both, ∞ as well as $-\infty$, when a gets very close to 1. In contrast, the isocline is bounded when the majority of firms become pessimistic, formally, for $a < 0$.

The unconventional shapes of both isoclines give rise to multiple equilibria which are located in the phase diagram 2.2a where both isoclines intersect. The figure suggests the emergence of two co-existing business cycle regimes illustrated by the two closed orbits (bold blue lines). The arrows within the plane indicate the off-equilibrium dynamics. In the following, we will differentiate between both business cycle regimes by referring to the limit cycle that oscillates around $E_{LI} = \{0, \underline{\lambda}\}$ to being the low-indebted and the regime that swings around $E_{HI} = \{\overline{a}, \overline{\lambda}\} \approx \{-0.073, 0.748\}$ the high-indebted regime, where the line on top of the variable indicates the high equilibrium. There exists a third point of rest in the plane that refers to an unstable saddle point. The stable arms of the saddle point are illustrated by the solid red lines which, contemporaneously, represent the separatrix, that divides the plane into two distinctly different types of qualitative dynamic behavior. Accordingly, a shock that drives the trajectory above the separatrix initiates the trajectory to converge to the upper limit cycle, the high-indebted regime, each manifold starting below the separatrix converges to the southern limit cycle, the low-indebted regime. The fact that the phase plan is split into two distinct areas invalidates global stability and makes a detailed global analysis redundant. Furthermore, it turns out that the periodicity of the high-indebted regime amounts to 6.3 years and of the low-indebted regime to 11.9 years. The business cycle length of the low-indebted regime appears to be fairly long, but, is compatible with the NBER business cycle definition of Burns and Mitchell (1946). In particular, the authors defined the time domain of a business cycle between more than one and up to twelve years. It follows that the periodicity of the resulting motions are still in an admissible range.

The sign pattern of the Jacobian matrices evaluated at both equilibria are given by

$$J_{LI} = \begin{pmatrix} + & - \\ + & + \end{pmatrix} \qquad \text{and} \qquad J_{HI} = \begin{pmatrix} + & + \\ - & + \end{pmatrix}. \tag{2.17}$$

For the explicit expressions and numerical values of the Jacobian see the appendix (equations (A.1.1)-(A.2.14)). The subindex LI and HI indicates the respective business cycle environment, i.e. the low- and high-indebted regime. The point of rest of the low-indebted regime is locally stable if the eigenvalues of J_{LI} have negative real parts, which is the case when J_{LI} has a positive determinant and a negative trace. In contrast to the Jacobian (2.16) discussed in section 2.5.1, the self-feedback entry of λ becomes now positive which in turn indicates that the law of motion $\dot{\lambda}$ is unstable under the current parameter calibration. The steady state of the low-indebted regime is unstable since the Jacobian exhibits a positive trace which suffices to render the equilibrium point unstable. As the dynamics around E_{LI} and its Jacobian suggest, the stabilizing dynamics of the debt ratio, i.e. $\partial\dot{\lambda}/\partial\lambda$, are not necessary for the emergence of limit cycles. Despite of the periodicity, the dynamics surrounding the steady state of the low-indebted regime does not essentially differ from those described in section 2.5.1. Hence, we will not discuss it in a more profound manner.

The sign pattern of the Jacobians in (2.17) suggest that the dynamic behavior of the high-indebted regime differs qualitatively from the low-indebted regime particularly with regard to the the mutual feedbacks.[8] In particular, both entries in the off-diagonal switched its sign which in turn induces the motions in the high-indebted regime to move in a clockwise manner. The main reason for that issue lies in the effect of λ on $\dot{a}$. The new equilibrium point E_{HI} possesses a higher debt ratio $(\overline{\lambda})$ and thus a higher steady state lending rate $(\overline{\jmath})$.[9] Around the higher equilibrium point the debt-led capacity utilization effect is stronger compared to the low-indebted regime, as can be seen from

$$\frac{\partial u(\overline{a}, \overline{\lambda})}{\partial \lambda} = \frac{s_f(1-s_c) - \gamma_\lambda}{\sigma\pi - \gamma_u} \left(\iota_\lambda \overline{\lambda} + \overline{\jmath}\right). \tag{2.18}$$

[8]Note that the equilibrium point E_{HI} is unstable since $tr(J_{HI}) > 0$. A saddle point can be ruled out due to $det(J_{HI}) > 0$.

[9]he assumption of such a huge financial accelerator $\iota_\lambda = 3$ is accompanied by unrealistic large magnitudes of the loan rate which in turn represents one of the shortcomings of the actual approach. Using the actual parameter setting which is depicted in table 2.1, the steady state loan rate at the fixed point E_{HI} amounts to $\overline{\jmath} = 1.374$ which exceeds any suitable order of magnitude by far. At this stage of the paper, we accept the disproportionate value and leave the solution of this shortcomings for future work on this issue.

since $\overline{\lambda} > \underline{\lambda}$ and $\overline{j} > \underline{j}$. This effect is, however, relatively weak compared to the stimulating effect of corporate debt on utilization via the sentiment index. Increasing debt, together with strong acceleration effects, improves the general business sentiment significantly and immediately induces firms to invest more. Utilization persistently exceeds the desired benchmark value ($u > u^d$) in the upper orbit. Consequently, Proposition 1 is permanently violated. Hence, the effect of debt on utilization is sufficiently large that it outweighs the direct negative effect of debt on the sentiment index in the switching index (2.13). Compared to the low-indebted regime, the sign of $\partial\dot{a}/\partial\lambda$ is positive and induces the trajectories to move clockwise.

Figure 2.2b shows the resulting cyclical motions of some key economic variables. Note that the particular time series are normalized in order to assort them around a specific value, strictly speaking, the periodical cycles *a)* in the top half refer to the low-indebted and *b)* in the half below to the high-indebted business regime. The cyclical features of the bottom closed orbit exhibit similar characteristics as the unique cycle described in section 2.5.1.

Consider now the case where the economy is hit by unforeseen shocks that causes the trajectories to converge from the bottom to the upper limit cycle. The co-movements of the cyclical motions illustrated in figure 2.2b suggest that everything turns topsy-turvy. In this respect, suppose that firms' start to de-leverage their balance sheets. The decline in the debt ratio leads to an immediate decrease in utilization. Although capacity utilization has been decreased, it exceeds the desired rate (u^d) over the entire business cycle in the high-indebted regime. Since firms' debt service is still high and the decline in aggregate demand reduces their revenues, corporate profits diminish in response while the general sentiment index still improves for a marginal time horizon. The joint impact of a reduction in the debt ratio and the decline in firms return differential outweighs the positive spread of the utilization rate from its desired counterpart, which is amplified by the strong acceleration effect, and induces the sentiment index to decrease. Even though de-leveraging of corporate debt reduces the general economic performance, the economy permanently exceeds its production capacity by far while firms' leverage ratio approaches high values over the recurrent business cycles.

One may argue that such a business environment is, at least from an economist's point of view, doubtful and not reasonable at all since highly indebted enterprises that permanently work over their production capacity indicate an overheating economy. It is further questionable whether such states of the economy are sustainable and desirable. However, the high-indebted business regime reaches at some periods a turning point where a convergence to the steady state is induced, an inherent destabilizing mechanism ensures that the low business cycle will not be reached without any further exogenous perturbations. Corporate leverages will remain high which possibly mimics the observations of Graham et al. (2015a), i.e. the gradual increase of aggregated trend leverages.

The dynamic insights of the present framework are worth discussing. Large counter-moving disturbances, e.g. policy actions, may probably ensure a regime switching where the trajectories of the high-indebted regime may be guided back to the low states. The emergence of two periodic cycles are closely linked to the numerical values of the financial accelerator ι_λ and firms' perception of debt default risk ϕ_λ. This fact in turn stresses the importance of firms' lending and the banking sector's borrowing decisions on the system's stability. If we consider hypothetically that the banking mark-up and thus firms' external financing structure is governed by the public banking supervision, debt-regulation becomes a crucial factor in stabilizing the economy.

Regulation, or macroprudential policy, closely links the corporate financing structure to macroeconomic policies and is therefore worth to consider in such models of the business cycle. This can further be motivated by the findings of Graham et al. (2015a). They identified that firms' external funds in the US are regime dependent. In particular, firms' leverage ratio increased remarkably during the last century. This increase occurred mainly in the unregulated industrial sector and affected firms of all sizes while the development of the leverage ratio within the regulated sector evolved in a stable manner.

2.6 Concluding Remarks

This paper presented a stylized model that reflects the dynamic interaction of corporate debt and the general business sentiment in a debt-led capacity utilization and accumulation regime (whereas the debt-burdened case is also considered but merely provided within the appendix in order to emphasize the flexibility of the model configuration). Both dynamic laws are configured in a non-linear manner where the notion of the sentiment index accounts for heterogeneity among firms in their subjective sales expectations. From the simulation exercises we can infer that the dynamic interaction of the firms' leverage ratio and the investor sentiment may produce distinct periodic solutions. In one case, we showed that the model is able to generate a uniquely determined business cycle regime where the cyclical motions of the variables fluctuate around some specific benchmark values. It was shown that the arising limit cycles give rise to recurrent Minsky-Koo kind recessions where the economic downturn is essentially caused by balance sheet distress. It was further shown that for large shocks to the firm's external financing structure, the economy may drift to a co-existing high-indebted regime with a reversed causality regarding the lead-and-lag behavior of the variables. Accordingly, this situation is characterized by highly leveraged firms which permanently operate beyond their production capacities and never attain the desired state. This scenario is represented by an attractive limit cycle in which the economy will remain unless no further sufficiently large exogenous perturbations occur. The exogenously induced movement from the bottom- to the upper limit cycle leads to a regime switching from the low- to the high-indebted regime which, potentially, can generate a permanent increase in the trend leverage. With this work, we further emphasize the flexibility of the underlying neo-Kaleckian model in the sense that departing from it in distinct directions may result in different interesting dynamic behaviors. The numerical simulations suggest that the emergence of the high-indebted regime depends on the bank's borrowing conditions (ι_λ) as well as the investors' perceptions of how the economy, and thus the firms future sales, may be affected by a potential debt default through a rapid pace of debt accumulation (ϕ_λ). Technically speaking, multiple equilibria arise by increasing the impact of the non-linear nature of the increment of debt on the capital accumulation rate.

This paper did not elaborate on this specific issue, future related work could emphasis the importance of policies preventing the possibility of converging to the high-indebted regime, or at least, to execute forces that aim to control the regime switching. Natural candidates are macroprudential policies that either constraint firm's demand or bank's supply of credits. Accordingly, future research on this topic should aim to consider macroprudential policies as macroeconomic stabilization tools and its effects on boom-bust cycles. By doing so, commercial bank's behavior has to be elaborated in a more rigorous way, so that regulation can be analyzed in a clearer and more profound manner.

Chapter 3

The Systemic Risk of Corporate Credit Securitization

3.1 Introduction

In the upswing since the financial market crisis, corporate debt has increased noticeably in several economies, particularly in the US. Along with increased leverage ratios of firms, securitization of corporate loans has regained importance. In view of its possible systemic relevance, regulatory authorities, responsible for market supervision, start to re-intensify their monitoring, while for years the issue of securitization had receded into the background due to the illiquidity of the market after the crisis (cf. Fed, 2019; FSB, 2019). Moreover, a new standardized type of securitization has been proposed in the European Union to increase the volume of cross-border lending while, at the same time, it is supposed to minimize negative feedback effects of troubled securitization vehicles on the banking sector (cf. Commission, 2015; Véron and Wolff, 2016). Against the background of these developments, the paper at hand deals with the following research questions: What systemic risks are created by different levels of securitization propensity and what are the medium- to long-term consequences for the real economy? Can these risks be mitigated by preventing banks from keeping the equity tranche of the securitization in the banking book? What institutional structure of the banking sector in terms of bank size and in terms of the design of a bank rescue mechanisms can minimize these risks?

The academic literature on the systemic risks of securitization can be divided into an empirical strand, mainly concentrating on the mechanisms before and during the financial market crisis of 2007, and into a more theory-guided model-based strand which attempts to capture the balance sheet changes that a pooling of credit claims and its subsequent sale to capital market investors brings about. Empirical studies mostly conclude that securitization has played an important role in the deepening of the last financial crisis - be it because *i)* a laxer credit screening takes place after loans have been securitized (cf. Keys et al., 2010), *ii)* securitization amplifies the positive effect of low interest rates on bank risk taking too much (cf. Maddaloni and Peydró, 2011), *iii)* the securitized loans cannot claw back once the originator goes bankrupt which may unfold systemic effects (cf. Gorton and Metrick, 2012), *iv)* the risk transfer from banks to capital market investors does not work efficiently (cf. Acharya et al., 2013) or *v)* a possible freeze of the securitization market tightens credit supply conditions, after banks got used to this type of funding (cf. di Patti and Sette, 2016).

Among the modeling approaches, macroeconomic agent-based models deserve special reference. This approach generates aggregated dynamics which allow for more than a strict replication of microeconomic optimization in equilibrium, but instead result from the interaction of economic agents with heterogeneous behavior and beliefs (cf. Deissenberg et al., 2008; Lengnick, 2013; Dawid et al., 2014). These models are therefore well suited to understand how the failure of a single entity within the financial system causes cascade failure (cf. Battiston et al., 2007; Delli Gatti et al., 2010; Fischer and Riedler, 2014). This also relates to the question about an optimal degree of diversification, as diversification can decrease the idiosyncratic risk for a single entity, but increases the (neglected) systemic risk through stronger connectivity (see Wagner, 2010; Gennaioli et al., 2013). In recent years, agent-based modelers started to pay attention to sectoral completeness at the macroeconomic level and took their models closer to the data in terms of both calibration and validation (cf. Caiani et al., 2016; Mazzocchetti et al., 2018). At the same time, macroeconomic models have been further elaborated so that they include balance sheets from specific financial market institutions including shadow banks (cf. Bhaduri et al., 2015; Moreira and Savov, 2017; Botta et al., 2018). We follow this strand of literature and build a stock-flow-consistent macroeconomic model with an agent-based focus on corporate credit markets including a securitization process.

Several model-based studies conclude that high volumes of loan securitization increase the vulnerability of the financial system (cf. Gennaioli et al., 2013; Brunnermeier and Sannikov, 2014; Bhaduri et al., 2015; Moreira and Savov, 2017; Botta et al., 2018). However, with the exception of the paper by Mazzocchetti et al. (2018), few efforts have been made to carefully quantify the volume of securitization from which risks in the medium to long run are highly likely to become systemic and to produce harmful effects on the real economy. To the best of our knowledge, our study is the second to estimate this threshold of systemic securitization propensity.[1] Moreover, we go beyond the analysis of Mazzocchetti et al. (2018) and investigate the consequences of different securitization intensities under alternative conditions. Our scenarios attempt to cover different institutional designs of the banking sector and its connection to the special purpose vehicle (SPV), which represents shadow banking in our model. In particular, we investigate whether high securitization intensities remain without systemic effects, if there is no direct connection between banks and SPV through equity tranches or guarantees unlike in the years before the financial market crisis (cf. Acharya et al., 2013). In addition, we can analyze the resilience of the banking sector, depending on the size of

[1] We measure the volume of securitized loans in % of total loan volume in the period of origination of the securitization vehicle and use the terms securitization intensity or activity or propensity synonymously.

individual banks and depending on the design of a bank rescue mechanism.

Our results can be summarized as follows. In our model, significant adverse medium- to long-term effects become apparent, as soon as the securitization intensity reaches about 10% of the aggregate loan volume in the period of SPV origination. Under such conditions, welfare losses are realized irrespective of whether the collapse of the SPV leads to distortions in the banking sector, or whether increasing liquidity constraints dampen households' consumption due to their financial investment in the securitized tranches. A more concentrated banking sector reinforces the adverse shock of a liquidation of the SPV. In contrast, a faster and better equipped bank rescue mechanism in the form of levies within the banking sector helps to dampen the consequences of a possible collapse of the SPV.

This article is organized as follows. Section 3.2 summarizes selected literature on securitization, section 3.3 presents the main building blocks of the model while section 3.4 explains its calibration to US data. Section 3.5 presents a variety of simulation results depending on the institutional design of the financial sector. Section 3.6 validates the model on the basis of a Monte Carlo simulation depending on the stochastic terms. Finally, section 3.7 concludes. The full set of model equations, parameters and additional robustness checks is provided in an appendix B.

3.2 Related Literature

3.2.1 A brief history of securitization

The first securitization activities date back to the early 1970s when the US Government National Mortgage Association ('Ginnie Mae') participated in the granting of mortgages to first-time homeowners and refinanced this mortgage pool by issuing securities.[2] In the course of the 1990s, privately issued securitizations gained in importance. These types of securitization, sometimes called 'traditional' (cf. Chernenko et al., 2013), were mostly residential and commercial-backed mortgage securities (RMBS, CMBS) or consumer asset-backed securities (ABS), which bundle credit card debt, car and student loans into tranches to sell them to capital market investors. Their tranches are usually called senior, mezzanine and junior or equity according to their increasing liability in the event of default. These financial instruments

[2]'Freddie Mac' followed in 1971 and 'Fannie Mae' in 1981, while all these corporations received special government benefits in order to achieve the goal of strengthening home ownership.

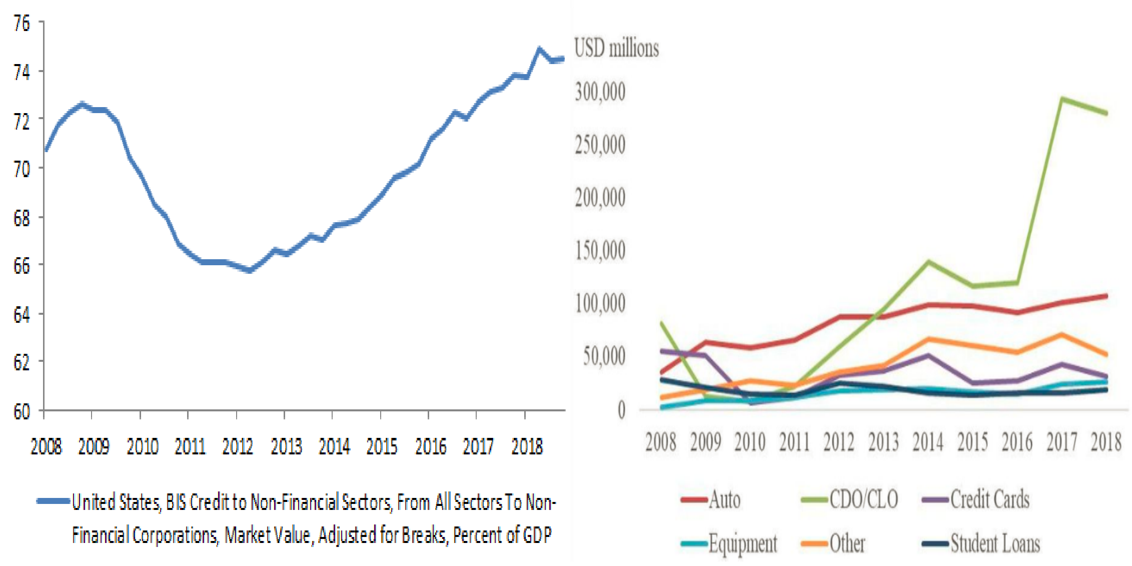
started to be issued and traded in the United Kingdom from the mid-1980s onwards, some years later the legal basis for such transactions was also established in continental Europe.

From the end of 1990s to 2007, the boom in securitization was mainly based on new types of securitization: *i* Sub-prime RMBS, where part of the underlying loans, not the tranche securities, had a non-investment grade credit rating. *ii* Collateralized debt obligations (CDO), which structured corporate loans and bonds. *iii* Short-term asset-backed commercial papers (ABCP), which were based on different types of long-term assets as in the case of CDO and ABS, but additionally contained guarantees.[3] With the first defaults in securitized asset portfolios in 2007, the market lost investors' interest and the special purpose vehicles (SPVs) got into trouble. In case of ABCPs, the SPVs were no longer able to service the debt from expiring securities due to the short-term refinancing structure of long-term assets. Sponsoring financial institutes had to step in (cf. Acharya et al., 2013).

Against this background, this paper attempts to discuss extents of corporate loan obligations (securitized corporate loans) that may unfold systemic risks which materialize in the medium to long-term. It is therefore insightful to recall the volumes that characterize the rise and fall of securitizations before and after the financial crisis of 2007. Pozsar et al. (2010) show that the assets of shadow banks in the US rose exponentially from close to zero in the early 1980s to as much as USD 20 trillion in 2007. From the mid-1990s, these assets started to exceed those of the traditional banking sector. In 2007, the ratio was almost 2:1. Segoviano et al. (2013) report that global issuance of private-sector securitizations increased from around USD 1.4 trillion to just under USD 2.9 trillion between 2000 and 2007. In Europe, the annual issuance rose from around EUR 100 billion in 2000 to about EUR 750 billion in 2007. By 2013, it had declined back to just under EUR 200 billion. For the U.S., Acharya et al. (2013) document that ABCPs alone had reached a considerable volume in macroeconomic terms in the run-up to the financial crisis of 2007: "ABCP outstanding grew from USD 650 billion in January 2004 to USD 1300 billion in July 2007. At that time, ABCP was the largest money market instrument in the U.S. [...] For comparison, the second largest instrument was Treasury bills with about USD 940 billion outstanding [...] [Furthermore in] July 2007, medium-term notes and capital notes of [related investment vehicles] accounted for about USD 400 billion" (Acharya et al., 2013, p. 516).

Although parts of our analysis will be transferable to other types of credit, we primarily

[3]Originating banks guarantee to repurchase maturing ABCPs, if the SPV is unable to do so.



(a) (b)

Figure 3.1: U.S. corporate credit and private issuance of securitization between 2008-2018. The left panel 3.1a is based on data from the Bank for International Settlements (BIS). The right panel 3.1b stems from Valladares (2019) based on data from the Securities Industry and Financial Markets Association (SIFMA).

deal with corporate credit markets. The main type of securitization relevant here is CDO. Segoviano et al. (2013) report that the global CDO issuance increased fivefold from around USD 200 billion in 2000 to about USD 1 trillion in 2007. Consequently at this time, the ratio between CDO issuance and new credit to the non-financial corporate sector in the U.S. was above 50%.[4] Figure 3.1 illustrates the evolution of U.S. corporate credit (relative to GDP) as well as the private sector securitization issuance since 2008. As indicated in the introduction, the CDO issuance volume has significantly recovered in recent years.

3.2.2 Empirical literature on securitization

The variety of reasons for the expansion and collapse of the securitization market can be roughly summarized as follows: In the expansion phase, banks' general motivation to pack and sell loans is to free up regulatory capital in order to meet the dynamic demand for new loans (cf. Acharya et al., 2013). Investors in general are seeking for high returns, while relying on risk-reducing benefits of diversification with respect to the assets in the credit pool (cf.

[4] According to BIS data, new credit from all sectors to non-financial corporations grew from 2006 to 2007 by roughly USD 1.1 trillion. The issuance of CDOs in the U.S. accounted at least for half of the global total.

Segoviano et al., 2013). Such aspects are also reflected in the presented model.

Segoviano et al. (2013) provide a more refined list of dangerous developments linked to the securitization market in the run-up to the crisis of 2007. These range from macroeconomic developments, such as continuously rising real estate prices and low interest rates,[5] to institutional characteristics such as a lack of control over lending standards,[6] misaligned incentives and principal agent problems between the institutions involved.[7] Similarly, Chernenko et al. (2013) examine securitized holdings of insurance companies and mutual funds. They find the behavior of (inexperienced) mutual funds managers to be more consistent with risk-neglecting beliefs than with performance-based disincentives. This is similar to the transmission channel proposed by Gennaioli et al. (2012). For insurance companies, in contrast, they identify higher investments in non-traditional securitization among poorly capitalized insurers. This points towards risk shifting as a result of agency problems (cf. Eisdorfer, 2008). In our model, we do not explicitly implement these characteristics. Instead, we induce the size and the timing of the SPV origination exogenously. However, these findings are helpful to understand how the securitization market could grow to gigantic volumes.

With regard to the bust of the securitization market, Chernenko et al. (2013) find little evidence of widespread fire sales, as for instance discussed by Brunnermeier and Oehmke (2013) in the context of financial networks. Rather, they conclude from weak transaction data that a self-reinforcing buyer strikes and therefore price adjustments took place. For the endogenous mechanism in our model, which can end up with the liquidation of the SPV, it is only relevant that a significant share of the companies, whose loans are securitized, are subject to a certain default risk. This is confirmed by the data set exploited by Chernenko et al. (2013) as the share of CDO holdings with AAA rating is only about 40% and even this share must be seen against the background of the rating process at that time. Models used by credit rating agencies poorly accounted for parameter and model uncertainty and ratings were often tailored to the needs of their clients (cf. Coval et al., 2009).

In a seminal paper, Acharya et al. (2013) analyze the role of ABCPs for the creation of the financial crisis of 2007. Among other things, they estimate the loss of investors in conduits

[5]Based on firm loan data from the Euro Area bank lending survey, Maddaloni and Peydró (2011) find that a one percentage point increase in the securitization intensity decreases the net percentage of banks reporting a tightening of credit standards by 19 points

[6]Based on panel data of securitized sub-prime mortgage loans in the U.S., Keys et al. (2010) find a doubling of securitization volumes being on average associated with about a $10\% - -25\%$ increase in firm defaults

[7]This includes banks, special purpose vehicles, mutual funds as investors, credit rating agencies, regulators

and of financial institutions that provided guarantees to this conduits. The authors find that, after including the events of 2007-onwards, conduit exposure significantly reduced bank equity, while the majority of investors were repaid by the guarantees. Overall, this means that little risk transfer from banks to outside investors was provided. In this context, Gorton and Metrick (2012) describe securitization of loans as the asset part of a new type of banking, which they call securitized banking. On the liabilities side, they identify repurchase operations (repo) as an essential component of funding. On the basis of spread data, the authors find empirical evidence that, although the 2007 events around the sub-prime housing market in the USA initially led to swings in counterparty risk, as measured by the spread between the LIBOR and the Overnight-Index-Swap rate, it was rather the subsequent reaction of repo haircuts that drove US banks into bankruptcy problems. Similar to the finding by Acharya et al. (2013), this means that the banks kept significant parts of the securitized loans in their portfolios. The analysis by di Patti and Sette (2016) can also be interpreted in that way: By means of difference-in-difference estimates, they show that the extent to which Italian banks tightened lending standards was positively related to the share of loans banks securitized before the crisis.

The lack of risk transfer is very important when discussing the systemic impact of increased securitization volumes ten years after the crisis. Some observers, in particular with regard to the European Capital Market Union, argue that the risks out of securitization can be contained if the products are standardized and transparent (cf. Commission, 2015; Véron and Wolff, 2016). This shall ensure that all tranches of securitized loans can be sold to capital market investors. More generally, the aim is to eliminate the deficit in risk transfer from the banking sector to capital market investors. However, as our model simulations show, such a structure does not change that systemic risks and harmful real economic consequences materialize as soon as the economy-wide securitization intensity exceeds a certain threshold.

3.2.3 Models including bankruptcies in credit networks

An essential building block for our model is corporate insolvency, in particular if it affects companies whose loans have been securitized. In this case, write-offs of assets reduce the SPV's profitability, which may trigger a bankruptcy cascade. For this reason, the literature on the effects of insolvencies in credit networks forms a cornerstone for our modeling approach. Battiston et al. (2007) develop a model of a production network in which retailer and supplier firms are connected by demand relations financed by trade credit. Given a constant number of suppliers and customers, the authors evaluate the propagation of firm insolvencies under different strategies. If firms adapt their orders when a supplier goes bankrupt instead of bearing the costs of a production loss, insolvency avalanches will be weaker. At the same time, such a strategy leads to a major supplier for each firm (process of concentration). Similarly in our model, a firm will only be affiliated with one bank, while a bank can have several corporate clients. Moreover, Battiston et al. (2007) analyze a scenario of dynamic interest rates, where an increase in default risk implies an increase in borrowing and hence production costs. This strengthens insolvency propagation in line with most empirical literature, e.g. Duffee (1999). Delli Gatti et al. (2010) use a dynamic-interest specification in a production network that also includes a banking sector. The interest rate is a decreasing function of the net worth of debitor firms, which pay less with lower leverage, and creditor banks, which demand less with lower leverage in order to attract more business. Delli Gatti et al. (2010) employ this specification within a randomized selection mechanism, which we calibrate to U.S. data.

Another result of Delli Gatti et al. (2010) is relevant for us, namely the conditions under which firm insolvencies propagate to bank insolvencies. The authors find that contagious effects crucially depend on the interconnectedness of single agent's to adjacent agents. In other words, systemic consequences are imminent from a negative shock on the individual agent (idiosyncratic risk), if the agent is sufficiently connected to an environment of bad debt. The stronger the feedback or the more agents (with bad debt) are involved, the higher the systemic risks. We expand the financial market in Delli Gatti et al. (2010) so that corporate insolvencies can be transferred to the SPV whose equity tranche is held by several banks. If one of them is a bank that just fulfills the regulatory capital requirements, it will also be threatened with insolvency. In turn, bank insolvencies create bottlenecks in financing. Thus, negative effects on aggregate demand may arise.

