Inauguraldissertation
zur Erlangung des akademischen Grades eines Doktors der Wirtschaftswissenschaften
(Dr. rer. pol.)

# Speculation and the economy

vorgelegt von
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an der Fakultät für Wirtschaftswissenschaften
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Juli 2015

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Thèse pour obtenir le grade de docteur ès Sciences Economiques

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# Acknowledgements

Carrying out this work would not have been possible without the support of a number of people. The help and support that I was fortunate to receive was scientific in nature but also of a moral and encouraging kind. I would like to thank Herbert Dawid and Antoine Mandel who contributed most of the advice to the thesis. They provided guidance and critical remarks that helped a lot in improving and shaping the thesis. Furthermore, they were a source of motivation and encouragement. I am especially grateful for their efforts in making work on this thesis possible throughout the entire duration. I would like to thank Jean-Marc Bonnisseau who facilitated the research stay in Paris. Without his support, carrying out this thesis under a Cotutelle-agreement would not have been possible. Taking it under his supervision was key to that undertaking. Also, his support and activity in resolving administrative issues was a great relief during the stay in Paris. Furthermore, I would like to thank the members of the committee who are willing to spend time and effort on the evaluation of the thesis.

Last, I want to thank those persons closest to me for their understanding and endurance of the restrictions that working on the thesis has put on the private part of my life.

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# Chapter 1

# Introduction

## 1.1 Motivation

Speculative behaviour is an inherent part of economic activity and can build up over time. "More confident expectations of a steady stream of prosperity and of an increase in profits induce investors to buy riskier stocks. Banks make riskier loans in this more optimistic environment. The optimism increases and may become self-fulfilling until it evolves into a mania." (Kindleberger and Aliber, 2005, p. 37.) This statement addresses two aspects of speculation. First, speculation contributes to asset price bubbles, for instance stock bubbles (Shiller, 1981; DeBondt and Thaler, 1985, 1987). Second, speculation may develop over time as a result of prosperous economic activity. The statement by Kindleberger and Aliber (2005) points out that speculation can also occur at the level of firm funding. More than that, speculation can be a direct result of prior funding - it can be self-fulfilling. The reason is the reflexivity of funding. Firms may be able to evolve better if they have access to funding. If they do, the funding was justified ex post. As investment is financed externally to a large extent (Allen and Santomero, 2001), the initial provision of funds may in fact be the very reason that the firm has made profits at all. The impact of this reflexivity was pointed out recently by the German committee for financial stability (Ausschuss für Finanzstabilität). In its first report to the German parliament about financial stability in Germany in June 2014, the committe stated that rent-seeking by financial institutions in the aftermath of the financial crises of 2007 resulted in "easy access to funding also for non-creditworthy firms and high emission volumes" (Deutsche Bundesbank, 2014, p. 8.). Furthermore,

this access in conjunction with financial risk at the housing market led to a "self-enforcing circle of non-sustainable price development and increasing debt levels and looser credit granting standards." (Deutsche Bundesbank, 2014, p. 1.) The same self-fulfilling character is present after that optimism vanishes and lenders realize that they have "too many risky loans. ...[T]hey become reluctant to renew these loans... The lenders also raise credit standards for new loans." (Kindleberger and Aliber, 2005, p. 78.) This reflexive mechanism is even clearer for the stock market. Investors buy stocks because they expect the price to rise while their demand is the very reason for a price increase thereafter. The market propels *itself* (Kaplan, 2003). Market-wide speculation, or manias, means that the expectations and the behaviour of the agents need to be aligned. Homogeneity in behaviour *due to expectations* has already been introduced by Keynes (1936) who called the entrepreneurial outlook "animal spirits" and later on Minsky (1970) acknowledged that in times of economic flourishing also optimism emerges among the members of both parties, lenders and borrowers. According to Kindleberger and Aliber (2005) speculation occurs in two stages. First, agents respond to shock in a rational manner. Second, the anticipations of capital gains play an increasing role. That means that in an early stage investors aim at earning interest from their investment and at the latter stage where speculation is predominant, they aim at a return from reselling the principal. For a survey of the formation of expectations literature in the economic context, please refer to Pesaran and Weale (2006).
Understanding the interplay between rising expectations of investors and hence their investing in projects that are more risky seems to be crucial for dealing with large economic fluctuations.[1] This thesis addresses the impact of speculation on the real economy. It focuses on the question how funding behaviour that is influenced by speculation contributes to economic development over time. The thesis addresses both possible sources: speculation at a financial market affecting the real economy as some kind of spill-over. And it addresses speculation arising out of the real economy as result of reflexivity in the financing process of economic activity. If credit is to a large extent a facilitator or a precondition of investment then it is crucial to understand its role in the emergence or decline of business on the real side of the economy.