3.2.4 Models including shadow banking activity

Qualitatively, the effects of shadow banking, especially securitization, are summarized similarly in model-based studies of different economic schools, irrespective of whether these studies employ utility-maximizing (macro-)financial models (cf. Gennaioli et al., 2012, 2013; Moreira and Savov, 2017), post-Keynesian stock flow consistent models (cf. Bhaduri et al., 2015; Botta et al., 2018) or an agent-based macro-model (cf. Mazzocchetti et al., 2018). These studies mention a possible welfare-increasing effect from credit expansion in the short-run, but in the medium- to long-run an increase in financial market fragility.

Gennaioli et al. (2012) develop a model for financial innovation, in which intermediaries create supposedly safe securities from cash flows because of a demand from investors that cannot be met by traditional securities.[8] The authors modify a standard model for financial innovation (Allen and Gale, 1994) so that investors (and possibly intermediaries) neglect certain tail-risks. Compared to the result under rational expectations, cash flows are then securitized excessively. A news update, such as 2007 the first house price decline in years, makes investors aware of the neglected risks and leads them to flee into the quality of traditional securities. Gennaioli et al. (2013) elaborate this approach by modeling not only aggregate but also idiosyncratic risks. Insurance against idiosyncratic risks, namely diversification, can interact with the neglect of aggregate risk. This leads to financial market instability.

Moreira and Savov (2017) emphasize the liquidity side of securitization. They endogenously model uncertainty as the outcome of a learning process. Investors are willing to rely on shadow money instruments, such as securitized assets, as long as these are likely to remain liquid. An asset price and economic activity boom follow, but fragility increases over time as investors focus on riskier assets. The corresponding rise in uncertainty raises shadow banking spreads, forcing financial institutions to switch to collateral-intensive financing (cf. Minsky, 2008). The subsequent collapse of the shadow banking sector, which has become too big, creates a Minsky moment and economic activity declines.

Bhaduri et al. (2015) develop a framework that explicitly includes shadow banks in addition to regulated financial institutions and non-financial sectors. Such a financial system has self-reinforcing credit expansion capabilities, but is also fragile because it is built on a gradually narrowing reserve and real capital base. The authors analytically identify different adverse regimes whose characterization, depending on capital income and on the composition effect between real economic and financial investments, ranges from stagnation to abrupt crashes. Botta et al. (2018) explore a short-run macro model with shadow banks. They show how shadow banks increase the profitability of the financial sector while enabling banks to meet capital requirements at the same time. The authors simulate a variety of shadow bank-driven regimes in which economic activity tends to be stimulated, productive capital

[8]As a reason for this excess demand in the run-up to the 2007 crisis, the authors refer to the decline in US treasury bonds in circulation after the reduction of government debt under the Clinton-administration. In addition, increased demand from abroad and a growing wealth inequality can be mentioned (cf. Jones, 2015).

formation declines and income distribution becomes more unequal.

Related to this literature, this paper focuses on medium to long-term effects of securitization. The paper that comes closest to our analysis is the one by Mazzocchetti et al. (2018), as the authors, like us, study the macroeconomic effects of different securitization intensities in an agent-based macro framework. However, the model design differs in important details. At first glance, the structure by Mazzocchetti et al. (2018) seems more complete with respect to a continuously simulated securitization process and different types of securitization (ABS pooling corporate loans, MBS pooling household mortgages). However, our approach of concentrating on corporate loan securitization with a single credit pooling per simulation run allows a more in-depth analysis of the SPV's liquidation effects on aggregate demand. This includes scenarios with different institutional designs of the financial sector and a proper consideration of a bank resolution mechanism. As we will see, results differ considerably.

3.3 An Agent-based Model of Corporate Credit Securitization

3.3.1 Framework and Simplifications

In this section we outline the basic features and some limitations of our model. We consider a closed economy that evolves in a sequential manner with discrete time index t and model life span $[0, T] = \{t \in \mathbb{N} | 0 \leq t \leq T\}$. Due to the complexity of the overall framework, which arises through the interaction and the mutual feedback of heterogeneous market participants - firms, banks, and shadow bank - we keep some parts of the model as simple as possible, in particular the household sector. For the sake of simplicity, we also abstract from an active government sector and an endogenous reaction of monetary policy set by the central bank. Labor market dynamics are only implicit. By all this simplifications, we aim to prioritize the transmissions that are essential to describe the effects of securitization on the business cycle. Precisely, we aim to elaborate the financial accelerator approach in an evolving credit network with a special focus on corporate loan securitization (cf. Bernanke and Gertler, 1989b; Greenwald and Stiglitz, 1993b; Kiyotaki and Moore, 1997b; Delli Gatti et al., 2010).

In the model, the private sector is divided into households and firms. The former acts as a single aggregate at the macroeconomic level, while the firm sector is microfounded and divided into a corporate (non-financial), banking and shadow banking (financial) sector.[9] Firms and banks are supposed to interact at the microeconomic level. Through this interaction the financial sector provides the external funding of firms' real economic investment projects. Investment in the capital stock drives economic growth in the model. We do not differentiate between distinct firm layers like capital and consumption good producers. This implies that firms act exclusively at the demand side for credit and do not fund each other.[10] Similarly, the banks appear only as credit supplier for the corporate sector, i.e. interbank transactions are neglected. In the model, loans generate deposits as long as capital requirements are met (endogenous money creation). In the following, we consistently use $i \in \{1, \dots, N_C\}$ for the index of firms and $k \in \{1, \dots, N_B\}$ for the one of banks.

A firm can finance its business investment by issuing new shares, by retaining earnings or by borrowing money from the bank. Firm-bank credit relations are created by a randomized partner selection mechanism, similar to the one proposed by Delli Gatti et al. (2010) and Caiani et al. (2016). In particular, in each period t, each firm i picks a subset $M = \{1, \dots, n << N_B\}$ of banks and requests a loan from the one which offers the best conditions, i.e. the loan with the lowest interest rate. As long as all banks in the subset M are solvent, we assume the transaction costs for the loan matching to be low enough that they can be neglected.

In case of firm insolvency, the firm's assets and liabilities are frozen so that the firm can no longer participate in economic activity. At the same time, solvent firms take over the investment capacities and customers of the insolvent firm so that the desired level of investment at the macro level remains the same in the production planning of the next period. We thus assume firms to grow bigger and bigger - a concentration process that prevents individual firm insolvencies from directly having a major impact on the real economic outcome. In contrast, this may happen via the financial sector. The reason why we take this approach is that it allows for a transparent and endogenous way of how firm insolvencies may affect the banking sector and the securitized loan portfolio, owned by the SPV, while direct production network effects go beyond the scope of our paper. Alternatively, one could model

[9]We henceforth refer to non-financial businesses with "firms" and to financial businesses with "banks", while shadow banking activity is represented by the special purpose vehicle (SPV).

[10]This is one reason why the resulting dynamics do not induce a pure power law distribution of (solvent) firm size in contrast to Delli Gatti et al. (2010) and Caiani et al. (2016). Instead, our density function for the firm size distribution shows discontinuities. Even more relevant for this potential shortcoming of our model is the firm concentration process which we model in the spirit of Rosen (1981). However, this modeling design is on purpose as it allows for an endogenous firm insolvency process without market entries.

a market entry for firms, which has to be laboriously calibrated to the data. However, we do not suspect any obvious bias from the selected modeling design with respect to the research questions.

A special feature of our model is the connection of the banking sector to the SPV responsible for securitization. Banks have the opportunity to sell parts of their granted corporate loan portfolio to enhance their lending capacity. The SPV carves up the cash flows related to the underlying pool of corporate debt into different tranches and sells the senior tranche securities as diversified credit bundles to capital market investors, i.e. the household sector.

3.3.2 Stock Flow Consistency

In order to illustrate the overall structure and coherence of the model, this section presents the balance sheet and the transaction flow matrix as it is common in the so-called stock-flow consistent literature (cf. Godley and Lavoie, 2006; Bhaduri et al., 2015; Caiani et al., 2016; Botta et al., 2018; Mazzocchetti et al., 2018). The stocks held by economic agents can be recorded in a double-entry balance sheet, which contains both, real and monetary assets and liabilities.

The rows of table 3.1 show assets and liabilities among sectors, which should in general sum up to 0. An exception is given by the capital stock, whose counterpart is the sum of the sectoral net wealth positions. The components of household net wealth - deposits, equities and tranche securities - result from a portfolio choice, but decomposition can also be influenced by insolvencies, in particular by a possible liquidation of the SPV. In our model, the net wealth position for firms and banks is small, relative to the one of the household sector. In table 3.1, these values can be considered to correspond to changes in the equity price. For the SPV, a net wealth position is forced to be 0, i.e. profits, arising from the interest rate spread between loans and tranche securities, are instantaneously passed on to the owner banks.

The upper part of table 3.2 describes economic agents' flows of revenues (+) and payments (−). The bottom part displays the balance sheet changes. Taking the household sector column as an example, the components of disposable household income, namely wages and capital income consisting of dividends and interest income, shown in the upper part of the matrix, are in opposition to consumption expenditures. The resulting net position, household net savings, can then be used to change asset positions in the form of deposits, bank or firm shares or senior tranche securities (A-tranche) resulting from the securitization of the corporate loans (CLO). Finally, all inputs and outputs of the household sector add up to 0. In this respect, most entries in table 3.2 are self-explanatory. Notice that we do not impose any repayment rates on the equity tranche (B-tranche) with the consequence that the banking sector passes on the profits made by the SPV directly to its owners. These profits strengthen capital income in addition to the distributed profits of the corporate and the banking sector.

There are several ways to test and guarantee the stock flow consistency of the model. First, consistency of assets and liabilities at the micro level in (solvent) firms and banks can be established explicitly, e.g. by allowing for new share issues at the end of each period (see equation (3.10)). Secondly, some parameters can be calibrated so that a "missing equation" of the model and thus model stability is fulfilled implicitly (quasi steady state solution). In our case, this equation, which is not derived explicitly, describes the identity of capital (savings) and current account (investment). Hence, before accepting simulation results, we check the consistency of all balance sheets and between corporate investment and households' savings where the latter is computed as the first difference of household net (financial) wealth.[11]

	Households	Firms	Banks	SPV	$\sum$
Capital		$+K$			$+K$
Deposits	$+M$		$-M$		0
CDO/CLO (Securities)	$+S_A$		$+S_B$	$-S$	0
Loans		$-L_b$	$+L_b$		0
Securitized Loans			$-L_s$	$+L_s$	0
Equities	$+E_f + E_b$	$-E_f$	$-E_b$		0
Net Worth	$-NW_h$	$-NW_f$	$-NW_b$		$-K$
$\sum$	0	0	0	0	0

Table 3.1: Balance sheet matrix (before SPV liquidation). The notation refers to the variable letters depicted in table B.1 in appendix B.1 which are used throughout the paper, with the slight difference that capital letters are used instead. Additionally, we use $S_{A,B}$ for the A- and B-tranche of the SPV securities and L_s for the loans pooled by the SPV.

[11]Results are available on request.

	Households	Firms		Banks	SPV	$\sum$	
Cash receipts / outlays		Current	Capital				
Consumption	$-C$	$+C$					0
Wages	$+WB$	$-WB$					0
Investment		$+I$	$-I$				0
Profits	$+\Pi_f^d + \Pi_b + \Pi_{SPV}$	$-\Pi_f^d$	$+\tilde{\Pi}_f$	$-\Pi_b$		$-\Pi_{SPV}$	0
Deposit Interest	$+r_M M(-1)$			$-r_M M(-1)$			0
Securitization Interest	$+r_S S_A(-1)$					$-r_S S_A(-1)$	0
Loan Interest		$-rL_f(-1)$		$+rL_b(-1)$		$+rL_s(-1)$	0
Change in Deposits	$-\Delta M$				$+\Delta M$		0
Change in CDO/CLO	$-\Delta S_A$				$-\Delta S_B$	$+\Delta S$	0
Change in Loans			$+\Delta L$		$-\Delta L_b$	$-\Delta L_s$	0
Change in Equities	$-\Delta p_f E_f - \Delta p_b E_b$		$+\Delta p_f E_f$		$+\Delta p_b E_b$		0
$\sum$	0	0	0	0	0	0	0

Table 3.2: Transaction flow matrix (before SPV liquidation). The transaction flow matrix displays all cash flows in the economy, which can either stem from cash receipts or outlays from the income and expenditure matrix (top part) or from changes in assets and liabilities (bottom part). Δ indicates the discrete change (flow) of a variable and WB represents the wage bill which is due in each firm

3.3.3 The Sequence of Events

The following sequence of events characterizes the economic activity in each period:

1. *Production Planning and Credit Demand:* Firms estimate their sales opportunities in a growing economy and adjust desired investment demand. Credit demand is determined accordingly, taking into account internal financing options

2. *Partner Selection Mechanism:* The firm chooses a subset of potential credit suppliers. Each bank in the subset offers a customized credit contract from which the firm chooses the one with the "best" credit conditions, i.e. the lowest interest rate

3. *Credit Market Clearing:* Banks grant loans, if they meet the capital requirements

4. *Employment and Production:* Labor supply is only implicit in the model and assumed to follow demand. Each firm produces its output, based on its available resources

5. *Goods Market Clearing:* The (aggregate) household sector receives wages, interest and dividend payments from financial assets and determines consumption as a function of income and wealth

6. *Bank Asset Management:* In period t_{SPV}, parts of banks' assets, i.e. the corporate loans, are pooled into two tranches and securitized by a special purpose vehicle (SPV). Banks keep the B-tranche in their books, while the SPV buys the A-tranche and sells it to outside capital investors, i.e. the household sector

7. *Firm Failure:* A firm can go bankrupt, when its leverage ratio exceeds a threshold ratio close to 1. This happens endogenously, as some companies randomly enter into unfavorable credit conditions (high yield), while path dependency reinforces this process

8. *Bank Failure:* A bank can go bankrupt, if its equity ratio falls short of the regulatory minimum requirement. If a firm picks a bankrupt bank in the partner selection process, transaction costs are due which imply that realized investments fall below the desired level (credit constraints)

9. *Bank Rescue Mechanism:* A bankrupt bank is recapitalized after a certain time and up to a certain extent by a bank levy organized within the banking sector (resolution process)

10. *Shadow Bank Failure:* The SPV's revenues are the loan interest payments of those firms whose loans have been securitized. Cash flows suffering from firm insolvencies may induce negative profits for the banks involved (the B-tranche owners), as the SPV still has to pay full interest to capital market investors (the A-tranche owners). In this case, the banks decide to liquidate the SPV. Loans are then transferred back into the balance sheets of the respective banks, while the investor households receive deposits or equities in return. As a result, banks' equity ratios can decline

3.3.4 Production planning

We are guided by the production planning of companies as proposed by Caiani et al. (2016). Accordingly, firm's sales expectations are assumed to follow an adaptive form (equation (3.1)).[12] Besides, each firm i computes its planned capital accumulation rate necessary for production (equation (3.2)). This accumulation rate is a function of the return on capital and the expected demand (cf. Amadeo, 1986; Palley, 2017). To be precise, it varies positively with firm i's planned capacity utilization rate $u_{i,t}^D$ which, according to Caiani et al. (2016), is defined by the income-to-capital ratio adjusted to a firm-specific capital productivity disturbance $\mu_{i,t}^K$ (equation (3.3)).[13] Based on the accumulation rate the desired level of real investment (equation(3.4)) can easily be derived. By construction, these investments represent the first difference of the desired capital stock (equation (3.5)).[14]

$$c_{i,t}^D = c_{i,t-1}^D + \lambda\left(c_{t-1} - c_{i,t-1}^D\right) + \epsilon_{i,t}^c \quad \text{with} \quad \epsilon_{i,t}^c \sim \mathcal{N}(0, \sigma_c) \tag{3.1}$$

$$g_{i,t}^D = \gamma_1 u_{i,t-1}^D + \gamma_2 \left(\frac{\Pi_{t-1}}{K_{t-1}}\right) \tag{3.2}$$

$$u_{i,t}^D = \frac{y_{i,t}^D}{K_{i,t}^D(1+\mu_{i,t}^K)} = \frac{c_{i,t}^e + i_{i,t}^D}{K_{i,t}^D(1+\mu_{i,t}^K)} \tag{3.3}$$

$$i_{i,t}^D = g_{i,t}^D K_{t-1} \tag{3.4}$$

$$K_{i,t}^D = K_{t-1} + i_{i,t}^D \tag{3.5}$$

Strictly depending on credit market frictions, a margin between the stock of capital that was planned at the beginning of the period and the stock of capital that is realized at the end of

[12]Notice that superscript D indicates the expected or desired value of a variable, while realized variables are without a superscript. For instance, realized consumption c will be discussed in equation (3.10).

[13]$\mu_{i,t}^K = \mu_{i,t-1}^K + \epsilon_{i,t}^\mu$ with $\epsilon_{i,t}^\mu \sim \mathcal{N}(0, \sigma_\mu)$ is supposed to follow a random walk.

[14]For the sake of simplicity, capital depreciation is ruled out. Taking into account the depreciation would just require a re-calibration of the whole model without any obvious insights for the research question at hand.

the period may arise.

3.3.5 Partner Selection Mechanism

In order to finance the planned investment projects, each firm i supplements its internal funds by applying for a loan from a bank k. A selection mechanism is therefore needed to match the demand and supply of credit. This so-called partner selection includes some coordination steps (cf. Delli Gatti et al., 2010). In each period, each firm i chooses a random subset $M \in \mathbb{N}^{n\times 1}$ of potential credit suppliers. This set may also contain banks that had to file for insolvency. Each of the banks $k \in M$ offers firm i an individual and customized credit contract. The corresponding loan interest rate offer refers to

$$r_{i,t}^{k} = \tilde{r} + \rho_{LR}(LR_{i,t} - \overline{LR}) - \rho_{ER}ER_{t}^{k} + \epsilon_{i,t}^{r} \qquad \text{with} \qquad \epsilon_{i,t}^{r} \sim \mathcal{N}(0, \sigma_r). \tag{3.6}$$

The loan interest rate is coupled with the long-term average lending rate from the data ($\tilde{r}$). This denotes the intercept of the lending rate function. In addition, lending rates are influenced by three factors. *First*, the firm specific leverage ratio is taken into account relatively to a sector-wide reference level $\overline{LR}$.[15] Accordingly, if firm i's leverage ratio exceeds the reference measure, bank k perceives the firm as risky and charges a lending rate with a higher risk-premium. A low leveraged firm is supposed to be a favorable customer because its loans have a low probability of default. It receives a customized credit contract with a low interest rate, which may even fall short of the market rate $\tilde{r}$ for $LR_{i,t}$ being sufficiently low. The responsiveness to the firms' leverage ratio is measured with $\rho_{LR} > 0$.

The *second* factor the bank takes into account is bank specific, namely the bank's equity ratio. It enters the lending rate function negatively which implies that well-capitalized banks are able to offer lower loan interest rates in order to expand their business. Banks are supposed to make a loan offer in any case, whether they are approaching the regulatory capacity requirements or not. It follows that less capitalized banks are assumed to charge

[15] The reference ratio $\overline{LR}$ can be interpreted as the leverage ratio a firm faces to maintain stable profits, on average. As it turns out, the economy responds sensitively to it as it has an impact on the share of firms that may fail on their debt. Its calibration delivers numerical insights as it splits the firm sector into two territories depending on the uniform initial distribution of firms' funding structure. One territory consists of enterprises that eventually fail, because they are subject to a higher initial leverage ratio. Once a firm operates at $LR_{i,t} - \overline{LR} > 0$, it remains there since it faces permanently higher risk premia which gradually impairs its financial position. The lucky firms are those who operate at $LR_{i,t} - \overline{LR} < 0$. This configuration is on purpose in order to allow for a certain degree of firm insolvencies in the model. Firm insolvency builds the starting point for analyzing systemic risk that endogenously arise from shadow banking activity.

a higher lending rate, as they have to strengthen their equity base. The sensitivity of the bank's equity ratio is measured by the parameter $\rho_{ER} > 0$. *Thirdly*, the lending rate is also influenced by a stochastic term $\epsilon_t^r \sim \mathcal{N}(0, \sigma_r)$ reflecting the impact of residual factors on the banks' lending rate offer, such as costs from information asymmetries, banking competition pressure, neglected risks, etc.

Once the firm receives individual offers, it sorts the interest rate offers related to the banks in subset M_t in an ascending order and agrees to the "best" one, i.e. to the contract with the lowest loan interest rate. The sorted subset $\tilde{M}_t = \{\tilde{m}_{t,1}, \tilde{m}_{t,2}, ..., \tilde{m}_{t,n}\} \in \mathbb{N}^{n \times 1}$ thus contains members sorted from "best" to "worse", where n refers to the sample size. In each period, this process repeats without any memory effects, implying no autocorrelation among the parties to the contract, i.e. the stochastic process is independent.[16]

3.3.6 Firm and Bank Insolvencies

The interaction of banks and firms in the credit market determines the financing options of firms' investment projects and hence the accumulation of capital, which in turn induces economic growth. However, the durability of each agent's economic action varies according to the evolution of its funding structure. As common in ABM, firms and banks may go bankrupt when they run out of liquidity or do not meet regulatory requirements.

In the present framework, firm i is supposed to be insolvent when its leverage ratio $LR_{i,t}$ exceed a high threshold value, $\overline{LR}^{\max}$, close to 1. This does not necessarily mean that the firm has already stopped servicing its debt. It rather reflects the fact that banks start to deny the company i's creditworthiness and stop funding it. As a consequence, the firm terminates its business. Compared to the real economy, in such case, the firm would be able to continue (for some time) and to finance a small part of investment projects from its internal sources. However, such a subtle distinction goes beyond the scope of this paper because we do not aim to replicate exactly the share of firm and bank insolvencies in the economy, but rather in estimating the additional fragility that may result from different intensities of securitization.

Similar to the firm sector, banks are active economic agents as long as they are well-capitalized, i.e. they fulfill the regulatory minimum capital requirements. Formally, a bank k

[16] If memory effects are taken into account, the calibration becomes more complex in order to avoid a too highly concentrated banking sector consisting only of too-big-to-fail institutions. Such a credit network may arise from the high probability of the firms remaining at the house bank. See Battiston et al. (2007) for an extreme case of such a concentration process.

is insolvent if its equity ratio $ER_{k,t}$ falls short of the minimum requirement ratio $\underline{ER}^{\min}$ which is in line with the Basel III threshold.[17] It may be argued that the selected value, although close to the average of US banks, is not legally binding in all jurisdictions. However, in such a situation a bank would probably not pass a stress test. Hence, there would be no permission to continue banking operations since the bank is no longer reliable against financial turmoils.

3.3.7 Credit Market Frictions and Welfare Implications

Bank insolvencies correspond to credit market frictions which may compromise macroeconomic outcomes. In the process of the partner selection, financial costs may arise from the fact that not all potential credit suppliers in the subset $\tilde{M}_t$ are still solvent. In this case, there are additional costs to search for a suitable creditor. The available loan amount for business investments is reduced by these costs. The height of the costs is determined as follows: Before the firm signs the contract with the "best" bank, it monitors the bank's previous periods financial position as a proxy for the current solvency. Correspondingly, if a bank was already bankrupt in the previous period, the firm moves to the "second-best" bank and signs the loan agreement. If this bank, however, also faces solvency problems, the firm moves one step ahead. This process continues until the firm meets a solvent bank in the subset $\tilde{M}_t$ with which it signs a contract. Hence, the search costs strictly depend on attempts to find the next lender

$$S_{i,t} = \#\{k \text{ insolvent} | k \in \tilde{M}_t\}_{i,t} \cdot \bar{\mu}^S, \tag{3.7}$$

where $\bar{\mu}^S$ is a constant cost scaling parameter and $\#\{k \text{ insolvent}|k \in \tilde{M}_t\}_{i,t} = \{j-1\}_{i,t}$ with $j \in \mathbf{j} \in \mathbb{N}^{1\times n}$ indexes the first solvent and active member of $\tilde{M}_t$.

Solvent firms, with the exception of those subject to credit frictions, invest the same amount in their production capacity and generate sales. Here, search costs reduce the firms' loan availability. As a consequence, realized investment may fall short of the planned level, i.e. $i_{i,t} - i^D_{i,t} < 0$. If a firm is exclusively matched to insolvent banks, i.e. all members in $\tilde{M}_t$ face solvency problems, it can only invest up to its internal financing capacity. Formally, we

[17] Note that this does not correspond to the risk-adjusted, but to the absolute capital requirements.

get

$$\Delta l_{i,t} = \begin{cases} i^D_{i,t} - \tilde{\Pi}_{i,t-1} & \text{if} \quad \#\{k \text{ insolvent} | k \in M_t\}_{i,t} = 0 \\ (1 - S_{i,t})(i^D_{i,t} - \tilde{\Pi}_{i,t-1}) & \text{if} \quad 0 < \#\{k \text{ insolvent} | k \in M_t\}_{i,t} < n \\ 0 & \text{else.} \end{cases} \tag{3.8}$$

The firm's individual realized investment can then be derived by

$$i_{i,t} = \Delta l_{i,t} + \tilde{\Pi}_{i,t-1} \tag{3.9}$$

where the joint effect of the randomized credit network and the credit market frictions may cause a mismatch of planned and realized investment magnitudes. This deepens the heterogeneity in the firm sector.

In the model, aggregate demand consists of investment and consumption, i.e. $y_t = i_t + c_t$, where consumption is essentially a function of disposable household income and wealth:

$$c_t = \alpha_1 y^d_{t-1} + \alpha_2 m_{t-1} + \alpha_3 \left[(p^f_t e^f_t) + spvA_{t-1} \right] + \alpha_4 (p^b_t e^b_t). \tag{3.10}$$

Disposable income y^d consists of wages, ωy_t and various forms of capital income.[18] Household wealth consists of deposits (m_t), tranche securities ($spvA_t$), firm and bank equities (e^f_t and e^b_t) where the associated price functions are described in the equations (B.2.6) and (B.2.12) in the appendix.[19] So far, we have developed a model in sections 3.3.4 - 3.3.7, in which a higher number of bank insolvencies, arising from corporate credit default at the micro level, have a higher probability to result in lower aggregate demand at the macro level due to credit market frictions. To measure welfare in different simulation runs, we will simply refer to cumulative output, i.e. the welfare measure used is $U = \sum_{t=0}^{T} y_t$.

Before turning to the simulation results, we will elaborate the financial sector of the model in two ways. First, we add a bank rescue mechanism to recapitalize insolvent banks after a certain time and to a certain extent. Second, we add a special purpose vehicle (SPV) that

[18] These are interest and dividend payments specified in equation (B.2.31), (B.2.32) and (B.2.34) in the appendix. Also note that it is sufficient for a quasi steady state solution, if consumption is not a function of contemporaneous, but previous period's income multiplied by the capital accumulation rate.

[19] Their functional form (GARCH process and pricing by sector average) is generally supported by the literature. The parametrization is selected so that price dynamics only show small volatility (table B.1.2). In this context, a more comprehensive analysis, albeit interesting, goes beyond the scope of this paper.

allows banks to securitize part of their loan portfolio. As a consequence, we have to specify how the banks deal with potential losses of the SPV.

3.3.8 Bank Rescue Mechanism

In contrast to the firm sector, the model comprises a market re-entry mechanism for banks. This helps to stabilize the economy after bank crashes and allows to examine its efficiency on the basis of its parametrization. Since we do not explicitly model the government sector, the rescue mechanism is supposed to be organized within the banking sector. It works as follows:

All banks are sorted in a descending order according to their equity ratios $ER_{k,t}$. This ordering makes it possible to identify the insolvent banks and to store the duration of their insolvency. Banks are assumed to be at least ζ periods out of business. This duration is supposed to reflect the minimal sluggishness of insolvency proceedings. In this way, banks are identified that are eligible for resolution. Recapitalization of such bad banks is assumed to be carried out entity by entity which means that the best capitalized bank allocates a part of its equity to the worst one. The second best bank does the same with the second worst and so on. This procedure can be regarded as a simplified implementation of a resolution fund to which banks contribute depending on their own profitability proxied by their equity ratio. After all, banks have an interest in ensuring that the financial system does not collapse completely. The capacity of a resolution fund is nevertheless limited. Hence, market re-entries are restricted to a maximum number η of banks that can be re-capitalized in each period. If the number of eligible banks is greater than η, only η of them are chosen randomly. The remaining banks have to wait for recapitalization in the subsequent periods. The recapitalization costs amount to a fixed fraction κ of the equity capital of the best capitalized banks. If this "financial injection" suffices, the bank carries on operating on the market. If it is not sufficient, it waits for further help in the subsequent period.

The most salient feature of this bank-specific rescue mechanism is its parsimonious parametrization, while avoiding arbitrary inflows into the economy. In related and not necessarily consistent approaches, bankrupt companies are simply replaced by new market entrants with fixed asset structures (cf. Delli Gatti et al., 2010).

3.3.9 Securitization and Shadow Bank Failure

This section discusses the implications of balance sheet changes related to securitization activities. Our model basically follows the principle of effective demand. This implies that the mere outsourcing of corporate loans from the bank balance sheet to the special purpose vehicle and thus the increase in lending capacity does not have a welfare-enhancing effect if there is no simultaneous increase in investment and credit demand. Nevertheless, there will be a small impulse on household capital income and thus consumption, which results from the fact that the interest rate on tranche securities is higher than the deposit rate, i.e. $r_M < r_S < r_L$. However, it may be objected that other studies, e.g. Altunbas et al. (2009) and Botta et al. (2018), find stronger positive effects on production, at least in the short term. Hence, to validate our model, we examine also a scenario in which securitization starts from an environment where strong credit frictions are present (section 3.5.7). As it turns out, there are indeed welfare enhancing effects under such conditions.

If an increasing number of defaults is observed in the securitized corporate loan portfolio, the owner banks decide to liquidate the SPV, as the investors holding the A-tranche securities as a yield object are not prepared to waive their claims from the outset. In the event of SPV liquidation, two possible balance sheet changes can be studied: *First*, the banks bear the impairment costs of the loan portfolio. In the model, this is reflected by the fact that the banks take back the corporate loans at nominal value against deposits, i.e. at the expense of the equity ratio. *Second*, capital market investor households bear the costs. In this case, the banks merely have a kind of trustee function for the loan portfolio. In the model, this is reflected by the fact that, although corporate loans are reintroduced into the bank balance sheets at their nominal value, these are exchanged for newly issued bank shares, i.e. not at the expense of the bank equity ratio.

3.4 Model Calibration

Complex models, including different levels of economic activity (micro and macro), may suffer from over-parametrization. In the following, however, we carefully discuss and motivate the parameter selection. Section 3.6 presents the results of a Monte Carlo simulation for the benchmark calibration depicted in table B.2 while appendix B.5 provides a sensitivity analysis for selected parameters .[20]

Table B.1.2 in the appendix contains the complete list of parameters. Apart from the initialization, the parameters can be divided into two categories: *First*, those set directly to the data or values from the literature. *Second*, those calibrated to achieve certain target ratios or relations. Besides, model properties, such as the stock-flow consistency, may be affected with changes in certain parameter values due to the missing equation already mentioned in section 3.3.2. As it turns out, this effect is especially strong for the marginal propensity to consume out of disposable income α_1. To guarantee stock-flow consistency, we carefully chose the numerical parameter calibration that is discussed in the following.

3.4.1 Initialization

Fischer and Riedler (2014) introduce an agent-based model of financial markets in which heterogeneous agents trade a risky asset, while prices evolve endogenously under chartists' and fundamentalists' price expectations. We build on their results about an emerging log-normal distribution of bank size. This motivates us to select the initial value distribution of banks' assets correspondingly. We then allocate an identical amount of equity for all banks to guarantee the solvency right from the start, i.e. $\theta_B > \underline{ER}^{\min}$. This implies a log-normal distribution for the equity ratios. Other initial values, in particular firm leverage ratios below $\theta_C < \overline{LR}^{\max}$, are uniformly distributed as common in the literature. During the initialization process we make sure that the identity equations in the model hold.

3.4.2 Parametrization according to the literature

With regard to the propensity to consume out of deposits α_2, we refer to Carroll et al. (2011). The wage share and the share of distributed profits in total profits are based on the US average since the 1980s (cf. Belabed et al., 2017). For the minimum capital requirements of banks we refer to Hoenig (2018). The selected threshold of 5% for $\underline{ER}^{\min}$ is between the rather low requirements of Basel III and the average capitalization of large US banks. The evolving distribution of capital-to-asset ratios is in this way in the range of US commercial banks, as described by Karmakar and Mok (2015) (see appendix B.4). For the maximum firm leverage ratio we refer to Hovakimian et al. (2001) and Graham et al. (2015b). As a rough estimate, we

[20]The source code of our model allows to extend these analyses. Results are available upon request.

are guided by the authors' data summaries which propose that observable capital ratios (and as a consequence creditworthy requirements in the model) of firms $1-\overline{LR}^{\max}$ are significantly higher (at least twice as high) than those of banks.

3.4.3 Targeted Parameters

For the calibration of the other consumption propensities we apply the following ordering $\alpha_4 < \alpha_3 < \alpha_2$ according to the liquidity of the respective assets. Hence, bank shares are supposed to be least liquid, as they are subject to specific risks, unlike the non-financial shares.[21] For the tranche securities we also assume a higher propensity to consume, since the (supposed) diversification benefits are highly appreciated by the investors. We calibrate the marginal propensities to invest in the capital stock γ_1 and γ_2 so that the (private sector) investment ratio of the economy is within a realistic range between 15% and 20%.

We use two scaling parameters to ensure that the returns on the various assets follow the order $r_M < r_S < r_L$ which implies that the deposit rate is lowest and the average corporate loan rate is highest. The interest rate on the tranche securities lies in between these two interest rates. This relation is motivated by the household's incentive to invest in the tranche securities compared to the deposits, while the SPV achieves an average profit equal to the spread between the lending rate and the securitization interest.

3.5 Results

3.5.1 Model Dynamics

Figure 3.2 presents model dynamics from a simulated path with a securitization intensity of 1%, and re-scaled US data for the period 1969 to 2008. Overall, the model shows a satisfactory replication of the US data. Nevertheless, it should be emphasized that the model cannot be expected to replicate the data perfectly. One reason is that the model treats the economy as a closed system without foreign trade and payments. With this caveat in mind, the following observations can be made.

Due to the concentration process in the firm sector of the model, the remaining solvent firms have such a market power and internal financing capacities after about 20 years that

[21] The non-financial sector consists of different industries. Thus, there is always a higher probability that part of the property rights can be sold on good terms for consumption purposes.

their investments can largely be financed from these resources. Correspondingly, the aggregated credit volume and accumulated deposits evolve below the empirical benchmark in the intermediate periods (panels 3.2a and 3.2d in figure 3.2). The simulated path underestimates the proportion of insolvent banks[22], which should however be seen in the context of a very low securitization intensity so that the securitized loan portfolio is barely affected by corporate insolvencies (panels 3.2b and 3.2c). Panel 3.2e moreover displays that over the simulation periods, the capital stock is somewhat underestimated by the model. Towards the end of the simulation period, however, weak real economic investment activities in the 2000s have led the observable capital stock to move back towards the simulated path. By definition, a similar coincidence is obtained for net investments as the first difference of the capital stock (panel 3.2f). Since the aggregated demand in the model consists only of the domestic private sector, the trend growth of consumption and GDP is also somewhat weaker than in reality (panels 3.2g - 3.2i).

Note that the underestimated trend growth in some time series does not affect the validity of our analysis. The presented benchmark paths are sufficiently stable so that the effects of systemic risks can be investigated. Moreover, section B.5 in the appendix successfully validates the model on the basis of its (cyclical) conformity with empirical data, both on the micro and on the macro level.[23] On this basis, we can conduct various scenario analyzes as a next step.

3.5.2 A scenario in which the banks bear the risk: What happened in the financial crisis?

This section examines a path-dependent scenario in which most of the risks associated with corporate loan securitization remain in the bank books (cf. Acharya et al., 2013). We distinguish between three securitization intensities ($\nu_{SPV} = 1\%$, $\nu_{SPV} = 10\%$ and $\nu_{SPV} = 20\%$).

With the securitization of loans, i.e. the transfer of loans from the bank balance sheets to the SPV, which starts after 10 periods, the amount of deposits in the economy decreases. The investor households exchange their deposits for the A-tranche securities issued by the SPV

[22]Due to availability concerns with respect to bank-specific data, we use the commercial and industrial US delinquency rates from the Federal Reserve.

[23]In detail, we compare the model and the observed data with respect to the distribution of banks' capital ratios. On the macro level we investigate auto- and cross-correlations of detrended GDP components.

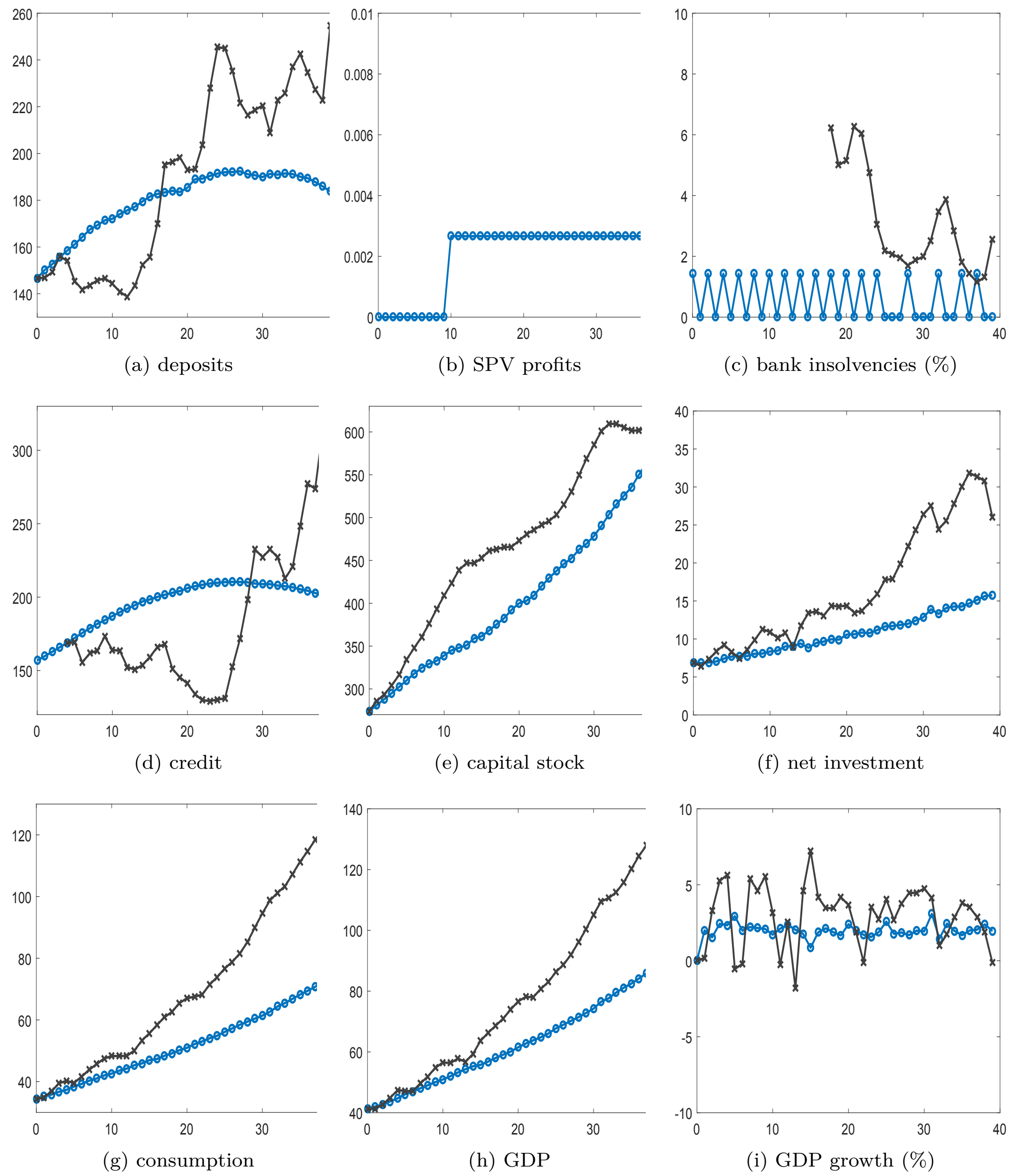


Figure 3.2: A benchmark scenario. The blue line (o) shows the model dynamics at a securitization intensity of 1%, the black (x) re-scaled US data for the period 1969 to 2008

(figure 3.3a). The higher the securitized volume, the higher the profits the SPV generates from the interest margin (panel 3.3b). As long as securitization does not lead to an increase in bank insolvencies (panel 3.3c), there will hardly be any real economic consequences. The investment, consumption and aggregate income paths are stable until then (panels 3.3d - 3.3f).

Due to the presumed firm concentration process, defaults in the securitized portfolio occur at some point, the higher the securitization volume is (panel 3.3b). Under these circumstances, the SPV suffers profit declines and even losses, as interest income declines for identical expenses. Due to the losses, the owner banks decide to liquidate the SPV. Since this scenario assumes the banks to be contractually obliged to bear the risk, they compensate the investors in the form of bank deposits. This means that the re-transfer of corporate loans weakens the equity ratios of the banks involved.

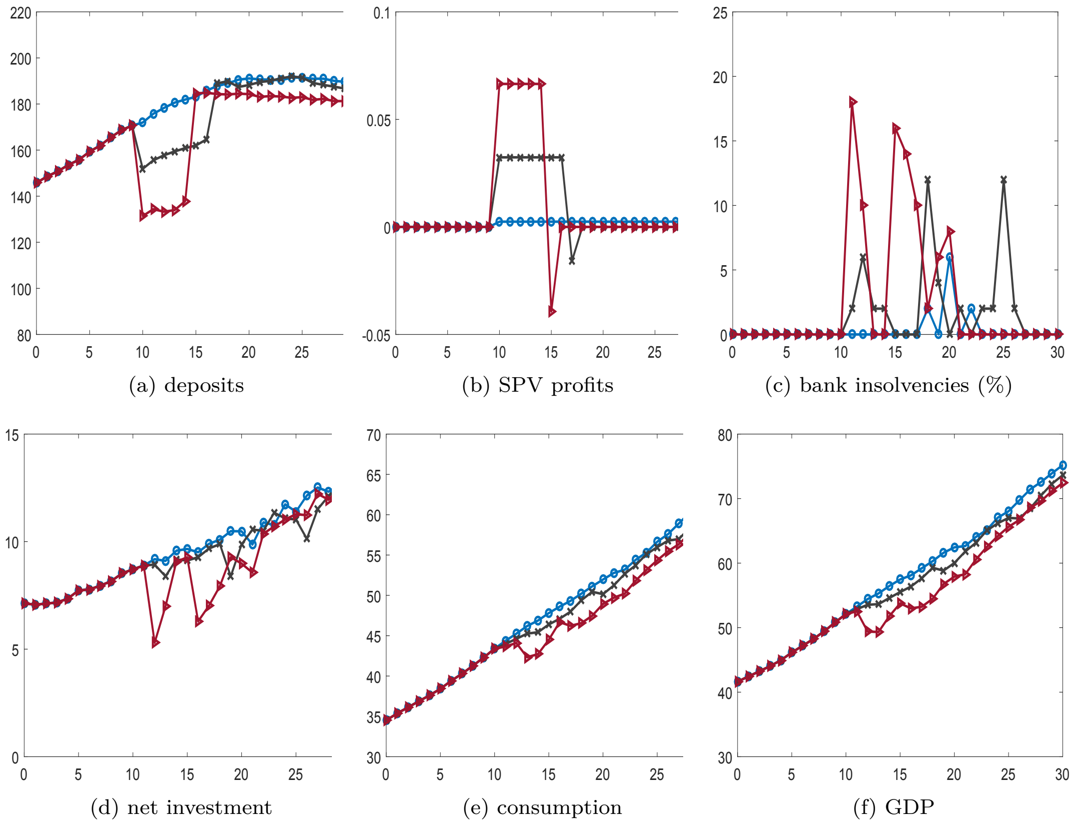


Figure 3.3: A scenario where banks bear the risk. Model dynamics at a securitization intensity of ν_{SPV} =1% (blue o-line), ν_{SPV} = 10% (black x-line) and ν_{SPV} = 20% (red triangle-line)

Depending on the securitized volume, this can lead to an increase in bank insolvencies (panel 3.3c). As a consequence, real economic investment activity is affected by resulting credit frictions as described in section 3.3. Production suffers and, in the wake of income losses, consumption does (panels 3.3d - 3.3f). Figure 3.3 illustrates how strongly the systemic risks along this transmission channel take effect, given a securitization intensity of 20%. However, even at an intensity of 10%, welfare losses seem significant compared with the benchmark intensity of 1%. The black line steadily moves below the blue line (panel 3.3f).

3.5.3 A scenario in which investors bear the risk: Does a standardized market really reduce systemic risks?

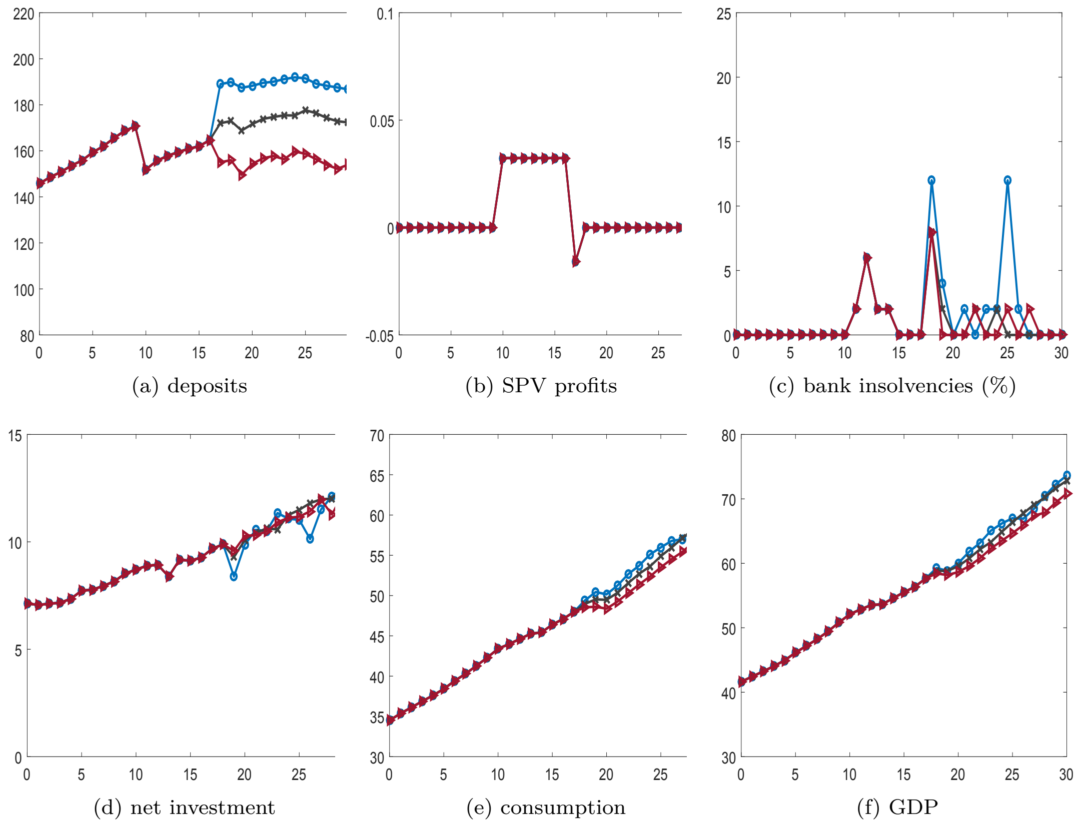


Figure 3.4: A scenario where the capital market investors bear the risk. The securitization intensity is always 10%. Model dynamics at bank risk participation of $\delta = 70\%$ (blue o-line), $\delta = 85\%$ (black x-line) and $\delta = 100\%$ (red triangle-line)

This section explores a scenario in which a more efficient risk transfer from the banks to the capital market investors takes place. Some observers argue that this can be achieved by standardizing the products on the securitization market (cf. Commission, 2015; Véron and Wolff, 2016). Our study focuses on the macroeconomic question of whether in this way harmful real economic effects of an increased securitization intensity can be avoided in the medium to long term. Based on the previous findings, we now fix the securitization intensity at 10% for all upcoming simulation paths (seen in figure 3.4b).

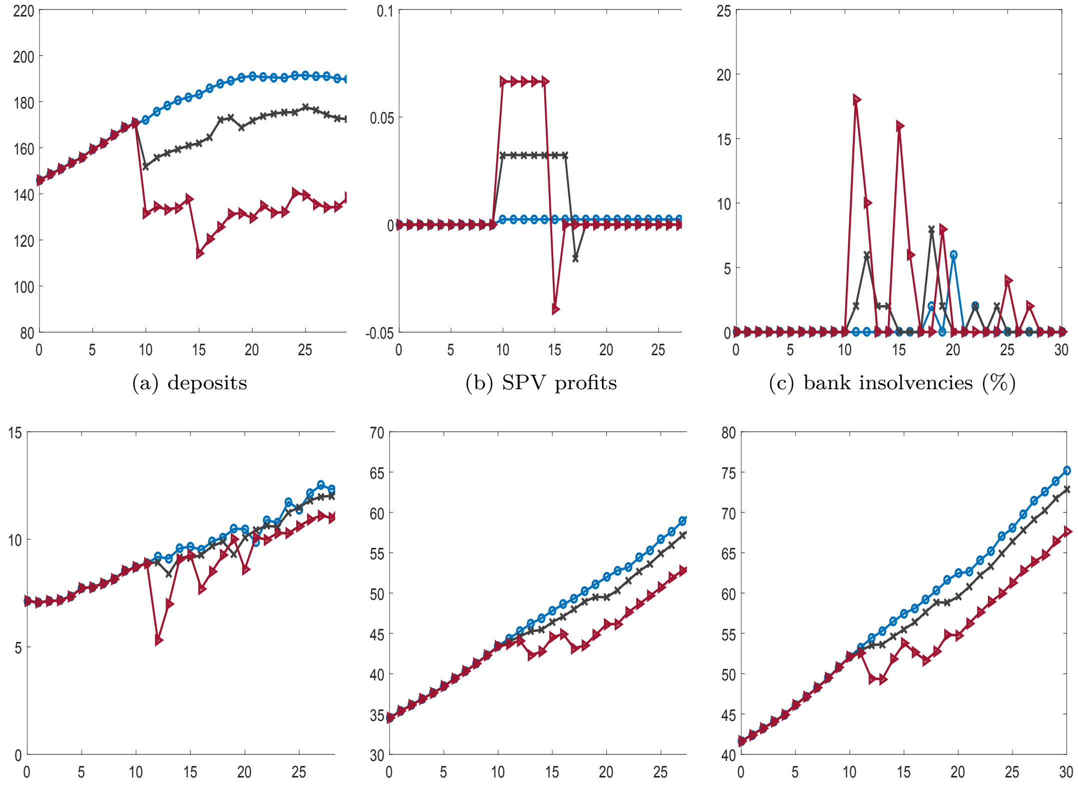
In contrast to the previous scenario in which the equity tranche obliged the banks to bear 100% of the losses, we now consider different degrees to which investors participate in potential losses. In other words, this scenario assumes that the equity tranche securities are partially sold on capital markets. We distinguish between a B-tranche share remaining in the bank book of 70% (figure 3.4 blue o-line), 85% (black x-line) and 100% (red triangle-line).[24] The last value characterizes an already known scenario (black line in figure 3.3, red line in figure 3.4), which now serves as a benchmark.

The overall result may be surprising because investor risk participation does not improve welfare at the macro level (figure 3.4f). The opposite is the case, if one compares the 70% with the 100% risk absorption of banks where the blue line of aggregate demand moves steadily below the red one. How does this result come about? Two counterbalancing effects can be observed. On the one hand, as expected, the increased investor risk participation leads to fewer bank insolvencies after liquidation of the SPV (panel 3.4c). As a result, there are less frictions on the credit supply side in financing real economic investments (panel 3.4d). On the other hand, the increased investor risk participation dampens consumption (panel 3.3e), which is because the re-transfer of corporate loans to bank balance sheets is no longer exclusively at the expense of the equity ratios. Instead, investors now partly receive bank shares in return. These are less liquid assets, which imply lower consumption. Overall, the systemic risks of an increased securitization activity continue to materialize.

3.5.4 Interaction effects of securitization and investors' loss absorption

In a next step, both previous scenarios can now be combined by simultaneously increasing securitization intensity and investor risk absorption. This scenario takes possible interaction effects into account. Figure 3.5 shows the results. In quantitative terms, there is indeed an interaction effect. If we compare the sum of the welfare reductions, i.e. the distances between the blue and red lines in figures 3.3 and 3.4, with those of the combined scenario, the latter is significantly larger.

[24] A 100% sale of the equity tranche does not seem possible, because the rating of the tranche securities should as a consequence deteriorate noticeably.



(a) deposits (b) SPV profits (c) bank insolvencies (%)

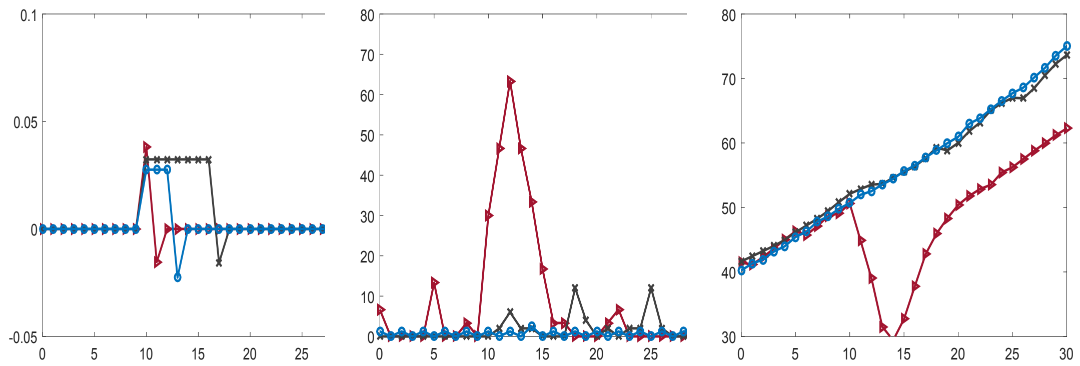
(d) net investment (e) consumption (f) GDP

Figure 3.5: A scenario where the risk is shared among the investors and the banks. Model dynamics for the securitization intensity and bank risk participation $\nu_{SPV} = 1\%$, $\delta = 100\%$ (blue o-line); $\nu_{SPV} = 10\%$, $\delta = 85\%$ (black x-line) and $\nu_{SPV} = 20\%$, $\delta = 70\%$ (red triangle-line)

3.5.5 Effects of the banking sector structure

Usually, the ratio of the number of different types of agents, in our case firms and banks, matters in agent-based models. To investigate this, we keep the securitization intensity, the bank loss absorption and the number of firms constant, while the number of banks in the model changes. The more banks there are in the model, the smaller the banks tend to be, although this does not necessarily apply in each and every pairwise comparison between the paths.

Figure 3.6 shows the results of the scenario. There are nonlinearities with respect to the lifetime of the SPV which do not follow a straightforward explanation (panel 3.6a). In fact, it is not, as might be expected, the least concentrated banking sector that implies the



(a) SPV profits (b) bank insolvencies (%) (c) GDP

Figure 3.6: A scenario for different banking sector concentrations at $\nu_{SPV} = 10\%$ and $\delta = 100\%$: Total number of banks $N^b = 80$ (blue o-line); $N^b = 50$ (black x-line) and $N^b = 30$ (red triangle-line)

longest life span of the SPV, but a medium concentrated one.[25] In the case of the highest concentration of the banking sector, however, it takes the least time to wind up the SPV. The bank insolvencies, (panel 3.6b) arising as a result of the securitization activities, allow to draw the following conclusion: The more concentrated the banking sector, the higher the number of insolvencies. This is related to the fact that after the liquidation of the SPV a larger loan portfolio is re-transferred per bank. The effects on the equity ratio are correspondingly more severe. While the consequences for the real economy hardly differ between a low and a medium-concentration banking sector scenario, the welfare-reduction is massive when the banking sector is highly concentrated (panel 3.6c).

3.5.6 Effects of the bank rescue mechanism

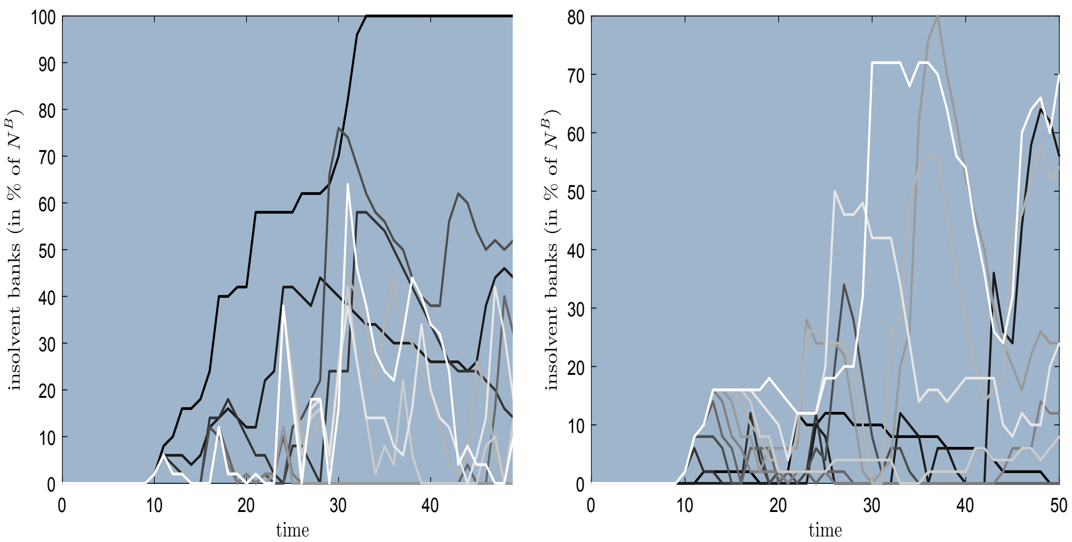
To illustrate the efficiency of the bank resolution, we study the sensitivity of bank insolvencies (and thus indirectly of credit frictions) to two parameters of the rescue mechanism. These are firstly the maximum number of banks that can be recapitalized per period η and secondly the duration until recapitalization ζ (duration of insolvency proceedings). For the sensitivity analysis, both parameters are incremented by 1 in the range [0, 10]. Figure 3.7 shows the results for each parametrization, whereby the following applies: The higher the parameter, the brighter the line. Results are clear-cut and as expected. The higher the number of banks admitted to recapitalization, the less bank failures are observed over the entire simulation

[25] Note that bank insolvencies can occur before the SPV is liquidated. This can induce an increased number of corporate insolvencies which then increases the probability of loan defaults in the securitized portfolio.

period (left panel). The longer the duration of the insolvency proceedings, the more bank failures are observed (right panel). In other words, if adequately equipped, a levy organized within the banking sector can be especially effective for the mitigation of the consequences of excessive securitization.

3.5.7 Under which conditions can securitization be beneficial for an economy?

Some studies, e.g. Altunbas et al. (2009) and Botta et al. (2018) mention a stimulating effect of securitization on real economic production at least in the short term. In this section we want to work out whether such an effect is also possible in our model and if it is, under which conditions. Since the model is primarily demand-driven, we have to create starting



(a) Bank insolvencies subject to changes in η (b) Bank insolvencies subject to changes in ζ

Figure 3.7: Robustness of the banking sector depending on the bank rescue mechanism

surroundings where significant credit supply-side frictions already exist before securitization. Then there is the possibility that the SPV origination will dissolve these frictions as the equity ratios of the banks increase in the wake of the corporate loan outsourcing. Figure 3.8 shows such results. Panel 3.8a shows that the life of the SPV is only slightly shorter at the higher securitization intensity of 10% than at the lower one of 1%. In this simulation, the joint effect of the higher securitization volume and the bank rescue mechanism succeeds in stabilizing the banks' balance sheets efficiently (panel 3.8b). Accordingly, aggregate demand is developed more vibrantly in the simulation with the higher, than with a lower securitization intensity

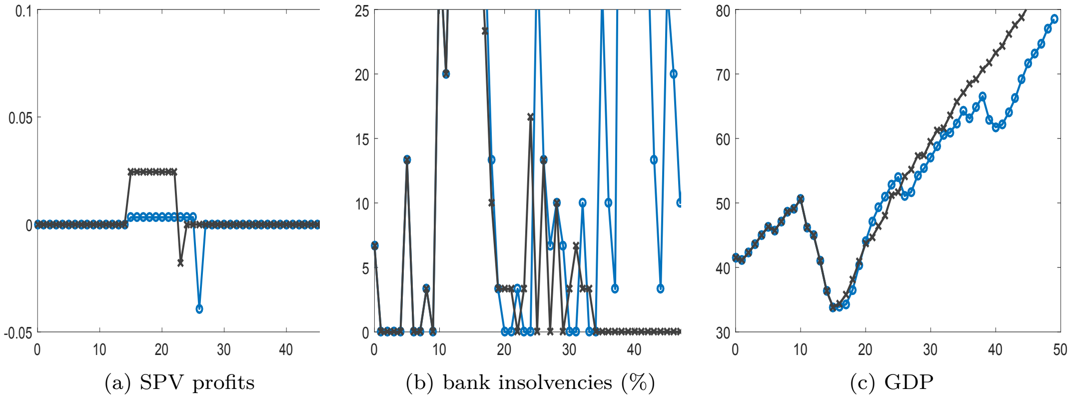


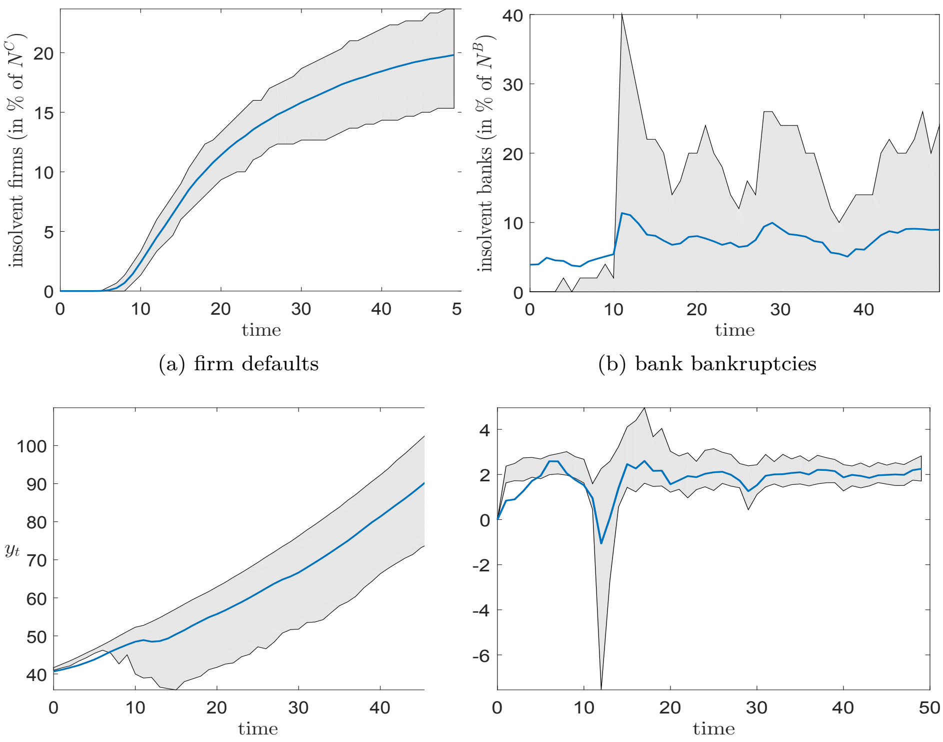
Figure 3.8: A scenario where securitization yields welfare gains with parametrization $\nu_{SPV} = 1\%$ (blue o-line) and $\theta_{SPV} = 10\%$ (black x-line). For the sake of exposition, we further re-calibrated the experiment to pronounce the effects. We chose $\rho_{LR} = 0.1$ (instead of $\rho_{LR} = 0.06$) and $\overline{LR} = 0.65$ (instead of 0.5). We further postponed the securitization timing (instead of the 10th period).

(panel 3.8c). On the one hand, this analysis confirms the findings of the studies quoted above. On the other hand, it is important to note that this scenario does not hold without loss of generality: *First*, we do not find any welfare-enhancing effect when the economy is in a demand-driven regime. *Second*, apart from the short to medium-term welfare gains, the presented scenario does not preclude that the systemic risks of increased securitization activity may materialize in the long run.

3.6 Robustness

The results so far are subject to path dependency. In this section, we therefore conduct a Monte Carlo analysis with 1000 replications to ensure that the findings hold under stochastic shocks. Figure 3.9 shows the results for a securitization intensity of 10%. Indeed, the transmission mechanism as described in section 3.5 is not limited to some outlier path performances. Rather, the pattern of an increased securitization volume implies a higher probability of bank insolvencies and thus welfare losses is maintained across the paths. Further, robustness checks are conducted in section B.5 of the appendix using sensitivity analysis for the parametrization of the partner selection mechanism, the investment and the consumption function.[26]

[26]Compare section 3.4 on model calibration.



(a) firm defaults (b) bank bankruptcies

(c) GDP (d) GDP growth rate

Figure 3.9: The plot displays results for 1000 paths with a securitization intensity of 10%. The blue line shows the mean replications.

3.7 Conclusion

This paper attempts to carefully quantify the securitization intensity of corporate loan obligations that may unfold systemic risks that materialize in the medium to long term. Some observers may criticize the simplicity of the model, especially regarding the assumption of a single SPV that is connected to multiple banks. However, this can be countered with a reference to the new securitization framework in the EU (cf. Commission, 2015). Like in the US, it explicitly allows credit and derivative links between the SPV and multiple financial intermediaries. Furthermore, it may be criticized that the securitization intensity is not a policy variable and thus cannot be directly controlled. This is correct in itself. However, macro-prudential instruments can be tailored also to influence shadow banking transactions, and where these instruments have not yet been developed or activated, this should be done.

Overall, our results indicate that the only quantification of the optimal securitization intensity known to us from the literature, - estimated by Mazzocchetti et al. (2018) at 15% -

is too high. Instead, we find significant welfare losses as soon as the securitization intensity approaches 10% of the economy's total loan volume at some period. Welfare losses are realized irrespectively of whether the collapse of the SPV leads to distortions in the regulated banking sector or whether increasing liquidity constraints dampen household consumption. Moreover, the optimal level of the securitization intensity will depend on whether the economy is in a credit supply-constrained regime. If not, the optimal level will be closer to 1% than to 10%. Our findings are therefore also intended as a warning: the revitalization of corporate credit securitization in recent years does not promise to be healthy for future macro and financial stability.

Chapter 4

Low Interest Rates, Bank's Search-for-Yield Behavior and Financial Portfolio Management

4.1 Introduction

The excessive risk-taking of financial intermediaries, and especially of the banking sector, is nowadays acknowledged to be one of the most important threats to macroeconomic stability. In this context, various studies such as Rajan (2006), Dell'Ariccia and Marquez (2006), Maddaloni and Peydró (2011), Delis and Kouretas (2011) and recently Adrian et al. (2019), among others, have established a link between the relatively low interest rates prevailing in the most industrialized countries over the last two decades,especially in the US and in Europe, and the excessive risk-taking of the banking sector (see also Buch et al. (2014) for survey-based evidence on bank risk-taking). Indeed, as risk-free assets like sovereign bonds ceased to be profitable investments, banks and other financial intermediaries turned to a *search-for-yield* behavior linked with an excessive risk-taking which, in conjunction with weak banking supervision, led to a build-up of systemic financial risk and lastly to the Global Financial Crisis.

Besides from Dell'Ariccia and Marquez (2006), two notable studies which focus in detail on the mechanisms behind the banks' *search-for-yield* behavior are Dell'Ariccia et al. (2014) and Martinez-Miera and Repullo (2017). Dell'Ariccia et al. (2014) set up a partial equilibrium model where risk-neutral banks raise deposits and invest them in a risky loan portfolio which they monitor at a given cost which is quadratic in the monitoring effort. They show that this monitoring effect can be either negatively or positively related with the risk-free policy rate depending on the extent of the bank's capitalization. Similarly, in Martinez-Miera and Repullo (2017) risk-neutral (monitoring) banks maximize profits by using an optimal monitoring intensity which is not observable to investors. This creates a moral hazard problem which is the key friction of their approach: A reduction in the policy rate, induced e.g. by an increase in the supply of savings, lowers the loan rate spreads, but also increases the relative size of the non-monitoring banking system. This in turn decreases the monitoring intensity of traditional (monitoring) banks and thus favors their default probability.

In contrast to these studies, the present paper contributes to the existing literature on search-for-yield behavior by focusing on the risk aversion dimension of the decision making of financial intermediaries. More specifically, we develop a simple model of financial intermediation where a bank grants loans to a firm in a traditional manner and, additionally, manages an asset portfolio consisting of risky and risk-free assets. In contrast to most of the existing literature where lenders are often considered to be risk-neutral or to be able to diversify out risks perfectly, we assume following Greenwald and Stiglitz (1993a) that both the firm that requests loans to finance its production costs and the bank are risk averse: the firm's managers fear the possibility of default, and the bank's managers, featuring a mean variance utility, are averse to re-allocate the bank's asset portfolio towards a higher exposure to asset price risk.

We show that under certain conditions, the bank managers' risk aversion may lead to credit rationing, represented by an inverse "C" shaped loan offer curve similar to the one in Jaffee and Stiglitz (1990), though emerging from a different microfoundation. Accordingly, the loan offer curve is positively sloped over the range where the probability of default rises with the size of the credit, as higher lending rates compensate the bank for the higher probability of default on larger loans. At some point, the loan offer curve becomes backward-bending due to the convex penalties the bank managers face from expanding the loan supply. As a result, the borrower becomes credit rationed since the bank is unwilling to expand the loan size independently from the level of the offered interest rate.

We then use our model to investigate how the bank chooses the riskiness of its asset portfolio for different levels of the bank's funding rate (the rate of return on risk-free asset), assumed to be equal to the policy rate. We obtain the following main results: *First*, loose monetary policy, i.e. a lower policy rate leads to a reduction of the loan interest rate charged by the bank, and thus to "cheaper" credit similarly to Dell'Ariccia et al. (2014), with the exception that we do not have a risk-shifting effect since the bank's funding costs are supposed to be exogenous. *Second*, a reduction in the policy rate generates an incentive for a *search-for-yield* behavior by the bank, as it induces the bank to re-allocate its asset portfolio towards more risky assets. This is due to the increasing opportunity costs and the positive interest rate pass-through effect that amplifies the re-allocation of asset in the bank's financial portfolio in equilibrium. Although the bank is assumed to be risk averse, it gradually substitutes out risk-free with risky assets when the reference (risk-free) interest rate declines, as it is standard in portfolio choice models. And *third*, we show that the bank's financial position, which we define here as the Tier 1 capital ratio according to the guidelines of the Basel III accord (Basel Committe on Banking Supervision, 2017a, p. 140), is weakened by decreasing policy rates, as the bank shifts from a well-capitalized to a poor-capitalized position as the policy rate declines. Consequently, since the bank is willing to take more risk in low interest rate regimes in order to maintain stable profits, the bank's financial position reaches the minimum capital requirements as the policy rate approaches zero.

The remainder of this paper is organized as follows: Section 4.2 introduces the model and examines its equilibrium. Section 4.3 studies through comparative statics the impact of monetary policy on the model's equilibrium, as well as the asset re-allocation effects resulting from a variation in the risk-free interest rate. In that section we also examine the bank's risk-taking behavior by relating it to a measure of the bank's capital ratio. Section 4.4 draws some concluding remarks from this study.

4.2 The Model

4.2.1 The Firm

The firm's behavior is as in Greenwald and Stiglitz (1990, 1993a). Accordingly, we assume a profit maximizing firm which sells its goods at a price P determined according to

$$P = u\bar{P}, \tag{4.1}$$

where $\bar{P}$ denotes the average market price and u is the firm specific relative price, which is a randomly distributed variable with $u \sim NID(\mu_u, \sigma_u^2)$.[1] Without a loss of generality, we normalize the average market price $\bar{P}$ and expected relative price $E(u)$ to $\bar{P} = E(u) = \mu_u = 1$. We denote the probability density and cumulative distribution functions (CDF) of u as $f(\cdot)$ and $F(\cdot)$, respectively.[2]

The firm's production costs are financed by the firm's equity or net worth and by loans obtained from the commercial bank. Accordingly, the loan incurred by the firm is equal to

$$B = g(Y) - W, \tag{4.2}$$

where B represents the loan amount, $g(Y)$ the production cost function and $W = W^n/\bar{P}$ is the firm's real net worth, which under the normalization of $\bar{P} = 1$ coincides with the firm's

[1] As a robustness exercise, we have also derived the model under the assumption that relative prices are distributed uniformly with $u \sim U(0, 2)$. This specification led to qualitatively similar results. We decided to report the model based on the normal distribution, since it is more realistic and does not exhibit heavy tails.

[2] The original strand of the literature on credit rationing (see e.g. the seminal work by Greenwald and Stiglitz, 1993a) treated the relative price u in a general fashion, without specifying its distribution. Our model is related to work by Delli Gatti et al. (2005), who implemented the microfoundations of Greenwald and Stiglitz (1993a) into an ABM framework by considering a uniformly distributed random variable.

nominal net worth W^n. We further assume that the firm's production function is

$$Y = \phi K^{\frac{1}{2}} \quad \text{with} \quad \phi > 0,$$

where the term K represents a composite of the input factors required by the production process. Hence, the firm's total production costs are

$$g(Y) = p_k K = \psi Y^2 \tag{4.3}$$

for $\psi \equiv p_k/\phi^2$, where p_k represents the total price of the composite of input factors. As the production costs are convex in Y (and the production function is concave in K), it holds

$$\frac{\partial g(Y)}{\partial Y} > 0, \quad \frac{\partial^2 g(Y)}{\partial Y \partial Y} > 0, \quad \frac{\partial Y}{\partial K} > 0 \quad \text{and} \quad \frac{\partial^2 Y}{\partial K \partial K} < 0.$$

As the firm is assumed to determine its production level before the relative price shock u is realized, it may be forced to default on its debt if the firm's debt obligations exceed its realized sales revenues, i.e. if $PY - R^b B < 0$, where R^b and B denote the loan rate and loan volume upon which the firm and commercial bank agreed, respectively. By (4.2), the firm remains thus solvent when the stochastic relative price u is above a threshold given by

$$u \geqslant R^b \left(\frac{g(Y) - W}{Y} \right) \equiv \bar{u}. \tag{4.4}$$

Based on this default threshold $\bar{u}$, we can now derive the firm's default probability as the CDF of the underlying distribution of the random variable u evaluated at the critical relative price $\bar{u}$:[3]

$$Pr\left[u < R^b \left(\frac{g(Y) - w}{Y} \right)\right] = \int_0^{\bar{u}} f(u)du = F(u). \tag{4.5}$$

Also following Greenwald and Stiglitz (1993a) we assume that the firm managers' are rewarded for maximizing the firm's expected (real) profit, but are also penalized for debt funding due to shareholders' aversion towards a possible bankruptcy. Hence, the managers'

[3]To ensure that the firm possesses a certain resilience against disadvantageous random price shocks, we further assume that the parameters of the firm's production function and the relative price's distribution are such that the firm hit by the average shock is solvent in the equilibrium, namely that $\mu_u > \widehat{\bar{u}}$.

problem is given by

$$\max_{Y} E\left\{PY - R^b(g(Y) - W) - \Upsilon(Y)F(u)\right\} \tag{4.6}$$

where $\chi(Y)$ is a bankruptcy cost function, weighted by the probability of default (4.5). These bankruptcy costs increase proportionally with the level of the firm's output, formally:

$$\Upsilon(Y) = \chi Y \tag{4.7}$$

where $\chi > 0$ is a scaling parameter.[4] As the firm is assumed to be a price-taker in the market for loans, the firm treats the contractual credit rate R^b as an "exogenous" variable set by the bank (cf. Gale and Hellwig, 1985). In other words, the bank defines its optimal loan supply, i.e. the pair of loan quantity and price (the loan rate), and the firm chooses the point along the bank's loan supply curve which maximizes its expected profits, as it will be discussed below.

The first-order condition of the firm's optimization problem in equation (4.6) is

$$\begin{aligned} 1 - \psi 2YR^b - \chi\left[F(u) + Yf(\bar{u})\frac{\partial \bar{u}}{\partial Y}\right] = 0 \\ 1 - \psi 2YR^b = \rho \end{aligned} \tag{4.8}$$

where $\rho = \chi\left[F(u) + Yf(\bar{u})\frac{\partial \bar{u}}{\partial Y}\right]$ are the marginal bankruptcy costs with $\frac{\partial \bar{u}}{\partial Y} = R^b\left(\psi - \frac{W}{Y^2}\right)$.

In absence of the marginal bankruptcy costs ρ, the first-order condition in equation (4.8) suggests that the average market price (which is normalized at unity) coincides with the marginal costs $\psi 2YR^b$ in the optimum which is a standard result. If instead the firm acts in a risk averse manner, the marginal bankruptcy costs ρ increase rapidly and in a nonlinear manner that implies that there is a permanent mismatch between price and marginal costs. Accordingly, the average market price exceeds the firm's marginal costs depending on its

[4]We use this specification of the bankruptcy costs for the sake of analytical tractability. Greenwald and Stiglitz (1993a) justify it by arguing that bankruptcy afflicts larger firms more, because they hire relatively more managers, who in turn fear that their position, power and income would be impaired in the event of bankruptcy. In comparison, Delli Gatti et al. (2005) assume a quadratic cost function. Other approaches are mostly related to the "costly state verification" (CSV) problem of asymmetric information which goes back to the works of Townsend (1979) and Bernanke et al. (1999). Accordingly, entrepreneurs are funded by banks that cannot fully observe the entrepreneur's effort. The bank is thus engaged in costly monitoring which in turn reduces credit risk due to a reduction of the lenders' default probability. Both approaches, the bankruptcy and the monitoring costs, deliver simililar results as long as the respective costs are sufficiently convex in Y.

production level Y, its financial wealth W, the contractually determined loan rate R^b and the degree of uncertainty regarding the firm's (post-contractual) relative price, i.e. the distribution functions $F(\,\cdot\,)$ and $f(\,\cdot\,)$. Together with the financing condition (4.2), this solution can be transformed to firm's optimal credit demand function

$$B^D = \arg\max_B E\left\{PY - R^b(\psi Y^2 - W) - \chi(Y)F(u) \mid Y = \sqrt{(1/\psi)(B+W)}\right\} = m(R^b, W). \tag{4.9}$$

From equation (4.9) we derive the following proposition:

Proposition 2 *Let the random sales price be uniformly distributed with any arbitrarily chosen support, i.e.* $u \sim U[\underline{x}, \overline{x}]$ *with* $0 \leqslant \underline{x} < \overline{x}$*, then the loan-demand curve is negatively sloped and convexly shaped in the lending rate* R^b*. It follows that* $m'_{R^b} = \partial m(R^b, W)/\partial R^b < 0$ *and* $m''_{R^b} = \partial^2 m(R^b, W)/\partial {R^b}^2 > 0$ *hold.*

The analytical proof of this Proposition can be found in appendix C.2. As an analytical discussion of the curvature of the loan-offer curve for a normally distributed random sales price is quite unwieldy we illustrate it in figure 4.1. The figure illustrates the optimal loan demand for the case of a normally distributed random variable u for different values of the bankruptcy costs parameter χ using the parameter values reported in table C.1 in appendix C.1.[5] As this figure clearly illustrate firm's optimal loan demand is sufficiently convex even in the case of a normal distributed random variable u and low values of χ.

The figure shows that firm's credit demand is declining in χ, *ceteris paribus*, while its curvature becomes more pronounced for increasing values. Note that the convexity of the loan demand function does not exclusively arise by virtue of the nonlinear bankruptcy costs. Instead, the credit demand curve possesses the convexity properties even in the case when the marginal bankruptcy costs in equation (4.8) are zero, i.e. $\rho = 0$. We will tackle this issue with the help of the following lemma:

Lemma 1 *In absence of marginal bankruptcy costs* ($\rho = 0$) *the credit demand curve is uniquely defined and convex in the loan rate* R^b*.*

The proof of this Lemma is provided in appendix C.3.

[5]The analytical proof for the convexity of this loan demand function in the loan rate R^b for the case of a normally distributed random variable u can be found in appendix C.3.

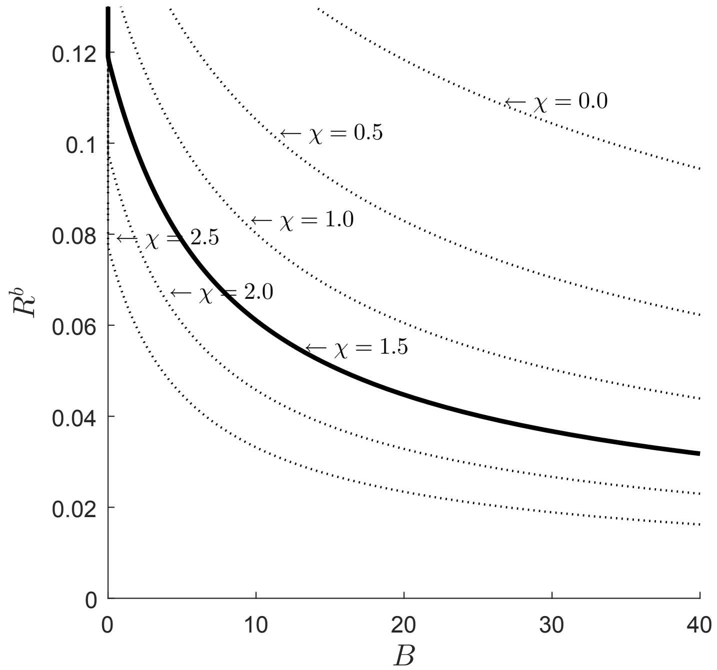


Figure 4.1: The firm's optimal loan demand for different values of the bankruptcy costs parameter $\chi \in [0, 2.5]$.

4.2.2 Bank Behavior and Asset Management

The bank is considered to act as a financial intermediary with no liquidity constraints. For the sake of simplicity, we assume that it raises its funds D from outside investors, subject to an infinitely elastic supply with a fixed return R^d. In other words, $R^d D$ represents the bank's deposit liabilities.[6]

The bank manages a financial portfolio consisting of three financial assets: (i) the aforementioned loan to the firm B, for which the bank can set the interest rate R^b; (ii) a risky asset A (such as an index of stocks) with a price p^a; and (iii) a risk-free asset Q with a fixed return R^q, which we will interpret as a sovereign bond. The bank's balance sheet is therefore

[6]Under the traditional money creation mechanism, the bank is price-taker on the market of commercial savings, i.e. small enough to be able to attract sufficient number of depositors on the one hand, but unable to influence the deposit rate R^d, on the other hand. Under the modern money creation mechanism, the bank automatically creates an equivalent deposit account for the debtor, hence its liabilities coincide with assets (abstracting from the interbank network). Regardless of the interpretation, our assumption implies that the bank's liabilities are independent of its risk-taking behavior, i.e. the deposit rate does not depend on the bank's own capital ratio or the regulatory minimum capital requirements (cf. Repullo, 2004).

$$B + Q + p^a A = D + W^b, \tag{4.10}$$

where W^b is the bank's equity capital. The bank's profits are then defined as the income stream net of funding costs given by

$$\Pi = R^b B + R^a A + R^q Q - R^d D. \tag{4.11}$$

Analogously to the firm's problem, the bank maximizes its expected profit

$$\max_{A,B,Q} E\left\{\Pi - \Psi(B)F(u)\right\} - \frac{\gamma}{2} Var(R^a A) \tag{4.12}$$

subject to the budget constraint given by its balance sheet (4.10) (cf. Greenwald and Stiglitz, 1988, 1993a).

The latter two terms in (4.12) account for the two sources of risk for the bank. The first penalty comes from the loan component B of the bank's portfolio. Whenever the bank issues a loan B to the firm, the latter can bankrupt with probability $F(u)$, in which case the bank faces a penalty cost $\Psi(B)$.[7] For the sake of simplicity, we will further assume that this penalty cost is a linear function ηB for some $\eta > 0$. Notice that because the default probability $F(u)$ is nonlinear with B, this is not a restrictive assumption. The second penalty term stems from the risky asset component A of the bank's portfolio. We assume that the bank evaluates this asset based on the standard mean-variance utility function, in which the variance $Var(\cdot)$ on the return of A represents the risk penalty associated with that asset, and γ is the constant absolute risk aversion parameter.[8]

Due to the possibility that the firm will default on its debt, the expected or risk-weighted rate of return is given by

$$E[R^b] = R^b(1 - F(u)) + \left(\frac{Y}{B} - \eta\right) \int_0^{\bar{u}} u f(\bar{u}) du. \tag{4.13}$$

[7]The penalty term $\Psi(\cdot)$ can be interpreted as an actual real cost to the bank, as the bank's management risk aversion towards lending, as a risk management measure imposed by the financial oversight, or a blend of these three.

[8]We also considered a specification of the bank's objective (4.12), in which these two penalty terms were replaced by the variance of the bank's portfolio as whole, i.e. a mean-variance utility function on the whole Π. This specification is analytically difficult to work with, since its first order condition contains a joint and highly nonlinear term $Cov(R^a, R^b)$. We leave a thorough analysis of this alternative specification for future research.

The expected lending rate involves the contractually determined return R^b to the lender, which is fully repaid with probability $(1 - F(u))$ (if the firm survives). In the case of bankruptcy, however, the bank recovers as much as possible, hence the second term of the equation (please refer to appendix C.4 for a formal derivation).

The maximization of the bank's objective function (4.12) can be expressed as[9]

$$\begin{aligned} B^S &= \arg\max_B E\left\{R^a A - RD + R(D + W^b - p^a A - B) + R^b B - \eta B F(u) - \frac{\gamma}{2} Var(R^a) A^2\right\} \\ &= h(R^b, R). \end{aligned} \tag{4.14}$$

Maximizing the bank's objective function (4.12) w.r.t. the risky stocks A yields

$$A = \frac{E[R^a] - p^a R^q}{\gamma Var(R^a)}, \tag{4.15}$$

whereas the bank sets the demand for the risk-free asset Q to clear its balance sheet (4.10). It is important to emphasize here that the bank knows the functional form of the firm's loan demand, and also understands how the loan interest rate and volume influence the distribution of the firm's profit. In other words, when the bank optimizes the term $E[R^b]B$, it internalizes the behavior of the firm, and – to use terminology from Game Theory – acts in accordance with the Best Response. This means, however, that the bank's credit supply curve for the firm can only be determined numerically, given strong nonlinearities in equation (4.14), which arise in particular from the firms' distribution function of relative prices. The credit supply B further depends on the actual loan rate R^b, the funds rate R^q and the firm's net worth W.

The optimal demand for the risky asset A in equation (4.15) is a standard result of the mean-variance utility function. It characterizes how well the expected return of a risky asset compensates the investor for her perceived risk, and equals the expected excess return of the risky over the risk-free asset, normalized by $\gamma Var(R^a)$, where γ measures the bank's degree of risk aversion.[10]

The bank's first order conditions have an interesting interpretation. Both demand for the

[9]Notice that in appendix C.5, we also provide a simple version of the banking sector where we discuss the implementation of monitoring costs on the shape of the loan-offer curve. As it turns out, the resulting credit contract conditions, loan volume and loan rate, behave similar to those implied by equation (4.14)

[10]Notice that if the bank was risk neutral (with $\gamma \to 0$), its demand for the risky asset would diverge to $\pm\infty$ for any non-zero excess return.

risky asset A and supply of the credit B depend on the return of the risk-free asset R^q. On the other hand, the loan supply does not depend on the risky asset's return and *vice versa.* This implies that the bank treats the risk-free asset as a benchmark, and expects a sort of risk premium – in comparison with R^q – on the two other assets, but the volume of these two assets remain independent from each other. In other words, credit and stock markets are not directly "linked" by the banks, who treat them as separate and unrelated entities.

4.2.3 Equilibrium

For the sake of simplicity we will assume that in fact $R^d = R^q = R$, where R represents the policy rate set by the monetary authorities.[11] The bank is price-taker on the market of the risk-free and risky assets, i.e. it treats p^a, R^a and as given. On the other hand, the bank is price-setter on the credit market: it decides on the contractual amount of credit $\widehat{B}$ and loan rate for the firm $\widehat{R}^b$, where the hat indicates the equilibrium value of a variable. Note that an equilibrium, i.e. the loan contract, is found by the market clearing condition $\widehat{B} = B$. Formally, let market clearing be described as $z(R^b, R, w) = h(R^b, R) - m(R^b, W) = B^S - B^D = 0$. The loan rate is then determined according to

$$\widehat{R}^b = \arg\min_{R^b = \widehat{R}^b} \left\{ \left| z(R^b, R, W) \right| \mid R^b = \widehat{R}^b \right\} = \arg\min_{R^b = \widehat{R}^b} \left\{ \left| h(R^b, R) - m(R^b, W) \right| \mid R^b = \widehat{R}^b \right\}. \tag{4.16}$$

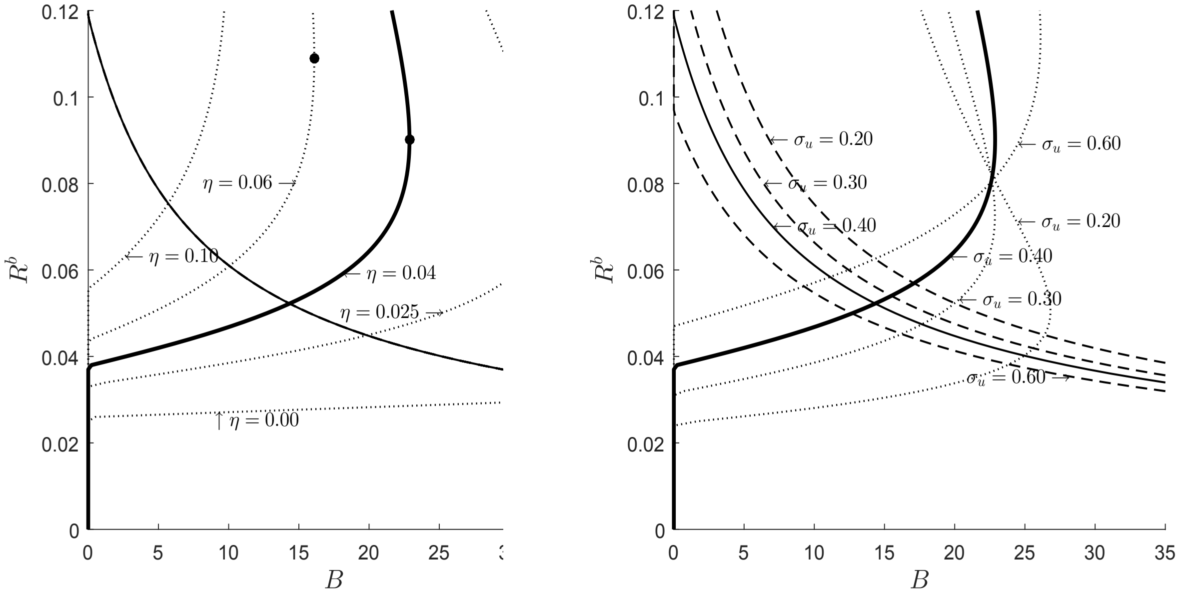
As both the loan supply and the loan demand curve are highly nonlinear, we could not compute an analytical expression for the equilibrium loan rate regardless whether the distribution of the random variable u is normally or uniformly distributed. However, it is fairly straightforward to identify the equilibrium numerically.

In order to characterize the properties of the model equilibrium we discuss in the next section how the risk aversion of the bank and the firm as well as the firm's default probability affect the loan market outcome.

[11] In practice these three rates are not exactly equal. In particular, the deposit rate R^d can vary from the other two. However, it does not affect our model much, since the term $R^d D$ is a constant in the bank's problem and does not influence its optimal solution. Further research can investigate what happens with R^d when the bank optimizes its deposit portfolio, or when the class of risk-free assets contains bonds with different maturity and yield.

4.2.4 Default Risk and Risk Aversion

In our model, the underlying riskiness of the real sector is reflected in the dispersion of the firm's relative prices, measured by their standard deviation σ_u. On the other hand, two parameters represent the attitude towards the real sector's default risk, namely the weights of the firm's and bank's bankruptcy costs functions ($\chi = 1.5$ and $\eta = 0.04$, respectively).



(a) The loan offer and variations in η

(b) The loan offer and dispersion σ_u

Figure 4.2: The shape of the loan offer curve and its dependence on the risk aversion parameter η and the standard deviation of the market shock σ_u. The thin black line refers to the loan demand curve while the bold black curve is the supply curve. The default case (bold lines) refers to $\eta = 0.04$ and $\sigma_u = 0.4$.

figure 4.2 illustrates the reaction of the equilibrium to changes in the risk weight η in the subset of $[0, 0.1]$ (left panel) and the standard deviation of the firm's individual price σ_u (right panel) using the parametrization reported in Table C.1 in appendix C.1. As illustrated in figure 4.2a, the firm is a price-taker and so the degree of the bank's risk aversion does not affect the credit demand. Unsurprisingly, the higher the risk weight η, the lower the demand, and therefore the higher the interest rate R^b and the lower the credit volume B in the equilibrium. Interestingly, under the current calibration, the model suggests that even a small change to that parameter has visible effects, which seem to be stronger for the credit volume. For instance, shifting η from $\eta = 0.04$ to $\eta = 0.06$ causes the equilibrium credit volume to fall by about one fifth, whereas the interest rate increases by around one percentage point. As discussed previously, when the interest rate R^b grows, the firm's chance of default increases as well, and at some point the bank reacts with credit rationing. As we see in figure 4.2a, the higher the risk weight η, the higher interest rate R^b is required to trigger credit rationing (where the points of inflection are illustrated by black dots), which implies that the credit equilibrium is associated with lower risk in the real sector.

In contrast, figure 4.2b displays how the loan demand and supply respond to changes in the dispersion of the relative sales price u. In contrast to the previous case, both supply and demand curves are affected, since both the firm and the bank internalize the possibility of the firm's debt default. As the standard deviation σ_u increases, the bank reacts to the risk by offering less loans, whereas the firm requests less credit and relies more on internal finance. As a result, the credit volume always decreases significantly while the increase of the interest rate is less pronounced. This suggests that the market equilibrium loan interest rate does not react sensitively to an increase in the real sector's riskiness.

4.3 Monetary Policy and Bank's Risk-Taking

We now turn analyze how monetary policy (represented by variations in the policy rate R) affects the loan market equilibrium as well as the bank's financial portfolio composition and its overall financial situation.

4.3.1 Loan Market Effects

Figure 4.3 illustrates the firm's loan demand (thin black line) and the bank's loan supply (bold black line) for varying values of the policy rate $R^b \in [0, 0.13]$ using the same numerical calibration as in the previous figures. For the sake of exposition, we plot the loan supply curve for different values of the policy rate contained in the set $R \in \{0.01, \ldots, 0.05\}$ (thin dotted line) where the reference scenario (bold black line) refers to $R = 0.02$. The loan demand curve is a convex, monotonically decreasing curve, as established in section 4.2.1, Proposition 2. On the other hand, the loan supply curve is convex, but backward-bending instead of monotonic. This result is consistent with the bulk of the literature, and was first raised by Hodgman (1960) and later advanced by e.g. Jaffee and Stiglitz (1990).

From a different vantage point, the backward-bending shape of the bank's loan supply (determined in equation (4.14)) implies that the bank's supply is strictly concave in the loan

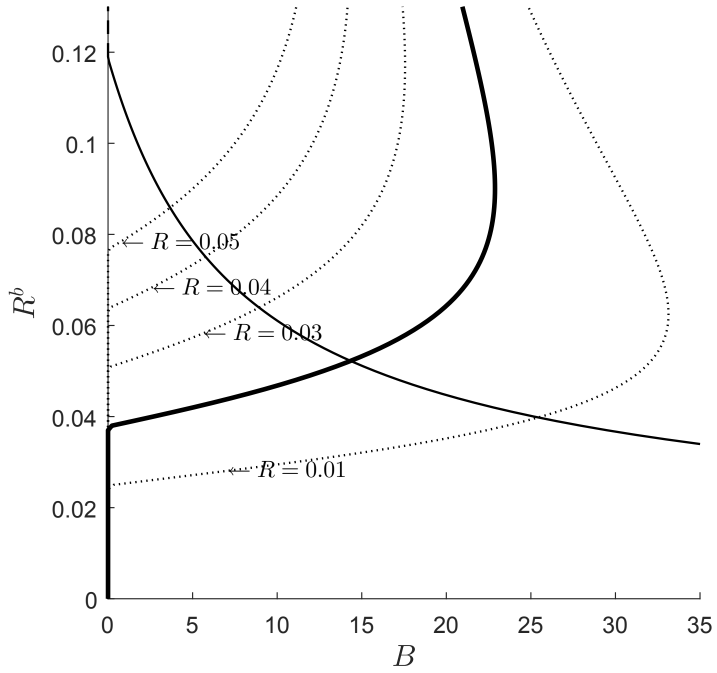


Figure 4.3: Loan supply and demand functions for $R^d = R^q = R \in \{0.01, \ldots, 0.05\}$

rate R^b. This can be interpreted as follows: An increase of the loan interest rate has two offsetting effects on the bank's profit. With a higher loan rate the realized relative price u of the firm will more likely fall below the solvency threshold $\bar{u}$ (see (4.4)), making the less likely to be able to repay its loan. On the other hand, with a higher interest rate, the bank earns a higher marginal return from the firm's loan which do not go bankrupt. In an intermediate range of the interest rate R^b, the second (positive) effect compensates the first (negative) effect, and the bank's loan supply is an increasing function ($h'_{R^b} > 0$). There exists a threshold value of the interest rate, however, for which the negative effect surpasses the positive effect and the loan supply curve becomes backward-bending ($h'_{R^b} < 0$). This triggers *credit rationing:* because of the firms' decreasing credit worthiness, the bank no longer has an incentive to increase the volume of credit that it offers (cf. Stiglitz and Weiss, 1981).

4.3.2 Bank Financial Portfolio Effects

As we already discussed earlier, the firm's optimality condition (4.9) does not directly depend on the reference policy rate. However, the bank does consider the policy rate when it optimizes its financial portfolio. As a result, there exists a substitution effect between the risk-free asset

Q on the one hand, and the risky assets A and B on the other hand, as seen in equations (4.14) and (4.15) respectively. This relationship can be analytically established for the risky asset A with $\partial A/\partial R = -p^a \gamma^{-1} Var(R^a)^{-1} < 0$. Furthermore, the monetary policy has an additional *pass-through effect* on the equilibrium lending rate $\widehat{R}^b$, which is summarized by the following Proposition.

Proposition 3 *When the loan contract $(\widehat{B}, \widehat{R}^b)$ is optimally chosen conditional on the bank's opportunity costs (R^a, R), the prevailing reference interest rate R and by excluding any solutions that would provoke credit rationing, i.e. $(\widehat{B}, \widehat{R}^b) \in \{(\tilde{B}, \tilde{R}^b) | \widehat{B} \in \mathbf{B},\ \widehat{R}^b \in \mathbf{R},\ h'_{R^b} > 0\ \forall\ \tilde{R}^b\}$ where $\mathbf{B}$ and $\mathbf{R}$ are admissible sets for the credit and the interest rate, then the contractual lending rate $\widehat{R}^b$ is weakly increasing in R, $d\widehat{R}^b/dR \geq 0$, and strictly increasing whenever the contractual loan rate R^b is not equal to its boundary solution.*

The proof is provided in appendix C.6.

This *interest rate pass-through effect* is also observable in figure 4.3 where it is shown that changes in the policy rate R may shift the supply for credit and thus the associated market equilibrium. In line with Proposition 3, an increase in the policy rate R is reflected in an upward shift of the loan-offer curve and hence of the loan market equilibrium, which in turn determines the repayment rate $\widehat{R}^b$ of the loan contract. From the bank's profit equation (4.11), we can infer $\partial\widehat{\Pi}/\partial\widehat{R}^b = \widehat{B} \geq 0$, which in turn raises the bank's gross profits in equilibrium. The bank managers re-allocates the bank's financial portfolio based on their risk aversion which is reflected in the bankruptcy cost penalty in equation (4.12). Since the expected lending rate bears the actual average risk margin, while the contractual loan rate is determined through negotiations between the firm and the bank, one can conjecture the following result:

Proposition 4 *The equilibrium loan risk premium, defined by $\widehat{RP} = \widehat{E[R^b]} - R$, declines in R, $d\widehat{RP}/dR < 0$.*

The proof on Proposition 4 for the random variable being drawn from a uniform distribution is reported in appendix C.7. The proof for the case where u is assumed to be normally distributed is analytically no longer tractable, but figure 4.4b illustrates that the loan risk premium (defined as $\widehat{E[R^b]} - R$) is higher for low policy rates R, slightly decreases as the policy rate increases and drops strongly at high policy rates. We will get back to this point and the arising discontinuities later in this section.

Proposition 4 is in line with Gilchrist and Zakrajšek (2012) and Muir (2017), who find that risk premia widen during recessions (where the policy rate is usually lowered) and especially during the last financial crisis in 2007. Consistently with the analytical results of Martinez-Miera and Repullo (2017), Proposition 4 also infers that the bank managers are more risk averse in low interest rate regions despite of their constant degree of risk aversion γ.

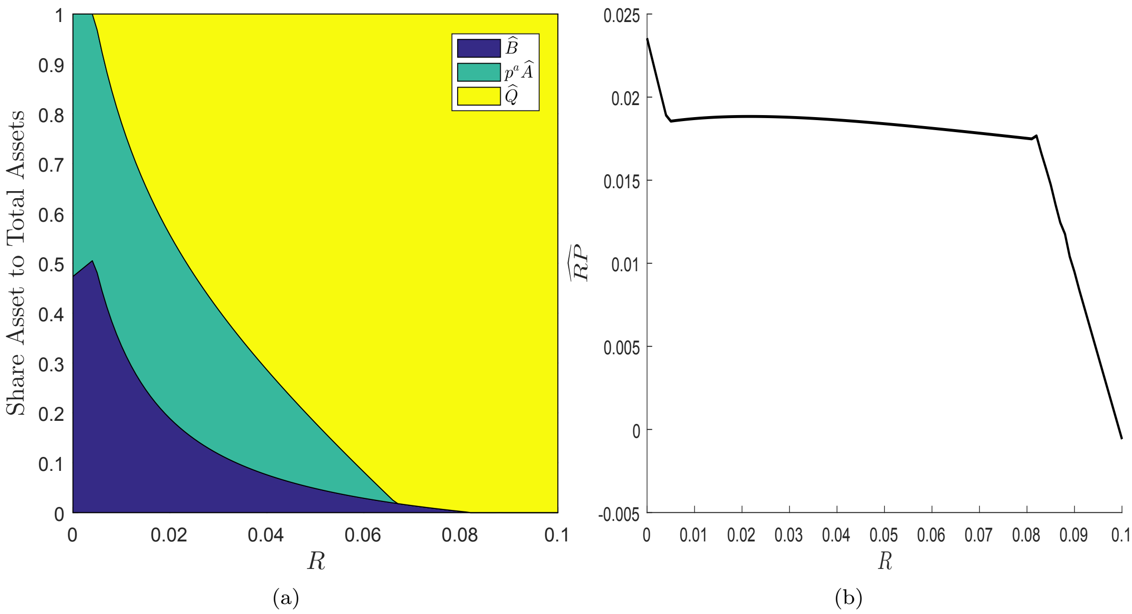


Figure 4.4: The bank's financial portfolio composition (a) and loan risk premium (b)

The reference interest rate R has also a direct effect on the demand for the risky asset A. A decline in the policy rate raises the expected net return on the risky asset (as seen in the numerator of equation (4.15)), which induces the bank to recompose its financial portfolio towards a more risky profile. This leads us to the following proposition.

Proposition 5 *If the policy rate decreases, the bank increases - ceteris paribus- its demand for the risky asset by* $p^a/(\gamma Var(R^a))$ *in the interior solution. The elasticity among the returns on the tradable assets is* $-(R^a + \mu_a)/[p^a(R^a - \mu_a)]$.

The proof is provided in appendix C.8.

Figure 4.4a illustrates this effect by displaying the bank's asset structure as a function of the policy rate. The shares of the loan, the risky asset and the risk-free asset in the bank's financial portfolio are depicted through the blue, green and yellow areas, respectively. An intuitive pattern emerges: with higher reference interest rates, the bank substitutes out the risky assets with the risk-free one due to the bank managers' risk aversion. This asset re-allocation explains the discontinuities we observe in the risk premium reported in figure 4.4b. There, the loan risk premium drops vastly in the reference interest rate R until a threshold rate $R = 0.005$ is met. We will refer to this boundary with $\underline{\varepsilon}$. With support of figure 4.4a, we can infer that the bank managers start to invest into the risk-free asset Q at $\underline{\varepsilon}$ inducing a re-allocation effect from the risky assets to the risk-free one. Beyond that boundary, where the bank manages the proper three-asset portfolio, the equilibrium loan risk premium decreases slowly. As indicated in the proof of Proposition 4 in appendix C.7, the loan risk premium is declining in this area as long as the interest rate pass-through effect is less than one-to-one to the change in the interest rate R. It follows that a rise in the interest rate R increases the expected loan repayment rate as well as the contractual loan rate, but in a less than a one-to-one correspondence. This in turn reduces the loan risk premium, $dRP/dR = d(\widehat{E[R^b]} - R)/dR \leq 0$. The next discontinuity appears at a relatively high rate of interest, at which the bank managers start to invest the entire amount of bank assets in the risk-free bond Q. This re-allocation effect is illustrated in figure 4.4a. We will refer to this threshold interest rate with $\overline{\varepsilon}$. Beyond this threshold, the equilibrium risk premium drops vastly because the bank's financial portfolio exclusively consists of the risk-free asset which induce the managers to reduce the risk premium on the loan, which is associated with a decline in the asset managers' risk aversion, as described before.

Even though we showed that the reference interest rate R does not exert a direct pressure on the firm's choice variables, such as its loan demand given by equation (4.9), it does exhibit an indirect effect on the bank's expected and actual loan rates of return via the default probability $F(\cdot)$ and through the market clearing mechanism reflected in changes in the loan market equilibrium as illustrated in figure 4.3.

4.3.3 The Bank's Financial Position

In this section we investigate how the bank's financial position is affected by changes in the policy rate. For this purpose we use the bank's capital ratio

$$\text{CAR} = \frac{W^b + \Pi}{B + p^a A} \times 100 \geqslant 10.5\% \tag{4.17}$$

as a measure for the bank's financial position. This ratio is defined along the guidelines of the Basel III accord. It relates the bank's minimum common equity (Tier 1 capital), consisting of the bank shareholder's equity and disclosed reserves, to the bank's risk weighted assets (RWA). Since in our model no dividends are distributed to the bank's shareholders, retained earnings coincide with total profits.

The RWAs are computed using the *Standardized Credit Risk Assessment Approach* (SA).[12] Under the SA, supervisors set the risk weights that banks use to determine the RWAs. For the sake of simplicity, and consistent with the assumptions related to the risk weights in e.g. Benes and Kumhof (2015), we choose weights for all risky assets of 100%.[13] Hence, each type of credit risk that appears in our model is weighted equally. The goal of the Basel guidelines was to strengthen the microprudential regulation by e.g. constraining bank leverage, imposing robust capital buffers, etc. One important instrument imposed by the guidelines are minimum capital requirements, which in the Basel III accord are ~~set~~ defined as the minimum capital adequacy ratio. This includes a 2.5% capital conservation buffer and amounts to 10.5%.[14] However, the more risk is incurred in the bank's asset portfolio, the greater the bank's RWAs, and the more its capital ratio is reduced. The bank's financial position is impaired when its capital ratio approaches the regulatory minimum capital requirements.[15]

[12]Beside the SA, the Basel Committee of Banking Supervision (BCBS) proposed the *Internal Ratings-Based Approach* (IRB) to calculate the RWAs for the assessment of credit risk. The goal of IRB is to provide a more accurate measure for credit risk in contrast to the SA, but it also requires banks to rely on more complicated estimation procedures. SA allows us to determine risk-weights in our model in a straightforward manner, and it is moreover the most common approach in the global banking sector (cf. Basel Committe on Banking Supervision, 2017b,a).

[13]According to the Basel III guidelines, a 100% risk-weight refers to general exposures to corporates with an external rating of $BB+$ to $BB-$ or even for unrated exposures. An overview for RWAs and the standardized approach to assess credit risk is provided by Basel Committe on Banking Supervision (2017b, Table 1)

[14]Notice that common and total equity capital coincide with each other in our model due to the absence of the bank's Tier 2 capital. Thus, we can also refer to the capital ratio in equation (4.17) as the capital adequacy ratio. The minimum requirements and the construction of the microprudential measures are recorded in Basel Committe on Banking Supervision (2017a, p. 137). We do not account for the countercyclical capital buffer due to the static nature of our stylized model and leave this issue for future research.

[15]In our model the bank does not face pecuniary costs from converging towards the minimum requirements. We leave this issue for future research.

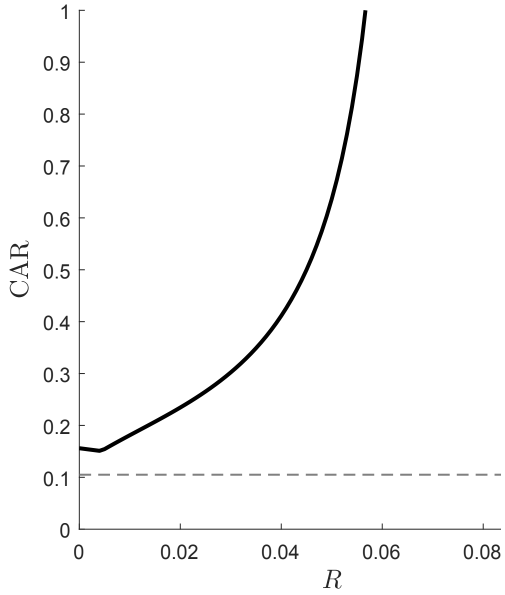
A supplementary measure to the risk-based capital requirement is the non-risk-based (Tier 1) leverage ratio which was introduced by the BCBS in order to (1) discourage destabilizing deleveraging processes, and (2) supplement and reinforce the risk-based capital adequacy requirement, serving as a non-risk-based "backstop" measure.[16] The leverage ratio comprises, however, bank's on- and off-balance sheet activity. It is formally defined as the percentage of the Tier 1 capital to the total (non-risk-based) exposures, namely

$$\mathrm{LR} = \frac{W^b + \Pi}{B + p^a A + Q} \times 100 \geqslant 3\%. \tag{4.18}$$

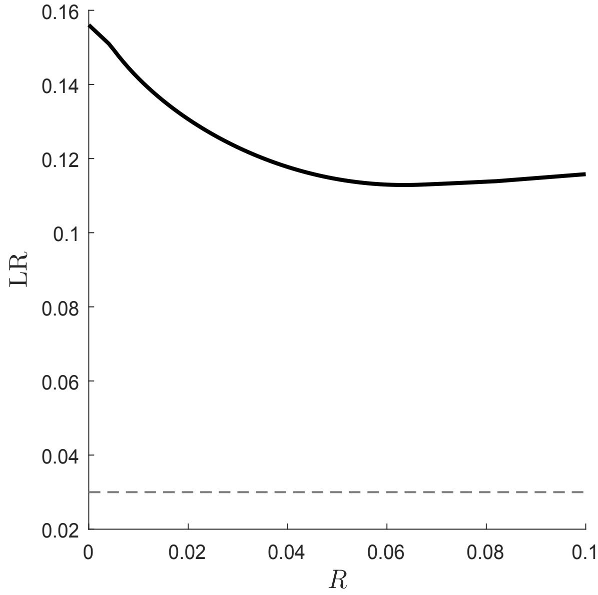
This leverage ratio relates closely to the risk-based capital ratio CAR in equation (4.17), because we weighted all risky exposures by 100% factor. The main difference between the two required ratios is that the total exposure measure in the leverage ratio (4.18) contains in addition the risk-free asset Q (which appears in the denominator). According to the Basel III guidelines, the bank must meet a 3% leverage ratio (4.18) minimum requirement at all time.

The effects of changes in the policy rate R on the bank's capital and leverage ratio (computed under the same model parameterization as in previous sections) are illustrated in figure 4.5. As illustrated in 4.5a, the capital ratio (4.17) is a strictly increasing function of the policy rate. In particular, in a regime with a moderate interest rate between hundred and four hundred basis points, the bank has a well-capitalized financial position, since its financial portfolio includes a significant amount of the risk-free asset. Even though the bank has "skin in the game", i.e. it holds a certain amount of the risky asset, it does limit its risk exposure due to its risk aversion. If the interest rate falls below hundred basis points, the bank moves from a well-capitalized to a critically under-capitalized position where it barely meets the Basel III minimum capital requirement of 10.5% (gray dashed line). This in turn makes the bank more vulnerable to financial distress, since it begins to *search-for-yield* and adjusts its asset structure towards the risky assets despite of its risk aversion. This substitution effect can also be observed in figure 4.4a, where we showed that for very low policy rates the bank stops buying risk-free bonds.

[16]Before the global financial crisis, many banks built up their leverage excessively, while at the same time reporting strong capital ratios. This led to a deleveraging process in the banking sector when banks were suddenly confronted with a rampart decline of asset prices which in response amplified the downward pressure on asset prices and sealed a vicious cycle that lead to the global financial meltdown. The additional regulation aims at preventing this type of developments from happening again.



(a) The capital ratio



(b) The leverage ratio

Figure 4.5: The bank's financial position in different interest rate regimes

Figure 4.5b displays the relationship between the policy rate and the bank's non-risk-based leverage ratio. It remains fairly stable, with the exception of the vicinity of the zero bound. Here, the leverage starts to increase, because the bank's demand for the risk-free asset Q approaches zero (cf. figure 4.4a), whereas small increases in the policy rate exert an upward pressure on the lending rate R^b through the pass-through effect. Once the policy rate exceeds the level of 0.6%, the bank starts to substitute out the risky exposures with the risk-free asset. The bank's average leverage ratio is equal to $\mu_{LR} = 12.19$ with the standard deviation of $\sigma_{LR} = 0.012$. These properties are broadly comparable with empirical observations, see appendix C.9 for details.

It is not uncanny that the two regulatory measures do not react in the same fashion to the policy rate. Indeed one cause of the 2007 global financial crisis was the build-up of excessive bank leverages, while many banks recorded at the same time strong risk-based capital ratios due to mispriced financial assets.

4.4 Concluding Remarks

As previously discussed, the search-for-yield behavior of the financial sector has been often linked with the ultra-low policy interest rates observable in recent years. Against this background we set up in this paper a stylized partial equilibrium model where both the borrower and the lender are risk averse: the firm's managers fear the possibility of default, and the bank's managers, featuring a mean variance utility, are averse to re-allocate the bank's asset financial portfolio towards a higher exposure to asset price risk. Within this theoretical framework we showed that lower policy interest rates may affect the bank's portfolio risk management while leaving the firm's demand function unchanged. As the policy (risk-free) rate decreases, the bank faces high opportunity costs, inducing the bank to rebalance its portfolio towards more risky assets in order to stabilize its profits. This search-for-yield behavior is reinforced through the positive interest rate pass-through effect which lowers the loan rate contractually determined with the firm. In compliance with empirical evidence, the model also replicates the stylized fact that the risk premium increases in low interest rate regimes. Further, when the interest rate approaches zero, the bank's capital structure moves from a well- to a poor-capitalized position, converging towards the minimum capital requirement.

There are several potential extensions of this study. First, due to the various strong nonlinearities on both the firm's and on the bank's side, our model could be studied analytically only when the relative price u followed a uniform distribution. Embedding the present framework into an agent-based model would overcome this shortcoming, probably delivering also further interesting insights on the consequences of a search-for-yield behavior by banks for macrofinancial stability.

And second, as it is done in the recent paper of Martinez-Miera and Repullo (2017), we did not incorporate the time dimension which plays a crucial role for many stylized facts which were found in the data. However, it would be interesting to extend the framework by a dynamic model to check whether it may match with some dynamic empirical regularities such as the procyclical nature of risk premia, countercyclical risk premia and the fact that the policy rates were "too low for too short" as the empirical results of e.g. Maddaloni and Peydró (2011) suggest. We expect our theoretical foundation to be flexible enough to adopt the main mechanism in other classes of financial-macroeconomic models, e.g. dynamic general equilibrium and agent-based models.

The model clearly exhibits testable implications for policy makers, such as the Basel Committee of Banking Supervision or even the central bank. First, we may consider that the bank has to face penalties whenever its capital ratios approach, or even fall short of, the regulatory minimum capital ratios. This induces the bank to take its capital ratios into account when composing its optimal asset composition. Second, in a dynamic version of this model, one could test the interplay between the countercyclical capital buffer, which was introduced with Basel III, and monetary policy and moreover, its effect on financial intermediation.

Chapter 5

Summary and Outlook

> "*One can safely argue that there is a hole in our knowledge of macro financial interactions; one might also argue more controversially that economists have filled this hole with rocks as opposed to diamonds; but it is harder to argue that the hole is empty.*"
>
> Reis (2018, p. 142)

Fluctuations in credit and capital flows may have a tremendous impact on the financial position of entities in the real economy and thus on the business cycle. Responsible for the transmission of shocks between the financial and the real sphere are macrofinancial linkages that arise due to market imperfections. This dissertation addressed some of these macrofinancial linkages and their inherent financial acceleration effects. Special emphases are paid to excess corporate leverages from the viewpoint of its *i)* origination, with the focus on the supply of the loans and thus the risk management of banks; *ii)* expansion, as financial institutions are incentivized to extend the credit supply, e.g. through securitization, to maintain high and stable profits and *iii)* bounded rational perceptions, responsible for the amplification of shocks through distinct aspects such as herding.

In chapter 2, a behavioral macroeconomic model was introduced where financial acceleration takes place through the bounded rational expectations of firm investors. Since firm investors are not capable to fully understand the proper economy, they choose their amount of business investments according to their subjective believes about the future prospects of the economy. These perceptions are misguided through different aspects, such as herding, which are not exclusively responsible for the financial acceleration *per se*, but, which are contributing trough re-enforcement. It was shown, that sufficiently strong shocks to the economy may lead to a "regime switching", driving the economy to a business cycle that exhibits excessive corporate leverage ratios and thus high risk premia on loan rates compensating the lenders for their risk-taking.

Chapter 3 elaborates this analysis by providing an ABM that is supposed to be a more realistic set-up and thus more capable to analyze real economic phenomena and policies. In particular, it is investigated how the economy may reach its risk-bearing capacity via the securitization of business loans and assessed how an intensification may translate into systemic risk. For this purpose, a numerical simulation study shows that increases in the securitization intensity, the ratio of all collateralized loan obligations to the aggregated amount of loans in the economy, may lead to huge negative welfare losses, cascade failures in the banking sector that render the markets more fragile and eventually to more pronounced financial acceleration. Further, the model predicts that a well designed bank rescue mechanism that aims to re-allocate bank equity capital among banks, mitigates financial acceleration through the stabilization of the banking sector and dampens the consequences of a possible collapse of the securitization market. In addition, we infer from the numerical exercises that the destabilizing tendencies arising from the inflating securitization market are stronger pronounced for a more concentrated banking sector. Hence, improvements in the banks' risk-sharing management might be stabilizing as well.

Finally, chapter 4 investigates the risk management of banks from a microeconomic perspective. Using a simple partial equilibrium model of bank lending, it is shown that a (representative) bank is incentivized to search-for-yield when the prevailing monetary policy interest rate in the economy is low. In particular, low interest rates induces banks to re-allocate their asset portfolio towards riskier exposures, no matter of whether the bank is risk averse or neutral, in order to avoid rising opportunity costs and to maintain stable profits. The increase in risk-taking makes the bank more vulnerable to shocks which is reflected in a decline in its financial position measured by the bank's equity ratio.

This dissertation does not explicitly aim to deliver policy suggestions for neither the monetary authority nor the banking supervision, we can nevertheless derive some implications from the studies presented in the chapters.

First, corporate indebtedness is a crucial indicator for other economic variables and thus matters for the design of monetary, micro- and macroprudential policies. However, the effects of corporate debt accumulation are twofold. On the one hand, the funding of business investment is essential to maintain economic growth, employment and wealth, on the other hand, high levels of corporate indebtedness are indicators for risk. Each of the chapters suggests that policy makers should care about corporate indebtedness as it may unfold destabilizing tendencies on real economic activities through macrofinancial linkages.

Second, policy makers should take into account the cognitive limitations of economic agents when they conduct their policies. As it is shown in Proaño and Lojak (2019), the supplementation of a simple Taylor rule by e.g. market risk premium measures, which take the agents' (mis-)perceptions into account, can be quite successful in stabilizing the economy. Related to chapter 2 of this dissertation, such policies might be successful in discouraging deleveraging processes and eventually to alleviate the leaning to drift towards high-leveraged business cycle regimes.

Third, even though the usage of financial instruments such as securitization facilitates the access to capital of small- and medium-sized enterprises through the reduction in the funding costs, policy makers shall take into account and try to avoid the inherent pitfalls that might strengthen financial acceleration.

Fourth, chapter 3 shows that a well designed rescue mechanism, that is conceptualized like a special fund that re-allocates bank equity capital from the most highly capitalized banks on the market to the critically under-capitalized banks, mitigates financial acceleration through the stabilization of the banking sector and thus the overall economy and dampens the consequences of a possible collapse of the securitization market.

Fifth, policy makers may conduct policies that aim to disentangle the banking sector concentration as it bears destabilizing potential. Broadly speaking, this may imply the facilitation of the competition in the banking sector, the avoidance of the formation of G-SIBs (globally and systemically important banks) and the improvement of the regulation for risky off-balance sheet exposures.

Finally, the banking supervision shall improve the guidelines for the risk management for individual banks. Basel III already points into the right direction with the pronunciation on RWAs. But, it is not clear yet, whether these guidelines are sufficient to antagonize banks' incentives to search-for-yield in periods when monetary policy is loose.

The initial quote at the beginning of this concluding chapter suggests that much has done in explaining macrofinancial linkages and macro-financial interactions *per se*, but this effort is supposed to be insufficient since there is still a huge gap in understanding the interconnection between the financial and the real sphere that remains to fill. This thesis is an attempt.

Future research on this topic may combine the approaches that were introduced in this thesis in order to assess macro- and microprudential policies. Since the gradual implementation of the Basel III guidelines has been completed recently, in January 2019, and its effects are hard to evaluate due to the lack of data availability, it could be considered to built an ABM taking all of the main aspects that were discussed in this thesis into account. In particular, a dynamic version of the partial equilibrium model introduced in chapter 4 which may serve as the banking sector microfoundation for a proper specified ABM such as introduced in chapter 3 may be considered. The extension by the dimension time creates a far more complicated decision problem for banks that has to be solved via dynamic programming using a Bellman equation. To ensure stock-flow consistency, the issuance of stocks and asset pricing is an aspect that must be carefully considered. The dynamic extension plays a crucial role as the actual banking regulation considers not just static minimum capital requirement ratios but also dynamic (cyclical) capital buffers. As the anticyclical capital buffer receives signals from evolution of real economic variables, e.g. GDP, one may consider to complement such buffers using leading variables with a high signaling power, such as the business climate index.

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Appendices

Appendix A

Derivations and Notes on the First Chapter

A.1 Derivation of the Jacobian of the Normal Debt Regime

In this part, we compute the Jacobian matrix of the two-dimensional system of differential equations, evaluated at the "normal" or "desired" steady state $E_{LI} = \{\underline{a}, \underline{\lambda}\} = \{0, 0.3\}$. The partial derivatives for the law of motion that governs the dynamics of the sentiment index w.r.t. the variable x corresponds to

$$\frac{\partial \dot{a}}{\partial x} = 2\nu \left[\frac{1}{\cosh^2(s)} \frac{\partial s}{\partial x} - \frac{\partial a}{\partial x} \right] \cosh(s) + 2\nu \left[\tanh(s) - a \right] \sinh(s) \frac{\partial s}{\partial x} \tag{A.1.1}$$

Since the switching index function is zero at the equilibrium point E_{LI}, so that the hyperbolic signs drop out of the equation, the latter expression boils down to[1]

$$\frac{\partial \dot{a}}{\partial x} = 2\nu \left[\frac{\partial s}{\partial x} - \frac{\partial a}{\partial x} \right].$$

Note that we denote the particular entries of the Jacobian according to J_{xy}, where the subscript represents the respective derivative of the law of motion $\dot{x}$ w.r.t. variable y. The entries of the Jacobian are given by the following expressions.

$$J_{aa} = 2\nu \left[\phi_a + \beta \left(\frac{\phi_u + \phi_r \pi}{\sigma\pi - \gamma_u} \right) - 1 \right] \tag{A.1.2}$$

$$J_{a\lambda} = 2\nu \left[A_1 - \phi_r i - (\phi_r \underline{\lambda} + \phi_\lambda) \iota_\lambda \right] \tag{A.1.3}$$

$$J_{\lambda a} = \beta(1 - \underline{\lambda}) + \frac{\beta \left[(1 - \underline{\lambda})\gamma_u - s_f \pi \right]}{\sigma\pi - \gamma_u} \tag{A.1.4}$$

$$J_{\lambda\lambda} = -\underline{g} - \hat{p} + \left\{ \frac{\left[\gamma_u (1 - \underline{\lambda}) - s_f \pi \right] \left[s_f (1 - s_c) - \gamma_\lambda \right]}{\sigma\pi - \gamma_u} + s_f - \gamma_\lambda (1 - \underline{\lambda}) \right\} (\iota_\lambda \underline{\lambda} + i) \, . \tag{A.1.5}$$

where

$$A_1 = \frac{(\phi_u + \phi_r \pi)[s_f(1 - s_c) - \gamma_\lambda](\iota_\lambda \underline{\lambda} + i)}{\sigma\pi - \gamma_u}$$

are composite parameters. Given the parameter calibration in table 2.1, the numerical values of the Jacobian matrices of the debt-led normal regime are, for *i)* scenario 1

$$J_{UC} = \begin{pmatrix} 0.7251 & -45.8931 \\ 0.0158 & -0.0515 \end{pmatrix} \tag{A.1.6}$$

[1] Note that $\cosh(0) = \frac{\exp(0) + \exp(0)}{2} = 1$, $\sinh(0) = \frac{\exp(0) - \exp(0)}{2} = 0$ and $\tanh(0) = \frac{\sinh(0)}{\cosh(0)} = 0$

with

$$tr(J_{UC}) = 0.6736 \qquad \text{and} \qquad det(J_{UC}) = 0.6861$$

and for *ii)* scenario 2

$$J_{LI} = \begin{pmatrix} 0.4527 & -19.2156 \\ 0.0173 & 0.0577 \end{pmatrix} \tag{A.1.7}$$

with

$$tr(J_{LI}) = 0.5104 \qquad \text{and} \qquad det(J_{LI}) = 0.3592$$

where LI indicates the "low-indebted" regime.

A.2 The Jacobian of the High Debt Regime

Note that the Jacobian of the high-indebted regime becomes more complex since the switching index function no longer corresponds to zero in steady state. Thus, the hyperbolic signs remain in the partial derivatives so that we have to rely on equation (A.1.1) for the first row of the Jacobian. Moreover, we need

$$\begin{aligned} \frac{\partial s}{\partial a} &= \phi_a + \phi_u \frac{\partial u}{\partial a} + \phi_r \frac{\partial f}{\partial a} \\ &= \phi_a + \frac{\beta(\phi_u + \phi_r \pi)}{\sigma\pi - \gamma_u} = B_1 \end{aligned} \tag{A.2.8}$$

$$\begin{aligned} \frac{\partial s}{\partial \lambda} &= \phi_u \frac{\partial u}{\partial \lambda} + \phi_r \frac{\partial f}{\partial \lambda} - \phi_\lambda \iota_\lambda \\ &= \frac{(\phi_u + \phi_r \pi)[s_f(1-s_c) - \gamma_\lambda](\iota_\lambda \overline{\lambda} + \overline{j})}{\sigma\pi - \gamma_u} - \phi_r \overline{j} - (\phi_r \overline{\lambda} + \phi_\lambda)\iota_\lambda \\ &= A_1(\overline{j}, \overline{\lambda}) - \phi_r \overline{j} - (\phi_r \overline{\lambda} + \phi_\lambda)\iota_\lambda = B_2 \end{aligned} \tag{A.2.9}$$

Consequently, the entries are

$$J_{aa}^{HI} = 2\nu \left[\frac{B_1}{\cosh^2(\overline{s})} - 1\right]\cosh(\overline{s}) + 2\nu\left[\tanh(\overline{s}) - \overline{a}\right]\sinh(\overline{s})B_1 \tag{A.2.10}$$

$$J_{a\lambda}^{HI} = \frac{2\nu B_2 \cosh(\overline{s})}{\cosh^2(\overline{s})} + 2\nu\left[\tanh(\overline{s}) - \overline{a}\right]\sinh(\overline{s})B_2 \tag{A.2.11}$$

$$J_{\lambda a}^{HI} = \beta(1-\overline{\lambda}) + \frac{\beta\left[(1-\overline{\lambda})\gamma_u - s_f\pi\right]}{\sigma\pi - \gamma_u} \tag{A.2.12}$$

$$J_{\lambda\lambda}^{HI} = -\overline{g} - \hat{p} + \left\{\frac{\left[\gamma_u(1-\overline{\lambda}) - s_f\pi\right]\left[s_f(1-s_c) - \gamma_\lambda\right]}{\sigma\pi - \gamma_u} + s_f - \gamma_\lambda(1-\overline{\lambda})\right\}\left(\iota_\lambda\overline{\lambda} + \overline{j}\right). \tag{A.2.13}$$

Since the particular entries of the Jacobian are analytically no longer tractable, we compute the sign pattern numerically. Accordingly, given the parameter calibration depicted in table 2.1 column Sc. 2, the sign pattern of the Jacobian evaluated at the point of rest $E_{HI} = \{\overline{a}, \overline{\lambda}\}$ is given by

$$J_{HI} = \begin{pmatrix} 0.4118 & 18.8439 \\ -0.0549 & 0.0537 \end{pmatrix} \tag{A.2.14}$$

with

$$det(J_{HI}) = 0.3592$$
$$tr(J_{HI}) = 0.4656$$

A.3 Debt Cycles in a Debt-Burdened Economy

In this part of the appendix, we show that the sentiment index configuration and the Kaleckian model are flexible enough to reproduce the feature of two contemporaneous co-existing business regimes even for a debt-burdened specification similar to the one of Ryoo (2013b). In contrast to the debt-led version, the accumulation rate depends on the debt ratio's magnitude (λ) instead of the firms' debt service ($j\lambda$). Note that a debt-burdened regime does also appear for sufficiently large values of γ_λ since the coefficient of the debt service in the nominator of equation (2.11) becomes negative, implying that $s_f(1-s_c) < \gamma_\lambda$. But, we rather rely on the specification of Ryoo (2013b) which is also responsible for the "paradox of debt" to occur, that describes a phenomenon where firms' efforts to de-leverage by cutting investments increases real economic activity instead of depressing it. However, the accumulation rate is given by

$$g = \underline{\gamma} + \gamma_u u - \gamma_\lambda \lambda. \tag{A.3.15}$$

It follows

$$u = \frac{\underline{\gamma} + \sigma\delta + s_f(1 - s_c)j(\lambda)\lambda - \gamma_\lambda \lambda}{\sigma\pi - \gamma_u}. \tag{A.3.16}$$

Regarding the numerical calibration, the parameters can be determined by the steady state values.

Proposition 6 *Suppose that capital accumulation is determined by equation* (A.3.15) *instead of* (2.7)*. Then the system may reach the desired steady states* $\underline{u} = u^d$ *and* $\underline{\lambda} = \lambda^d$ *by equation* (2.14) *of Proposition 1 and*

$$s_c = \frac{\underline{\gamma} + \gamma_u \underline{u} - \gamma_\lambda \underline{\lambda} - s_f \underline{f}}{(1 - s_f)\underline{f} + \underline{j}\underline{\lambda}} \tag{A.3.17}$$

with

$$\begin{aligned}
\underline{g} &= \underline{\gamma} + \gamma_u \underline{u} - \gamma_\lambda \underline{\lambda} \\
\underline{u} &= \frac{\underline{\gamma} + \sigma\delta + s_f(1 - s_c)\underline{j}\underline{\lambda} - \gamma_\lambda \underline{\lambda}}{\sigma\pi - \gamma_u} \\
\underline{f} &= \pi\underline{u} - \delta - \underline{j}\underline{\lambda} \\
\underline{j} &= i
\end{aligned}$$

We obtain cyclical solutions of the variables for the numerical parameter values $\gamma_u = 0.09$, $\gamma_\lambda = 0.08$, $\iota_\lambda = 0.7$, $\beta = 0.05$, $\phi_a = 0.2$, $\phi_u = 0.1$, $\phi_r = 0.9$ and $\phi_\lambda = 0.01$ where all other values are taken from table 2.1. Taking Proposition 6 into account, we get $s_c = 20,14\%$, $s_f = 20.86\%$, $\sigma = 0.368$, $\underline{g} = 4.36\%$ and $\rho^\star = 6\%$.

Figure A.1 shows that the model is also able to generate two-coexisting business regime under the debt-burdened configuration.

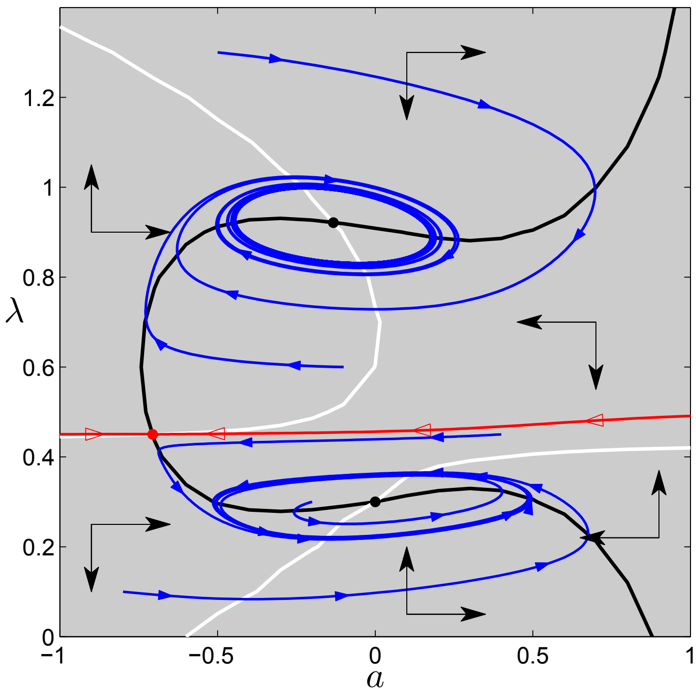


Figure A.1: Sentiment debt interaction in a debt-burdened regime. The blue lines are the trajectories, the bold black line refers to the $\dot{a} = 0$ isocline, the bold white line is the $\dot{\lambda} = 0$ isocline and the red line represents the separatrix of this economy. The arrows in the plane indicate the off-equilibrium dynamics.

Appendix B

Derivations and Notes on the First Chapter

B.1 Variables and Parameters

B.1.1 Variable List

Variable	Description	Equation(s)
	Macro Level	
c_t	household's consumption	(B.2.20)
e_t^f	corporate equities	(B.2.26)
e_t^b	bank equities	(B.2.27)
g_t	(realized) capital accumulation rate	(B.2.24)
i_t	(realized) investment	(B.2.25)
K_t	(realized) physical stock of capital	(B.2.22)
l_t	actual volume of corporate loans	(B.2.23)
m_t	deposits	(B.2.33)
p_t^f	corporate equity price	(B.2.28)
p_t^b	banks' equity price	(B.2.29)
y_t	output	(B.2.19)
y_t^d	disposable income	(B.2.18)
u_t	capacity utilization	(B.2.21)
$\tilde{\Pi}_t$	corporate retained earnings	(B.2.4)
Π_t^d	distributed corporate profits	(B.2.34)
Π_t^T	total corporate profits	(B.2.35)
r_t	average interest rate	(B.2.30)
r_t^m	deposit rate	(B.2.31)
r_t^{spvA}	return on the SPV-A security	(B.2.32)
$spvA_t$	SPV A-tranche security	(B.2.16)
$\Pi_{SPV,t}$	SPV profits	(B.2.17)
	Micro Level	
$e_{i,t}$	firm i's equities	(B.2.7)
$e_{k,t}$	bank k's equities	(B.2.11)
$ER_{k,t}$	banks' equity ratio	(B.2.14)
$i_{i,t}^D$	firm specific desired investment	(3.4)
$i_{i,t}$	firm specific investment	(3.9), (B.2.1)

$g_{i,t}^{D}$	firms' planned capital accumulation rate	(3.2)
$g_{i,t}$	firms' actual capital accumulation rate	(B.2.3)
$K_{i,t}^{D}$	firm i's planned level of assets	(3.5)
$K_{i,t}$	firm i's assets	(B.2.2)
$l_{i,t}$	firms' external funds	(3.8)
$l_{k,t}$	banks' assets	(B.2.10)
$LR_{i,t}$	firms' leverage ratio	(B.2.8)
$m_{k,t}$	banks' deposits	(B.2.13)
$\mu_{i,t}$	corporate capital productivity	footnote 13
$p_{i,t}^{f}$	equity price of each firm i	(B.2.6)
$p_{k,t}^{b}$	equity price of each bank k	(B.2.12)
Φ_t	firm market share	(B.2.9)
$\tilde{\Pi}_{i,t}$	firms' retained earnings	(B.2.5)
$\Pi_{i,t}$	firms' total profits	(B.2.4)
$r_{i,t}^{k}$	firms' loan interest rate	(3.6)

Table B.1: Variable list

B.1.2 Numerical Parameter Values

Description	Parameter	Value	Source and Motivation
		Values taken from the literature	
Marginal propensity to consume out of deposits (liquidity)	α_2	0.055	Carroll et al. (2011, Table 5)
Wage share and share of distributed profits	ω, χ	$0.7, 0.2$	Belabed et al. (2017, Appendix A)
Threshold equity ratio	$\overline{ER}^{\text{min}}$	0.05	Hoenig (2018, Column 4)
Threshold leverage ratio	$\overline{LR}^{\text{max}}$	0.90	Graham et al. (2015b, Table 1): $1 - \overline{ER}^{\text{min}} > \overline{LR}^{\text{max}}$
		Targeted Parameters	
Initial bank equity ratio	θ_B	0.07	motivated by $\theta_B > \overline{ER}^{\text{min}}$
Initial firm leverage ratio	θ_C	0.80	motivated by $\theta_C < \overline{LR}^{\text{max}}$
Marginal propensity to consume out of disposable income	α_1	0.60	calibrated to ensure stock flow consistency
Marginal propensity to consume out of corporate share holding	α_3	0.045	motivated by $\alpha_4 < \alpha_3 < \alpha_2$
Marginal propensity to consume out of bank share holding	α_4	0.03	motivated by $\alpha_4 < \alpha_3 < \alpha_2$
Marginal propensity to invest out of capacity utilization	γ_1	0.03	motivated by $0.15 < I/Y < 0.20$
Marginal propensity to invest out of profit rate	γ_2	0.025	motivated by $0.15 < I/Y < 0.20$
Scaling parameter linking deposit and loan rates	θ_r	0.85	motivated by $r_M < r_S < r_L$
Scaling parameter linking tranche and loan rates	θ_{spvA}	0.95	motivated by $r_M < r_S < r_L$
		Partner Selection Mechanism	
Number of firms	N_C	300	compatible with the N_B/N_C ratio in Delli Gatti et al. (2010)
Number of banks	N_B	50	compatible with the N_B/N_C ratio in Delli Gatti et al. (2010)
Loan rate intercept	$\tilde{r}$	0.04	average US prime rate charged by banks since 2001 (FED)
Benchmark firm leverage ratio	$\overline{LR}$	0.50	motivated by $\overline{LR} < \overline{LR}^{\text{max}}$

Loan rate sensitivity to firm leverage ratio	ρ_{LR}	0.01	plausibly chosen, sensitivity analysis available on request
Loan rate sensitivity to bank equity ratio	ρ_{ER}	0.06	plausibly chosen, sensitivity analysis available on request
Scaling paremeter for firms' matching costs	$\overline{\mu}^S$	0.05	plausibly chosen, sensitivity analysis available on request
Number of firms' potential credit supplier in subset M_t	n	5	plausibly chosen, sensitivity analysis available on request
Bank Rescue Mechanism			
Maximum number of recapitalized banks per period	η	5	plausibly chosen, sensitivity analysis available on request
Duration of the insolvency proceedings	ζ	2	plausibly chosen, sensitivity analysis available on request
Size of recapitalization	κ	0.2	plausibly chosen, sensitivity analysis available on request
Shock Processes (joint effect analyzed by MC)			
Firms' sensitivity to sale prediction errors	λ	0.01	assumed to maintain persistence
Standard deviation of the price expectation error term	σ_c	1.00	assumed to be standard normally distributed
Standard deviation of the capital productivity error term	σ_μ	0.1	assumed to have a low volatility (Caiani et al., 2016, p. 39)
Standard deviation of the loan rate error term	σ_r	0.007	assumed to have a low volatility (Caiani et al., 2016, p. 39)
Intercept in the GARCH firm equity price process	σ_0^P	0.05	assumed to induce a low volatility
Return sensitivity in the GARCH firm equity price process	σ_1^P	0.05	assumed to induce a low volatility
Persistence in GARCH firm equity price process	σ_2^P	0.05	assumed to induce a low volatility

Table B.2: Numerical parameter values

B.2 Model Equations

B.2.1 Production planning

$$c_{i,t}^D = c_{i,t-1}^D + \lambda \left(c_{t-1} - c_{i,t-1}^D \right) + \epsilon_{i,t}^c \quad \text{with} \quad \epsilon_{i,t}^c \sim \mathcal{N}(0, \sigma_c) \tag{3.1}$$

$$g_{i,t}^D = \gamma_1 u_{i,t-1}^D + \gamma_2 \left(\frac{\Pi_{t-1}}{K_{t-1}} \right) \tag{3.2}$$

$$u_{i,t}^D = \frac{y_{i,t}^D}{K_{i,t}^D (1 + \mu_{i,t}^K)} = \frac{c_{i,t}^e + i_{i,t}^D}{K_{i,t}^D (1 + \mu_{i,t}^K)} \tag{3.3}$$

$$i_{i,t}^D = g_{i,t}^D K_{t-1} \tag{3.4}$$

$$K_{i,t}^D = K_{t-1} + i_{i,t}^D \tag{3.5}$$

B.2.2 Corporate sector - after firm-bank interaction

$$\Delta l_{i,t} = \begin{cases} i^D_{i,t} - \tilde{\Pi}_{i,t-1} & \text{if} \quad \#\{k \text{ insolvent} | k \in M_t\}_{i,t} = 0 \\ (1 - S_{i,t})(i^D_{i,t} - \tilde{\Pi}_{i,t-1}) & \text{if} \quad 0 < \#\{k \text{ insolvent} | k \in M_t\}_{i,t} < n \\ 0 & \text{else.} \end{cases} \tag{3.8}$$

$$i_{i,t} = \begin{cases} \Phi_t \cdot i^D_{i,t} & \text{if} \quad \#\{k \text{ insolvent} | k \in M_t\}_{i,t} = 0 \\ \Delta l_{i,t} + \tilde{\Pi}_{i,t} & \text{if} \quad 0 < \#\{k \text{ insolvent} | k \in M_t\}_{i,t} < n \\ \tilde{\Pi}_{i,t} & \text{else} \end{cases} \tag{B.2.1}$$

$$\Delta K_{i,t} = i_{i,t} \tag{B.2.2}$$

$$g_{i,t} = i_{i,t}/K_{i,t-1} \tag{B.2.3}$$

$$\Pi_{i,t} = \Phi_t \Pi^T_t \tag{B.2.4}$$

$$\tilde{\Pi}_{i,t} = (1 - \chi)\Pi^T_t \tag{B.2.5}$$

$$\begin{aligned} p^f_{i,t} &= \exp\left\{ln(p^f_{i,t-1}) + \epsilon^p_{i,t}\right\} \quad \text{with} \quad \epsilon^p_{i,t} \sim N(0, \sigma^p_{i,t}) \\ (\sigma^p_{i,t})^2 &= \sigma^p_0 + \sigma^p_1 \cdot ln\left(\frac{p^f_{i,t}}{p^f_{i,t-1}}\right)^2 + \sigma^p_2 \cdot (\sigma^p_{i,t-1})^2 \end{aligned} \tag{B.2.6}$$

$$e_{i,t} = (K_{i,t} - l_{i,t})/p^f_{i,t} \tag{B.2.7}$$

$$LR_{i,t} = \frac{l_{i,t-1}}{p^f_{i,t-1} \cdot e_{i,t-1} + l_{i,t-1}} \tag{B.2.8}$$

$$\Phi_t = 1/N^C \tag{B.2.9}$$

B.2.3 Banking sector

$$\Delta l_{k,t} = \begin{cases} \sum_{i \in \Theta_k} l_{i,t} & \text{if no SPV is involved} \\ \sum_{i \in \Theta_k} l_{i,t} - \sum_{i \in \Theta_k \cup \Theta_{SPV}} l_{i,t} & \text{otherwise} \end{cases} \tag{B.2.10}$$

$$e_{k,t} = e_{k,t-1} \tag{B.2.11}$$

$$p^b_{k,t} = \begin{cases} p^b_{k,t-1} \cdot \left(1 + \frac{\sum_{k=1}^{NB} \Delta l_{k,t}}{\sum_{k=1}^{NB} l_{k,t-1}}\right) & \text{if} \quad ER_{k,t} \geq \overline{ER}^T \\ (l_{k,t} - m_{k,t})/e_{k,t} & \text{else} \end{cases} \tag{B.2.12}$$

$$m_{k,t} = l_{k,t} - p^b_{k,t} e_{k,t} \tag{B.2.13}$$

$$ER_{k,t} = \frac{p^b_{k,t} \cdot e_{k,t}}{l_{k,t}} \tag{B.2.14}$$

where Θ_k is the set of bank k's customers and $\Theta_{SPV} \subset \Theta_k$ incorporates the respective firms behind the securitized debt obligations.

B.2.4 The Special Purpose Vehicle (macro level)

$$\theta_{SPV} = \frac{\sum_{i \in \Theta_{SPV}} l_{i,t}}{\sum_{k=1}^{NB} l_{k,t}} \tag{B.2.15}$$

$$spvA_t = \sum_{i \in \Theta_{SPV}} l_{i,t} \tag{B.2.16}$$

$$\Pi_{SPV,t} = \sum_{i \in \Theta_{SPV}} r_{i,t} \cdot l_{i,t-1} - r^{spvA}_t \cdot spvA_{t-1} \tag{B.2.17}$$

where Θ_{SPV} refers to the set of firms whose obligations are pooled in the A-tranche.

B.2.5 The macroeconomic level - Household sector and aggregation

The household sector acts as an aggregate in the model[1]:

[1] Notice that the macro variables from the production planning are not listed here. They are simply obtained by summing up the correspondig micro variables

$$y_t^d = \omega \cdot y_t + \Pi_t^d + r_t \cdot m_{t-1} + r_t^{spvA} \cdot spvA_{t-1} \tag{B.2.18}$$

$$y_t = c_t + i_t \tag{B.2.19}$$

$$c_t = \alpha_1 y_{t-1}^d + \alpha_2 m_{t-1} + \alpha_3 \left[\Delta(p_t^f e_t^f) + spvA_{t-1}\right] + \alpha_4 \Delta(p_t^b e_t^b) \tag{B.2.20}$$

$$u_t = y_t / K_t \tag{B.2.21}$$

$$K_t = \sum_{i=1}^{N^C} K_{i,t} \tag{B.2.22}$$

$$l_t = \sum_{i=1}^{N^C} l_{i,t} \tag{B.2.23}$$

$$g_t = \Delta K_t / K_{t-1} \tag{B.2.24}$$

$$i_t = \sum_{i=1}^{N^C} i_{i,t} \tag{B.2.25}$$

$$e_t^f = \sum_{i=1}^{N^C} e_{i,t} \tag{B.2.26}$$

$$e_t^b = \sum_{k=1}^{N^B} e_{k,t} \tag{B.2.27}$$

$$p_t^f = \frac{\sum_{i=1}^{N^C} p_{i,t}^f \cdot e_{i,t}}{\sum_{i=1}^{N^C} e_{i,t}} \tag{B.2.28}$$

$$p_t^b = \frac{\sum_{k=1}^{N^B} l_{k,t} - \sum_{k=1}^{N^B} m_{k,t}}{\sum_{k=1}^{N^B} e_{k,t}} \tag{B.2.29}$$

$$r_t = \frac{\sum_{i=1}^{N^C} r_{i,t} \cdot l_{i,t}}{\sum_{i=1}^{N^C} l_{i,t}} \tag{B.2.30}$$

$$r_t^m = \theta_r \cdot \frac{\sum_{i=1}^{N^C} r_{i,t} \cdot l_{i,t}}{\sum_{i=1}^{N^C} l_{i,t}} \tag{B.2.31}$$

$$r_t^{spvA} = \theta_r \cdot \frac{\sum_{i=1}^{\Theta_{SPV}} r_{i,t} \cdot l_{i,t}}{\sum_{i=1}^{\Theta_{SPV}} l_{i,t}} \tag{B.2.32}$$

$$m_t = \sum_{k=1}^{N^B} m_{k,t} \tag{B.2.33}$$

$$\Pi_t^{\text{distributed}} = \chi \Pi_t^T \tag{B.2.34}$$

$$\Pi_t^T = (1-\omega) y_t \tag{B.2.35}$$

$$\tilde{\Pi}_t = \Pi_t^T - \Pi_t^D - \sum_{i=1 | i \notin \Theta_{SPV}}^{N^C} r_{i,t-1} l_{i,t-1} \tag{B.2.36}$$

B.3 Initialization

B.3.1 Initial Values

Variable	Description	Value
	Macro Level	
c_0	consumption	$0.7 \cdot y_0$
e_0^f	corporate equities	$\sum_{i=1}^{N^C} e_{i,0}$
e_0^b	bank equities	$\theta^b \cdot l_0^f$
g_0	capital accumulation rate	$i_0/K_0 = \delta$
i_0	investment	$\delta \cdot K_0$
K_0	physical stock of capital	200
l_0^f	volume of loans (macro level)	$\sum_{i=1}^{N^C}$
m_0	deposits	$l_0^f - e_0^b p_0^{e,b}$
u_0	utilization rate	y_0/K_0
y_0	output	$0.5 \cdot K_0$
$\tilde{\Pi}_0$	corporate retained earnings	$\Pi_0^T - \Pi_0^d$
Π_0^d	distributed corporate profits	$\chi \cdot \Pi_0^T$
Π_0^T	total corporate profits	$(1-\omega) \cdot y_0$
V_0	Household's financial wealth	$m_0 + p_0^f e_0^f + p_0^{e,b} e_0^b$
	Micro Level	
$e_{i,0}$	endowment of firm i's equity	$(K_0/N^C - l_{i,0})/p_{i,0}^f$
$e_{k,0}$	endowment of bank k's equity	e_0^b/N^B
$ER_{k,0}$	bank k's equity ratio	$(p_{k,0}^b \cdot e_{k,0})/l_{i,0}^k$
$i_{i,0}$	investment	$\delta \cdot K_{i,0}$
$g_{i,0}^D$	planned investment of firm i	$g_0 = \delta$
$K_{i,0}$	endowment of firm i	K_0/N^C
$l_{i,0}$	volume of firm i's loans	$LR_{i,0} \cdot K_0/N^C$
$l_{k,0}$	bank assets	see appendix B.3.2
$LR_{i,0}$	firms' leverage ratio	see appendix B.3.2
$m_{k,0}$	banks' deposits	$l_{i,0}^k - p_{k,0}^b \cdot e_{k,0}$
$p_{i,0}^f$	equity price of each firm i	1
$p_{k,0}^b$	equity price of each bank k	1

Φ_0	market share firm	$1/N^C$
$\tilde{\Pi}_{i,0}$	retained earnings of individual firm i	$(1-\chi)\Pi_{i,0}$
$\Pi_{i,0}$	total profits of individual firm i	$\Phi_0 \cdot \Pi_0^T - \tilde{r} \cdot l_{i,0}$

Table B.3: Initial values

B.3.2 Initialization Process

In this section, we highlight the initialization process of the model. Even though this process is often underdeveloped in the ABM literature, we pay special attention to it since we do not aim to violate the stock flow consistency at any stage. Furthermore, the model aims at the greatest possible proximity to data.

Note that firms are identically endowed on their asset side since we identically distribute the initial economic-wide capital stock among all firms $K_{i,0} = K_0/N^C$. The heterogeneity, however, arises due to randomly chosen financing structure LR_i among all firms. In particular, we assume that the firms' initial leverage ratios are drawn from a uniform distribution, formally $LR_{i,0} \sim \mathcal{U}(\underline{lr}, \overline{lr})$, where the support $(\underline{lr}, \overline{lr})$ is configured to cover a range of leverage ratios excluding insolvencies ($LR_{i,0} < LR^{\max}$). Then, we derive the respective firm equity position residually, i.e. $e_{i,0} = (K_{i,0} - l_{i,0})/p^f_{i,0}$ with the initial equity price normalized to one.

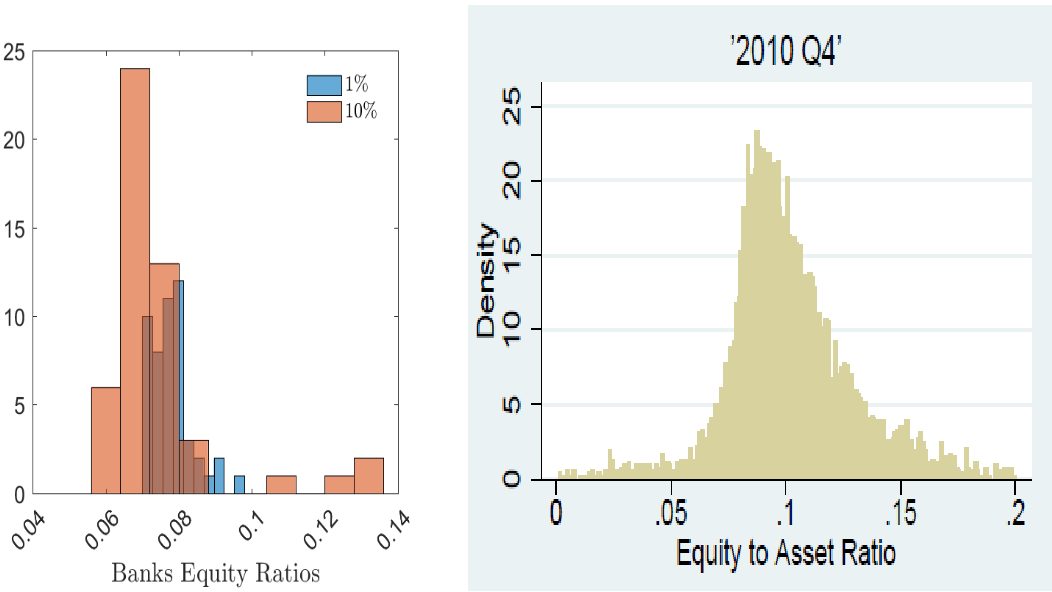
At a next stage, the initial network between firms and banks is chosen randomly. In detail, we construct an array that contains a flag for each firm. This array is denoted by $C = \{1, \cdots, N^C\}$ with N^C being the number of firms in the economy. We permute the array to obtain $\tilde{C}$. Next, we allocate the firms to the banks and formulate the initial credit contract. Accordingly, the set $\tilde{C}$ is divided into N^B equally sized subsets. If the quotient N^C/N^B is not an integer, each bank signs initial credit contract with $\lfloor N^C/N^B \rfloor$ number of firms while the remaining firms, if there are any, are allocated to randomly chosen banks. Hence, each bank k initially funds approximately the same number of firms. From the initial credit network, we compute the banks' assets by simply summing up the granted loans in bank k's portfolio. We obtain $l_{k,0}$. Using the initial values depicted in table B.3 we compute the banks' equity ratios. Even though the initial leverage ratios are uniformly distributed and the initial number of firms that get funded by each bank are roughly the same, the initial distribution of banks' equity ratios is bell shaped. Its kurtosis is about 3 which usually indicates a normal distribution. But note that the distribution cannot be symmetric because of minimum capital requirements.

B.4 Validation

Caiani et al. (2016) propose a procedure for the validation of stock flow consistent agent-based models with comprehensive sector mapping. We basically follow their approach and present a comparison of synthetic model data with observable data taking both cross-sectional properties at the micro level as well as time series properties at the macro level into account.

B.4.1 Validation at the micro level: The distribution of bank equity ratios

Figure B.1 shows the model distribution of banks' average capital ratios. The left panel, figure B.1a, was created based on a randomly selected path with a securitization intensity of 1% and 10%. The right panel, figure B.1b shows the corresponding descriptive density distribution of US commercial banks according to the data set exploited by Karmakar and Mok (2015).



(a) Simulation results

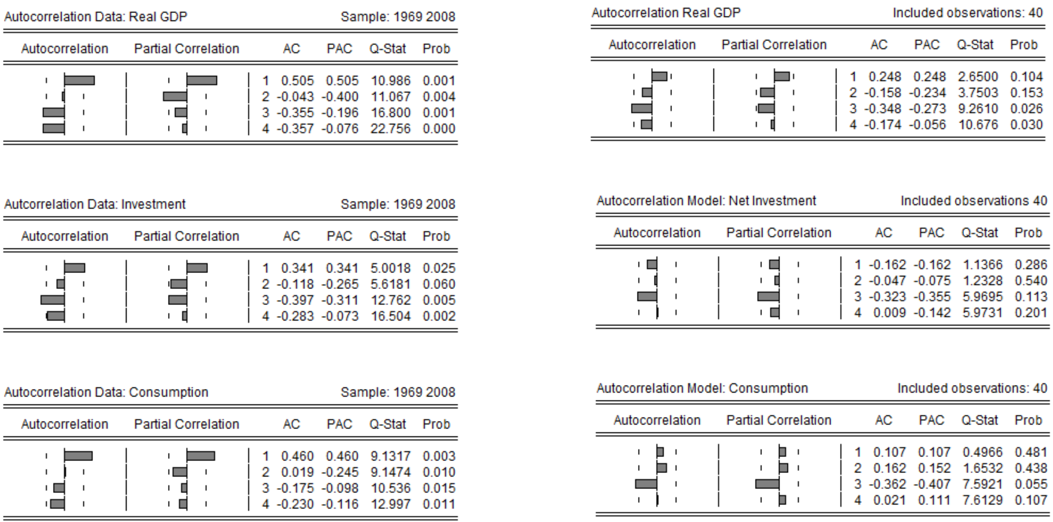
(b) Empirical results

Figure B.1: Distribution of bank equity ratios

Three main similarities between the model data and the observed data are striking: *i)* most banks have an equity-to-asset ratio of around 7%, *ii)* the distribution is skewed to the right, *iii)* only a small number of banks has an equity ratio of less than 5%. The most important difference is that, unlike in the model, the observable data include more banks with capital ratios above 10%, i.e. the model distribution is not complete in this sense. However, it should be noted that the data set by Karmakar and Mok (2015) does not contain non-commercial banks. Such a delicate subdivision of the banking sector is not possible in the model. However, the model also roughly matches the average equity-to-asset ratio of the large banks (GSIB) mentioned by Hoenig (2018).

B.4.2 Validation at the macro level: Auto- and cross-correlation

Figure B.2 and B.3 compare the observable (left hand) and model data (right hand) in terms of the auto- and cross-correlations of GDP components, after trend filtering the data.[2] Given that the model is subject to many simplifications at the macro level, all in all, the comparison provides a promising conformity.[3]



Autocorrelation Data: Real GDP — Sample: 1969 2008

	AC	PAC	Q-Stat	Prob
1	0.505	0.505	10.986	0.001
2	-0.043	-0.400	11.067	0.004
3	-0.355	-0.196	16.800	0.001
4	-0.357	-0.076	22.756	0.000

Autocorrelation Real GDP — Included observations: 40

	AC	PAC	Q-Stat	Prob
1	0.248	0.248	2.6500	0.104
2	-0.158	-0.234	3.7503	0.153
3	-0.348	-0.273	9.2610	0.026
4	-0.174	-0.056	10.676	0.030

Autcorrelation Data: Investment — Sample: 1969 2008

	AC	PAC	Q-Stat	Prob
1	0.341	0.341	5.0018	0.025
2	-0.118	-0.265	5.6181	0.060
3	-0.397	-0.311	12.762	0.005
4	-0.283	-0.073	16.504	0.002

Autocorrelation Model: Net Investment — Included observations 40

	AC	PAC	Q-Stat	Prob
1	-0.162	-0.162	1.1366	0.286
2	-0.047	-0.075	1.2328	0.540
3	-0.323	-0.355	5.9695	0.113
4	0.009	-0.142	5.9731	0.201

Autocorrelation Data: Consumption — Sample: 1969 2008

	AC	PAC	Q-Stat	Prob
1	0.460	0.460	9.1317	0.003
2	0.019	-0.245	9.1474	0.010
3	-0.175	-0.098	10.536	0.015
4	-0.230	-0.116	12.997	0.011

Autocorrelation Model: Consumption — Included observations: 40

	AC	PAC	Q-Stat	Prob
1	0.107	0.107	0.4966	0.481
2	0.162	0.152	1.6532	0.438
3	-0.362	-0.407	7.5921	0.055
4	0.021	0.111	7.6129	0.107

Figure B.2: Auto-correlations of real output, investment and consumption

[2] As standard for yearly data, we apply the Hodrick-Prescott filter with $\lambda = 100$.

[3] A lack of conformity in the form of differing signs can only be found in the first-order auto-correlation of investment and the cross-correlation between GDP and the second lag of consumption.

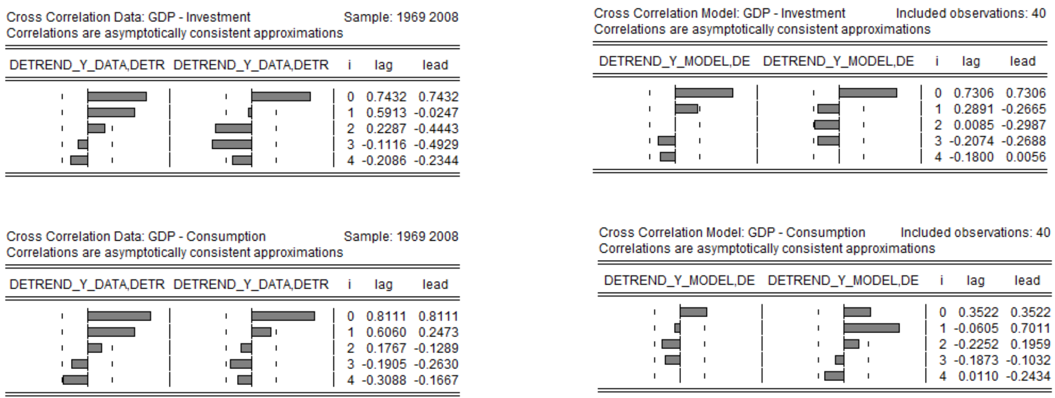


Figure B.3: Cross-correlations of real output-investment and real output-consumption

B.5 Sensitivity Analysis

This section presents the results of a sensitivity analysis for the parameters of the partner selection mechanism (figure B.4), the investment (figure B.5), and the consumption function (figure B.6). The general rule in the graphs is: The brighter the line, the higher the value of the parameter being examined.[4]

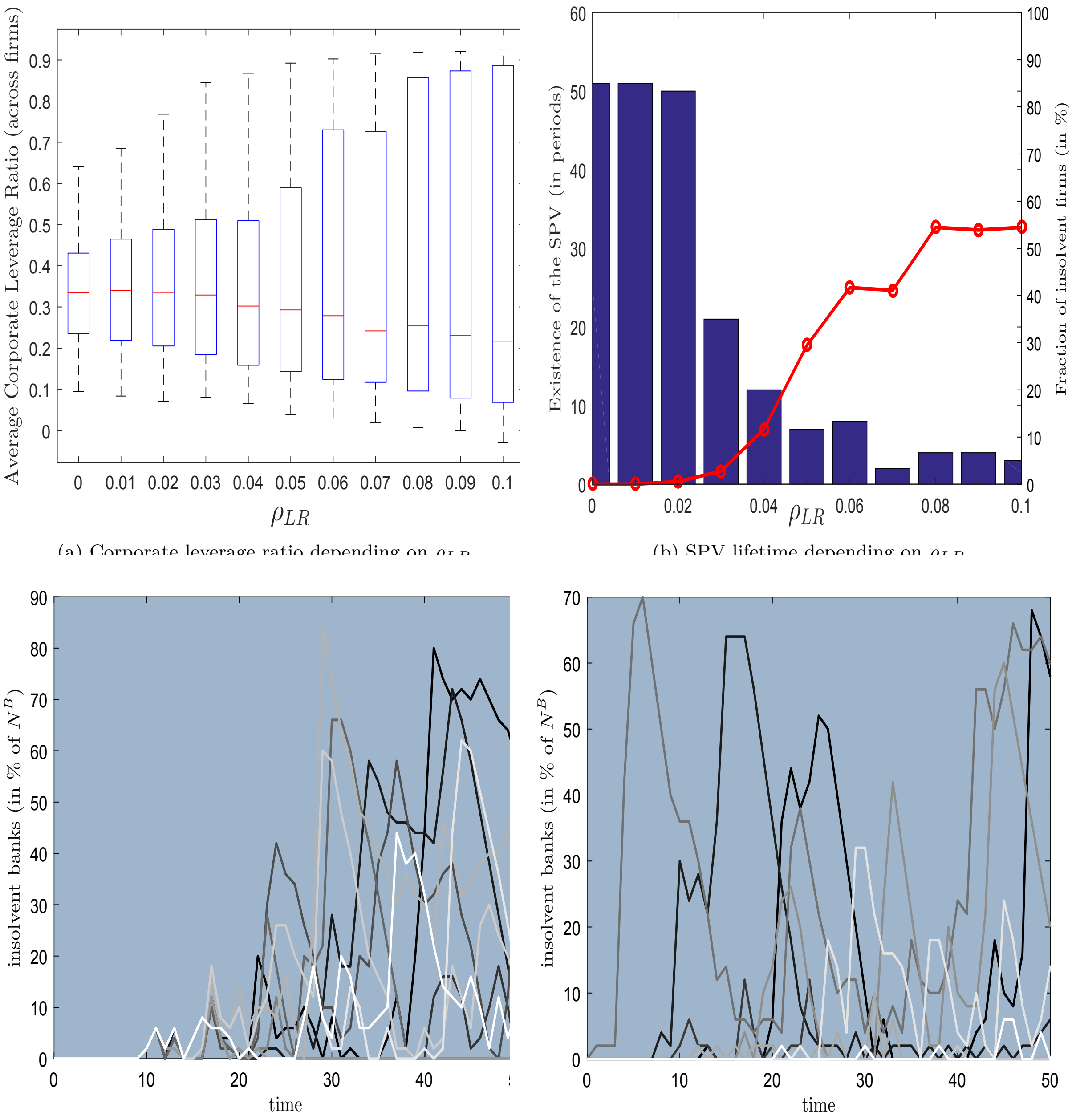
Panel B.4a shows for different values of the loan rate coefficient ρ_{LR} the resulting distribution of firms' leverage ratios, in particular their average (red) and their dispersion across firms. The blue box characterizes the area between the bottom and top quartile. Figure B.4b plots the share of insolvent firms to the total number of firms and the lifetime of the SPV as a function of ρ_{LR}. As is to be expected, the higher the lending rates that firms have to pay with respect to their leverage ratio, the more self-reinforcing and faster the process of firm concentration is. With an increasing ρ_{LR}, the model results in a higher proportion of insolvent firms in the economy and the probability rises that the securitized loan portfolio is also affected. Accordingly, the SPV is liquidated faster. Figure B.4c shows the effects of increasing search costs after a firm is matched with an insolvent bank. Nonlinearities occur, but in general it can be concluded that for a given level of credit frictions higher search costs lead to lower credit demand. As a result, the probability of future bank failures is reduced in the further course of the simulation run. Figure B.4d plots the effects of the bank subset size which determines the firm-bank matching opportunities. The larger this subset, the

[4]The respective parameter ranges and incremental steps are available on request.

greater the probability that a firm will be able to switch to a solvent bank which stabilizes the banking sector in the long-run.

With respect to coefficients of the investment and consumption function, it is worth to study the incurred costs of credit market frictions in terms of realized investment falling short of desired investment. Figure B.5 shows that the higher the propensities to invest, the higher the credit demand, which in turn increases the risk of excessive lending and, in the long term, of bank insolvencies and credit frictions.

With regard to the parameters of the consumption functions, the graphs B.6a and B.6c stand out because they show negative outcomes for high values of the respective parameters. Negative values correspond to realized investment exceeding desired one. This is in itself not plausible and illustrates that, at this point, too strong parameter changes endanger the model stability and, as can be verified, the stock flow consistency of the model. Figure B.6b shows that stronger consumption out of deposits stimulates growth, which limits bank insolvencies and thus credit frictions in the further course of the simulation run. The effects are similar for graph B.6d which illustrates consumption out of bank shares.



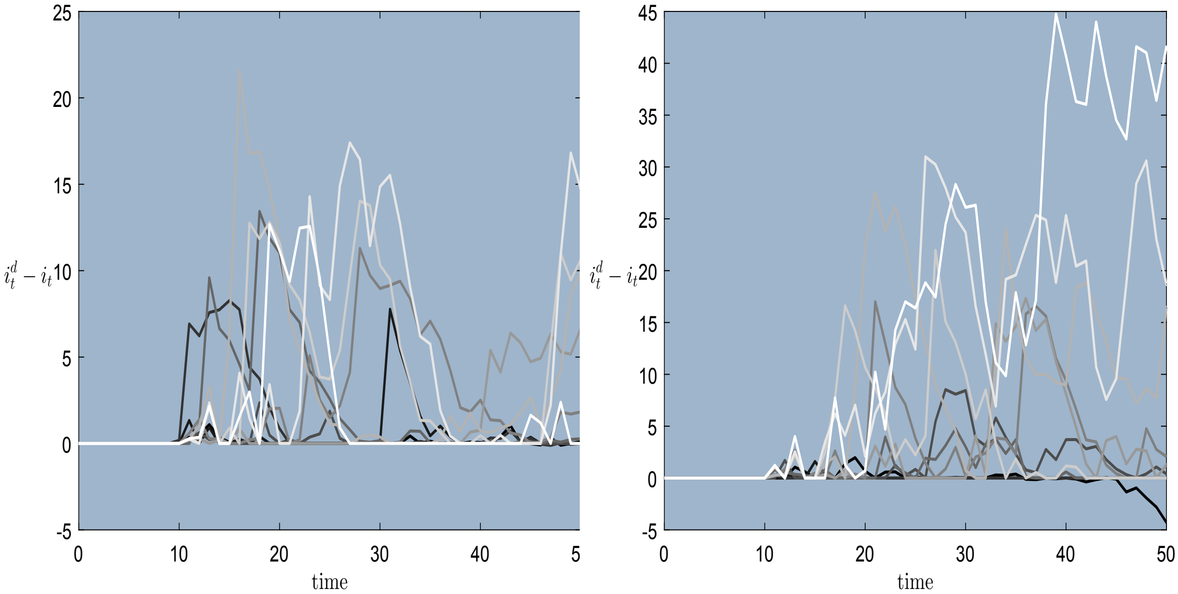
(a) Corporate leverage ratio depending on ρ_{LR}

(b) SPV lifetime depending on ρ_{LR}

(c) Bank insolvencies subject to changes in $\bar{\mu}^S$

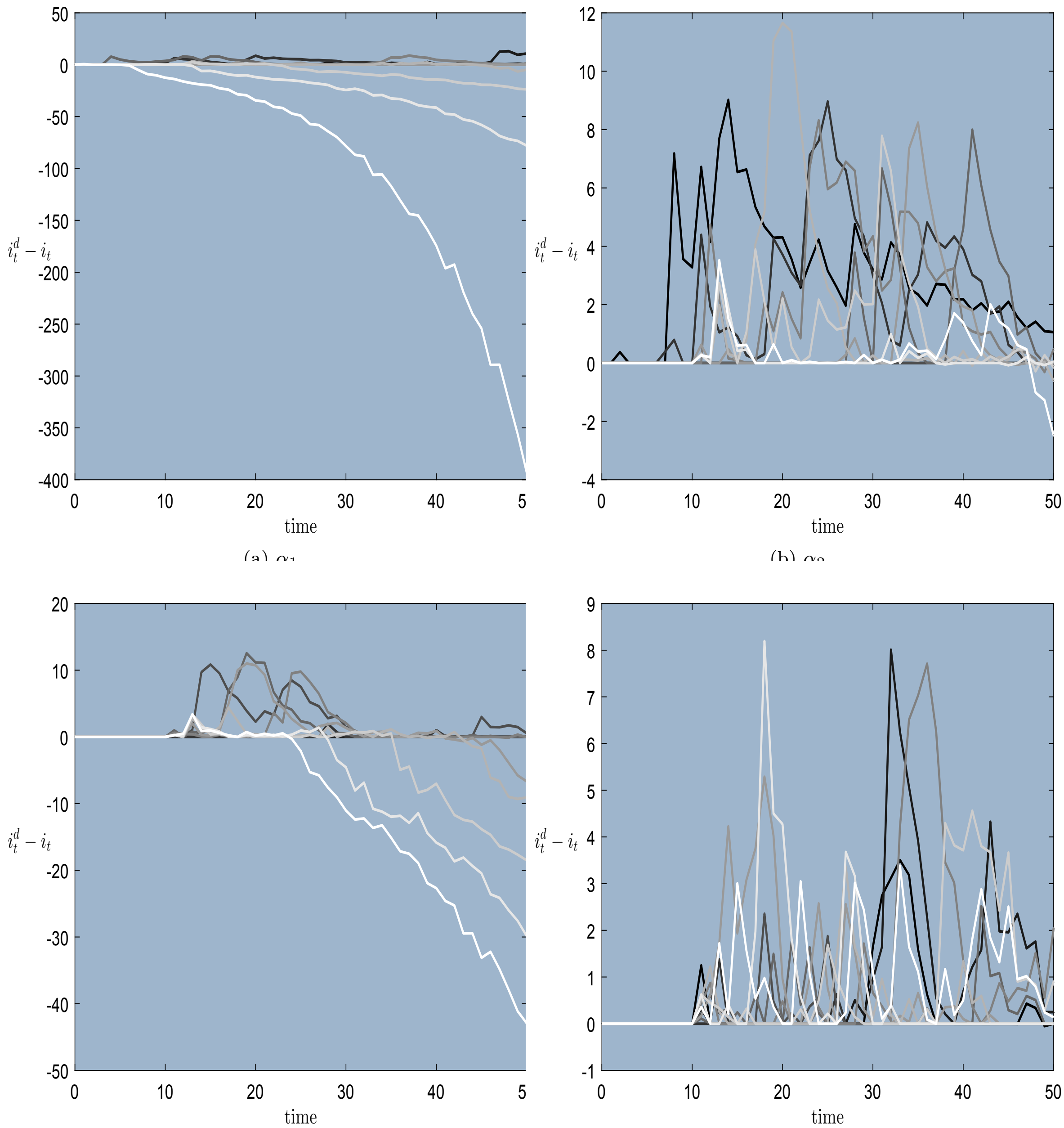
(d) Bank insolvencies subject to changes in M

Figure B.4: Effects of parameter changes in the partner selection mechanism



(a) γ_1 (b) γ_2

Figure B.5: Credit market frictions with respect to investment function parametrization



(a) α_1

(b) α_2

(c) α_3

(d) α_4

Figure B.6: Credit market frictions with respect to consumption function parametrization

Appendix C

Derivations and Notes on the Third Chapter

C.1 Numerical Values and Distribution Functions

The numerical values that are used to compute all figures in the main text are reported in the following table.

Table C.1: Baseline numerical values

Parameter	Description	Value
γ	risk aversion parameter	0.06
σ_a	standard deviation of stock return	0.1
μ_a	mean expected stock return	0.03
$\sigma_{\bar{u}}$	standard deviation of firm's relative price	0.4
μ_u	mean of firm's relative price	0.267
η	parameter in bank's bankruptcy cost function	0.04
χ	parameter in firm's bankruptcy cost function	1.5
ϕ	production parameter/output-capital ratio	1.4
ψ	production cost function parameter	0.51
p^a	stock price	0.6
$\bar{B}$	reference amount of loans	60
$\bar{Q}$	reference amount of risk-free assets	10
$\bar{A}$	reference amount of risky assets	10
D	amount of deposits	10
R^a	expected return on stocks	0.04
R	reference policy rate	0.02
$\bar{R}^b$	reference loan rate	0.06
W^b	initial equity capital of the bank	8
W	initial equity capital of the firm	15

Moreover, in order to compute the figures numerically, we assume that the random variable u follows a normal distribution which can explicitly be written as

$$f(\bar{u}) = \frac{1}{\sigma_u\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{\bar{u}-\mu_u}{\sigma_u}\right)^2\right]. \tag{C.1.1}$$

$$F(u) = \frac{1}{2}\left[1 + \text{erf}\left(\frac{\bar{u}-\mu_u}{\sigma_u\sqrt{2}}\right)\right]. \tag{C.1.2}$$

where erf is the error function given by $\text{erf}(z) = \frac{2}{\sqrt{\pi}} \int_0^z e^{-t^2} dt$ with $z = (\bar{u}-\mu_u)/(\sigma_u\sqrt{2})$.

C.2 Proof of Proposition 2

For the sake of simplicity, assume that the distribution of the random sales price u is the uniform distribution with support $[0, \overline{x}]$ to exclude negative market prices. Thus, the distribution function for the intermediate range $0 < u < \overline{x}$ is given by

$$f(u) = \frac{1}{\overline{x}} \tag{C.2.3}$$

$$F(u) = \int f du = \frac{R^b}{\overline{x}} \left(\frac{g(Y) - W}{Y} \right). \tag{C.2.4}$$

Using the firm's budget equation (4.2), the weighted bankruptcy function is $(\chi R^b/\overline{x})(\psi Y^2 - W)$. It follows that the marginal bankruptcy costs from equation (4.8) refer to $\rho = (2\chi\psi R^b Y)/\overline{x}$. Hence, the optimal level of production is

$$Y = \frac{1}{2\psi R^b \left(1 + \frac{\chi}{\overline{x}}\right)}.$$

The firm's loan demand function is then obtained by using the financing identity (4.2) again and by solving for B which gives

$$\psi Y^2 - W = B$$

$$Y = \sqrt{\frac{1}{\psi}(B + W)}$$

Replacing Y in the optimality condition yields

$$\sqrt{\frac{1}{\psi}(B + W)} = \frac{1}{2\psi R^b \left(1 + \frac{\chi}{\overline{x}}\right)}$$

$$\frac{1}{\psi}(B + W) = \frac{1}{4\psi^2 R^{b2} \left(1 + \frac{\chi}{\overline{x}}\right)^2}.$$

Finally, the optimal loan demand is given by

$$B^D = \frac{1}{4\psi R^{b2} \left(1 + \frac{\chi}{\overline{x}}\right)^2} - W = m(R^b, W) \tag{C.2.5}$$

with the following properties:

$$\frac{\partial m(R^b, W)}{\partial R^b} = -\frac{1}{2\psi R^{b^3}\left(1+\frac{\chi}{\overline{x}}\right)^2} < 0$$

and

$$\frac{\partial^2 m(R^b, W)}{\partial R^{b^2}} = \frac{3}{2\psi R^{b^4}\left(1+\frac{\chi}{\overline{x}}\right)^2} > 0.$$

Hence, we can infer that the loan demand function is convex in the lending rate R^b. The demand function is thus downward sloping in the lending rate, i.e. the more credit the bank is willing to provide to finance the firm's production project, the lower the interest rate the firm is willing to pay for the loan. These properties hold for any support $\overline{x} \lesseqgtr 0$ due to the quadratic character the distributional boundaries enter the equation.

C.3 Proof for Lemma 1

As already mentioned in the main text it is quite unwieldy to derive an analytical expression for the firm's optimal loan demand due to the strong nonlinearities in the marginal bankruptcy cost function for the case of a normally distributed variable u. Solving for the optimal level of production Y and under the validity of Lemma 1, we obtain the interior solution

$$Y = (2\psi R^b)^{-1}. \tag{C.3.6}$$

Since $\mathrm{d}Y/\mathrm{d}R^b = -(2\psi R^{b^2})^{-1} < 0$ and $\mathrm{d}^2Y/\mathrm{d}R^b\mathrm{d}R^b = (\psi R^{b^3})^{-1} > 0$ we can infer that optimal output is convex in the loan rate R^b.

Taking into account the concave production function and the finance identity (4.2), and setting the parameter χ in equation (C.2.5) to zero, we obtain the credit demand function

$$B^D = (4\psi R^{b^2})^{-1} - W \tag{C.3.7}$$

with $\mathrm{d}B^D/\mathrm{d}R^b = -(2\psi R^{b^3})^{-1} < 0$ and $\mathrm{d}^2B^D/\mathrm{d}R^b\mathrm{d}R^b = 3/(2\psi R^{b^4}) > 0$ that indicates that the loan demand function is also convex in the funding rate R^b at least in the case of zero marginal bankruptcy costs.

To show that the bankruptcy costs do actually contribute but do not essentially define the curvature of the credit demand function, i.e. its convex shape, figure 4.1 in the main text illustrates how sensitively the credit demand reacts to changes in the bankruptcy cost parameter χ in the domain $\chi = [0, 3]$. Subsequently, we may infer – at least for the considered domain $\chi = [0, 3]$ – that equation (4.9) satisfies $\partial B^d/\partial\chi < 0$ and $\partial^2 B^D/\partial\chi\partial\chi > 0$.

C.4 Composition of the expected lending rate

When the bank computes its expected return rate on granting credit to the firm, it takes into account two cases, namely *i)* the case when the firm remains solvent and *ii)* when it defaults on its debt. The expected payoffs are

$$E[R^b] = \begin{cases} R^b & \text{if} \quad u \geq \bar{u} \\ \dfrac{uY - \Psi(B)}{g(Y) - W} & \text{if} \quad u < \bar{u}. \end{cases} \tag{C.4.8}$$

Related to the critical sales price (4.4), the receives in the default case are considered to be the revenues net of bankruptcy costs relative to the firm's production costs. The expected (real) rate of return is then obtained by weighting the respective returns with the probability of survival and the average probability that ensures that the firm's ability to pay back the loan is impaired. The expected lending rate is

$$\begin{aligned} E[R^b] &= R^b(1 - F(u)) + \frac{Y - \Psi_j(B)}{B} \int_0^{\bar{u}} u dF(u) \\ &= R^b(1 - F(u)) + \frac{f(u)}{2} \left(\frac{\phi(B+W)^{\frac{1}{2}}}{B} - \eta \right) \left(\frac{R^b B}{\phi(B+W)^{\frac{1}{2}}} \right)^2 . \end{aligned}$$

C.5 Credit supply under monitoring costs

Bank's expected profits are given by

$$\begin{aligned} E[\Pi] &= E\left\{ \tilde{R}^a A + R^b B + R(D + w^b - A - B) - RD \right\} \\ &= E\left\{ (\tilde{R}^a - R)A + (R^b - R)B + Rw^b \right\} \end{aligned} \tag{C.5.9}$$

or as fraction of wealth

$$\begin{aligned} E\pi &= E\left\{(\tilde{R}^a - R)a + (R^b - R)b + R\right\} \\ &= E\left\{\tilde{R}^a a + R^b b + (1-a-b)R\right\} \end{aligned} \tag{C.5.10}$$

with $\pi = \Pi/w^b$, $a = A/w^b$ and $b = B/w^b$. Also note that

$$E[R^b] = R^b[1 - F(u) + M] - \frac{\bar{\eta}}{2}M^2 \tag{C.5.11}$$

$$\begin{aligned} E[\tilde{R}^a] &= R^a - \frac{\gamma}{2}Var(R^a)A \\ &= R^a - \frac{\gamma}{2}Var(R^a)aw^b \end{aligned} \tag{C.5.12}$$

with M being the monitoring intensity. $\bar{\eta} > 0$ is the cost term in this specific example. The bar on the variable is used to differentiate to the bankruptcy cost approach applied in the main body of the text. As the expected lending rate suggest, an increase in monitoring activity M increases the probability of success $1-F(u)+M$, i.e. the probability of repayment. Maximizing (C.5.9) w.r.t. the monitoring intensity M gives

$$\frac{\partial \Pi}{\partial M} = R^b - \bar{\eta}M = 0$$

and thus

$$\widehat{M} = \min\left\{\frac{R^b - R}{\bar{\eta}}, 1\right\} \tag{C.5.13}$$

Substitute the optimal monitoring intensity (C.5.13) into the expected profit equation to get

$$\begin{aligned} E\pi\Big|_{M=\widehat{M}} = E(\tilde{R}^a - R)a + \Bigg\{ & R^b\left[1 - F(\bar{u}(b, R^b)) + \frac{R^b - R}{\bar{\eta}}\right] \\ & -\frac{\bar{\eta}}{2}\left(\frac{R^b - R}{\bar{\eta}}\right)^2 - R\Bigg\} b + (1-a-b)R \end{aligned} \tag{C.5.14}$$

Next, the maximization of bank profits w.r.t. R^b yields

$$\frac{\partial E\pi}{\partial R^b}\Big|_{M=\widehat{M}} = \left[1 - F(\bar{u}(b, R^b)) + \frac{R^b - R}{\bar{\eta}}\right] + \frac{R^b}{\bar{\eta}} - R^b\left(\frac{\partial F(\bar{u}(b, R^b))}{\partial R^b}\right) - \frac{R^b - R}{\bar{\eta}} = 0$$

In brief, the default probability can be written as

$$F(\bar{u}(B, R^b)) = \frac{R^b}{2}\sqrt{\frac{\psi}{B+w}}B$$

or equivalently

$$F(\bar{u}(b, R^b)) = \frac{R^b}{2}\sqrt{\frac{\psi}{bw^b+w}}bw^b$$

then, the derivative is

$$\begin{aligned}\frac{\partial F(\bar{u}(B, R^b))}{\partial R^b} &= f(\bar{u}(B, R^b))\frac{\partial \bar{u}}{\partial R^b} \\ &= \frac{B}{2}\sqrt{\frac{\psi}{B+w}} \quad \Leftrightarrow \quad \frac{bw^b}{2}\sqrt{\frac{\psi}{bw^b+w}}.\end{aligned}$$

Hence, the FOC becomes

$$\begin{aligned}\left[1 - F(\bar{u}(B, R^b)) + \frac{R^b - R}{\bar{\eta}}\right] + \frac{R^b}{\bar{\eta}} - \underbrace{R^b\left(\frac{B}{2}\sqrt{\frac{\psi}{B+w}}\right)}_{=F(\bar{u})} - \frac{R^b - R}{\bar{\eta}} &= 0 \\ 1 + \frac{R^b}{\bar{\eta}} - R^b B\left(\sqrt{\frac{\psi}{B+w}}\right) &= 0\end{aligned}$$

Collecting terms yields the optimal interest rate for any given level of the loan (supplied by the bank)

$$R^b = \frac{1}{B\left(\sqrt{\frac{\psi}{B+w}}\right) - \frac{1}{\bar{\eta}}}. \tag{C.5.15}$$

This loan offer curve exhibits very similar properties compared to the functions depicted in figure 4.2 except of the fact, that there is no direct interest rate correspondence. In particular, we find $dR^b/dB > 0$ and $d^2R^b/dBdB > 0$ for a broad range of credit volumes and corporate equities.

C.6 Proof of Proposition 3

Let $\widehat{R}^b$ be a solution to the problem specified in (4.16) and exclude any solutions that lead to credit rationing, i.e. assume that $h'_{R^b} > 0$. From Proposition 2, we know that the demand for loans is shrinking in the lending rate $m'_{R^b} < 0$. Further, from figure 4.3 in section 4.2.3, we inferred that the bank's offered credit volume reacts negatively in the risk-free reference rate R, hence $h'_R < 0$. To carry out the comparative statics, we can use the *Implicit Function Theorem.* Correspondingly, let $z(\widehat{R}^b, R, W)$ be the market clearing function that is equilibrated for $\widehat{R}^b$. The theorem then states

$$\frac{d\widehat{R}^b}{dR} = -\frac{\frac{z(\widehat{R}^b,R,W)}{\partial R}}{\frac{z(\widehat{R}^b,R,W)}{\partial \widehat{R}^b}} = -\frac{z'_R}{z'_{R^b}} = -\frac{h'_R}{h'_{R^b} - m'_{R^b}} > 0. \tag{C.6.16}$$

In words, the model predicts a positive interest rate pass-trough effect for the interior solution, the domain where no financial market frictions in terms of credit rationing prevail.

C.7 Proof of Proposition 4

Similar to appendix C.2, we consider the random sales price u being uniformly distributed with support $[0, \overline{x}]$. The loan risk premium then refers to the expected risky return on lending less than the risk-free return, which reflects the opportunity to invest the amount into the risk-free asset Q, formally

$$\begin{aligned} RP &= E[R^b] - R \\ &= R^b(1 - F(u)) + \left(\frac{Y}{B} - \eta\right) \int_0^{\bar{u}} u f(u)\, du - R \\ &= R^b - R + \frac{R^{b2}}{2\overline{x}} \left(\frac{B}{Y}\right) - \frac{\eta}{2\overline{x}} \left(\frac{R^b B}{Y}\right)^2 \end{aligned}$$

which can also be expressed by

$$\begin{aligned} RP &= R^b - R - \frac{R^b}{2} F(u) + \frac{\eta\overline{x}}{2} F(u)^2 \\ &\text{or} \\ RP &= R^b - R - \frac{R^b}{2\overline{x}} \bar{u} + \frac{\eta}{2\overline{x}} \bar{u}^2 \end{aligned} \tag{C.7.17}$$

The equilibrium credit spread is obtained by evaluating the previous equation at the equilibrium point, it yields

$$\widehat{RP} = \widehat{R}^b - R - \frac{\widehat{R}^b}{2\overline{x}}\widehat{\overline{u}} - \frac{\eta}{2\overline{x}}\widehat{\overline{u}}^2. \tag{C.7.18}$$

The first derivative gives

$$\frac{d\widehat{RP}}{dR} = \frac{d\widehat{R}^b}{dR} - 1 - \frac{\widehat{\overline{u}}}{2\overline{x}}\frac{d\widehat{R}^b}{dR} - \frac{\widehat{R}^b}{2\overline{x}}\left[\frac{d\widehat{\overline{u}}}{dR} + \frac{\partial\widehat{\overline{u}}}{\partial\widehat{R}^b}\frac{d\widehat{R}^b}{dR}\right] - \frac{2\eta}{2\overline{x}}\widehat{\overline{u}}\left[\frac{d\widehat{\overline{u}}}{dR} + \frac{\partial\widehat{\overline{u}}}{\partial\widehat{R}^b}\frac{d\widehat{R}^b}{dR}\right] \tag{C.7.19}$$

where the part $\dfrac{\partial\widehat{\overline{u}}}{\partial\widehat{R}^b}\dfrac{d\widehat{R}^b}{dR}$ is zero by the *envelope theorem*. The derivative of the random sales price w.r.t. the reference interest rate is

$$\frac{d\widehat{\overline{u}}}{dR} = \frac{\left[\dfrac{d\widehat{R}^b}{dR}\widehat{B} + \widehat{R}^b\dfrac{\partial\widehat{B}}{\partial\widehat{R}^b}\dfrac{d\widehat{R}^b}{dR}\right]\widehat{Y} + \widehat{R}^b\widehat{B}\dfrac{\partial\widehat{Y}}{\partial\widehat{R}^b}\dfrac{d\widehat{R}^b}{dR}}{\widehat{Y}^2}.$$

Applying the *envelope theorem* again, the indirect derivatives $\dfrac{\partial\widehat{B}}{\partial\widehat{R}^b}\dfrac{d\widehat{R}^b}{dR}$ and $\dfrac{\partial\widehat{Y}}{\partial\widehat{R}^b}\dfrac{d\widehat{R}^b}{dR}$ are zero as well. Consequently, the derivative is

$$\frac{d\widehat{\overline{u}}}{dR} = \frac{d\widehat{R}^b}{dR}\frac{\widehat{B}}{\widehat{Y}}. \tag{C.7.20}$$

It follows, conditional on a positive interest rate pass-trough effect, i.e. if Proposition 3 holds, that $d\widehat{\overline{u}}/dR > 0$ as long as u is in the domain $0 < \widehat{\overline{u}} = \widehat{R}^b\widehat{B}/\widehat{Y} < \overline{x}$. Collecting all intermediate results, i.e. a positive interest rate pass-though effect $d\widehat{R}^b/dR > 0$, the positive effect on the critical sales price $d\widehat{\overline{u}}/dR > 0$ and assuming that the equilibrium threshold price $\widehat{\overline{u}} > 0$, then equation (C.7.19) is greater than zero, indicating that the risk premium that is charged in equilibrium rises with the reference interest rate R. Formally,

$$\frac{d\widehat{RP}}{dR} = \left(1 - \frac{\widehat{\overline{u}}}{2\overline{x}}\right)\frac{d\widehat{R}^b}{dR} - 1 - \left(\frac{\widehat{R}^b + 2\eta\widehat{\overline{u}}}{2\overline{x}}\right)\frac{d\widehat{\overline{u}}}{dR} \lesseqgtr 0.$$

Using equation (C.7.20) and the definition $\widehat{\widehat{u}} = (\widehat{R}^b\widehat{B})/\widehat{Y}$, one can simplify the latter result by writing

$$\frac{d\widehat{RP}}{dR} = -\frac{d\widehat{R}^b}{dR}\widehat{\widehat{u}} - \left(1 - \frac{d\widehat{R}^b}{dR}\right)\overline{x} - \frac{\eta}{\widehat{R}^b}\frac{d\widehat{R}^b}{dR}\widehat{\widehat{u}}^2 \leq 0 \tag{C.7.21}$$

which gives a unique negative solution for the case where Proposition 3 holds and the interest rate pass-through is less than or equal to one-to-one, i.e. $0 \leq d\widehat{R}^b/dR \leq 1$. Otherwise, the sign of the derivative depends on the risk aversion parameter η, the support of the random sales price $\overline{x}$ and the size of the equilibrium critical price $\widehat{\widehat{u}}$.

C.8 Proof of Proposition 5

To study monetary policy in terms of comparative statics we briefly recall the optimality condition referring to the demand for the risky asset when the credit contract is optimally signed. It is given by

$$\widehat{A} = \frac{E[R^a] - p^a R}{\gamma Var(R^a)}. \tag{C.8.22}$$

The re-allocation of the bank's asset portfolio towards A in responds to R may be inferred by simply calculating the slope of the optimality condition, it is given by

$$\frac{\partial \widehat{A}}{\partial R} = -\frac{p^a}{\gamma Var(R^a)} \tag{C.8.23}$$

If the expected return is assumed to be constant, the optimality condition (4.15) is linear with the slope expressed in (C.8.23).

We may also analyze how much the expected return on the risky asset must increase in order to maintain a stable demand on this asset in the case when the policy rate increases by 1%. Analytically we derive the MRS, it is given by

$$MRS_{\{R^a,R\}} = \frac{\partial \widehat{A}/\partial R^a}{\partial \widehat{A}/\partial R}. \tag{C.8.24}$$

The partial derivative w.r.t. R^a is given by

$$\frac{\partial \widehat{A}}{\partial R^a} = \frac{Var(R^a) - 2R^a(R^a - \mu_a)}{\gamma(R^a - \mu_a)^4}. \tag{C.8.25}$$

Substitute out both partial derivatives in equation (C.8.24) and notice that $Var(R^a) = (R^a - \mu_a)^2$, we get[1]

$$MRS_{\{R^a,R\}} = -\frac{R^a + \mu_a}{p^a(R^a - \mu_a)}. \tag{C.8.26}$$

Using the numerical values depicted in table C.1, we infer that the slope of the stock demand function is $\partial\widehat{A}/\partial R = -1000$, indicating that a decrease in the policy rate by 1% lowers the demand for the risky asset by 10 units which gives a change in the bank's balance sheet for this asset by $d(p^a\widehat{A}) = -6$. The substitution elasticity among the tradable assets refers to $MRS_{\{R^a,R\}} = -11.6667\%$.

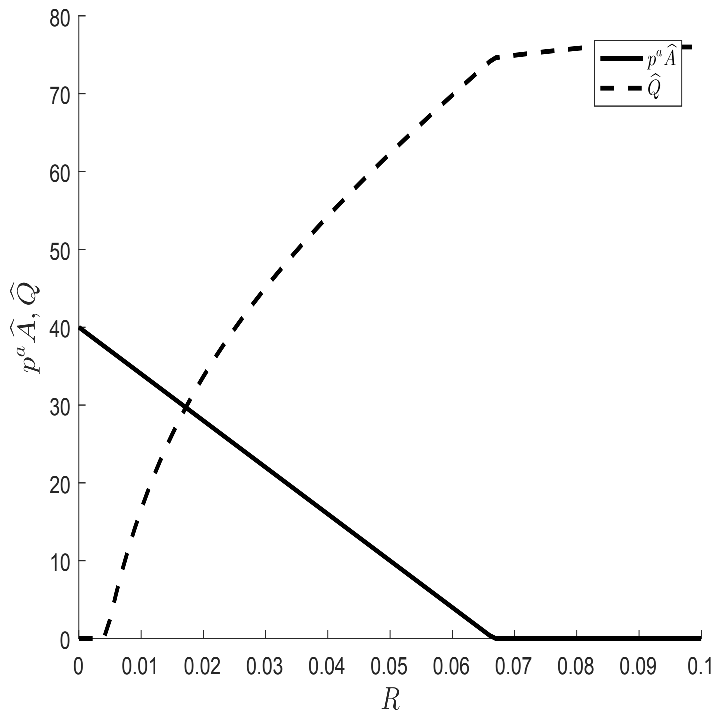


Figure C.1: The demand for the financial assets p^aA and Q

[1]The variance of the expected return on the risky asset is defined by $Var(R^a) = E(R^a - \mu_a)^2$. Since R^a already represents the expected value of the stock return, we leave the expectation operator E out by virtue of the law of iterated expectations.

C.9 Empirical data on the bank's leverage ratio

Figure 4.5b displays the bank's capital ratio which is the bank's equity capital (including retained earnings) relative to its RWAs. As the figure suggests, it possesses a relatively stable magnitude around 12% over the entire range of the reference interest rate R. In order to show that the leverage ratio exhibits a convenient order of magnitude, we compare it with the empirical time series of US banks' average capital-asset ratio in the time domain 2000-2016. The data has an annual frequency. The capital term comprises Tier 1 capital and total regulatory capital including distinct subordinated types of debt instruments that need to be repaid if the funds are required to maintain minimum capital levels. The term total assets includes financial as well as nonfinancial assets. A direct comparison is difficult since the data comprises several bank specific terms that are not covered in our stylized model, e.g. general and special reserves, provisions, Tier 2 and Tier 3 capital, etc. However, we refer to it as a directive to check the meaningfulness of the calibration and the results. The empirical bank reference leverage ratio is illustrated in the following figure.

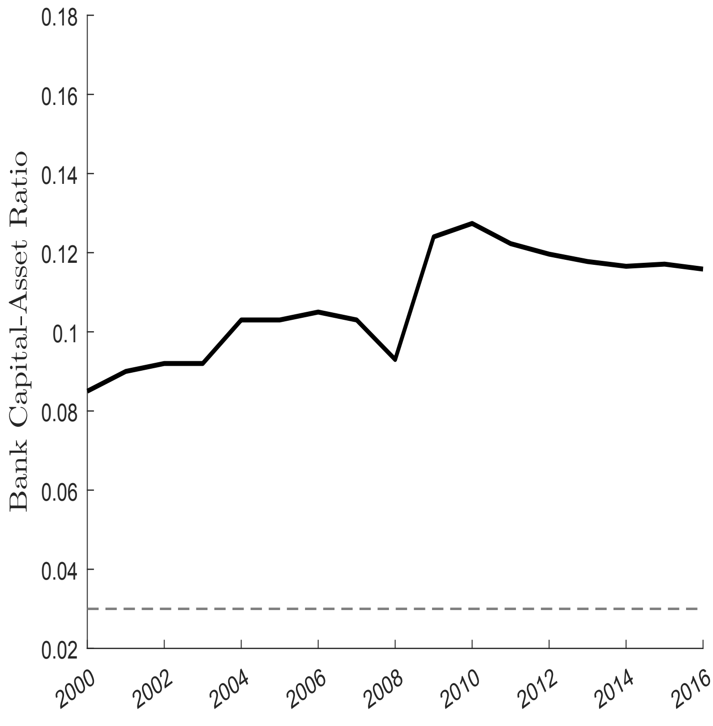


Figure C.2: Bank's capital-asset ratio in the US. Source: World Bank, Bank Capital to Total Assets for United States [DDSI03USA156NWDB], retrieved from FRED, Federal Reserve Bank of St. Louis;
`https://fred.stlouisfed.org/series/DDSI03USA156NWDB`, February 13, 2019.

Note that the bold black line refers to the data and the dashed gray line to the Basel III minimum requirement. It possesses a mean of $\widehat{\mu}_{LR} = 10.75$ with standard deviation $\widehat{\sigma}_{LR} = 1.35$. From the figure we can infer that the banks' average capital-asset ratio fluctuates relatively stable around its mean with the standard deviation of 1.36. It also shows that the banks' leverage ratio increased persistently in the post-crisis era, from 2008 onwards, when the FED lowered the federal funds rate close to zero.