This dissertation has three parts which also can be read as independent papers. The notation in each part stands for its own. This work aims at deepening the understanding of the ramifications between technological progress, expectations, funding constraints, and economic development. Therefore, an agent-based framework is used which is able to capture the various feedback effects between respective variables. We use computer simulations for carrying out the models since their complexity makes them

[1] Compare to Borio, 2012.

analytically non-solvable. The first part (chapter 2) explores how stock market frenzies influence the economy's output patterns when firms' use of credit depends on the stock market valuation as well. The second and third part (chapters 3 and 4) are intended to shed light on the emergence of technological progress in the presence of possible financing constraints that depend on each single firm's prospects. In both of the latter chapters, access to credit depends on the aggregate variables and on the relative position of each single firm in its corporate environment.

The first paper (chapter 2) incorporates stock prices into a model of business cycles. Throughout the entire chapter the bank lending channel is the transmitter of expectations to the real economy. Three well-known channels of influence of these stock prices on the real market are studied: credit rating, bankruptcy ruling and managerial compensation. The second and third paper focus on technological advancement when there are credit shortages based on the credit rating outcome. The second paper examines a single sector and identifies which parameters are most influential on the technological progress in the long run. The third paper focuses in particular on the impact of variety in the credit rating practice. The model is similar to the one in the second part but consists of two industrial sectors. Those compete for credit while one sector is more likely to improve technology. Competition establishes negative feedback of technological progress on credit supply for a sector.

Results in chapter 2 indicate that stock market dynamics have the potential to impact the business cycle via firm expectations. Market-wide optimism and pessimism can transmit to amplified swings on the business cycle because managers are willing to take different levels of risk. They derive their risk assessment from the stock market mood. Also, if there are times of high volatility this can add some severity in the amplitude of the business cycle.
Results in chapter 3 show that technological progress depends highly on the availability of credit. The way banks provide credit and assess the creditworthiness of firms is a key determinant of the pace of technological progress. Chapter 4 reveals that if there are competing sectors the bank routine is the key determinant of the evolution while the particular way it forms its expectations is of minor impact.

## 1.2 Background

### 1.2.1 Economic Activity and the Financial Market

Economic activity is characterized by so called business cycles. Business cycles are recurring phases of expansion and contraction in an economy. Business cycles are seen as being mainly driven by investment: "[w]e know now, thanks to over half a century of national accounts, that in practice it is indeed the fluctuations in investment which in general make the major quantitative contribution to movements in total output over the course of the business cycle." (Ormerod, 2009, p. 28, footnote 6.)
Schumpeter (1942) points out that the fluctuations in output occur due to severe changes in technology which trigger an almost complete reorganization of the economy. Fisher (1930) and also Keynes (1936) attribute credit shortages to be a major source of declining economic activity. The main source of those shortages is the changing value of asset prices and the liquidity preference, that is, the less valuable assets become, the more demand for a safety buffer emerges and thus, the less credit will be circulating (Minsky, 1970). Borio et al. (2015) strengthen this view as they investigate the connection between price deflation and output growth empirically. They use a sample of 38 countries for a time span over 140 years up to 2013 and find that asset price deflation is crucial for retarding output growth while goods price deflation has a negligible impact. Furthermore, Borio (2012) characterizes stylized facts about a financial cycle in this context. Credit and property prices co-vary significantly. Also, the financial cycle has a lower frequency as the business cycles. On average, the business cycle lasts 8 years, while the financial cycle has double that length. Peaks in the financial cycle are closely related to systemic banking crises and last, the credit-to-GDP deviation and the asset-price-deviation from long-term averages are very good indicators for upcoming financial crises.

Speculation in terms of optimistic expectations can be beneficial for the economy at least in the short run if investment is financed. In this case, it does not divert funds from productive activity but is dangerous nevertheless. Even if investors are rational, excessive leverage can occur due to optimistic outlooks fueled by rising collateral values which results in a boom-bust circle. If the financial market is hurt along the way, the bust may end in a recession (Minsky, 1970; Kindleberger and Aliber, 2005; Geanakoplos, 2010). There have been several financial crises followed by recessions for instance the 'black Friday' of 1929 or the 'dotcom-bubble' of 2000. There was a severe crisis in 2007-2009 due to the subprime mortgage based credit default swap exposure where eventually, credit defaults triggered the crisis. The 'dotcom-bubble' occured because information technology drove *stock prices* up (Dell'Ariccia et al., 2012). The subprime mortgage crisis was predominantly a crisis in the financial sector, triggered by innovative risk sharing schemes leading to too much leverage (Semmler, 2011, pp. 244-245). A downturn in the economy taking the scale of a depression is linked to the financial sector as "[a] necessary condition for a deep depression is a prior financial crisis." (Minsky, 1970, p. 62.) This statement is supported by empirical findings for 14 countries over more than 140 years where cycles that involve financial market breakdowns show much more pronounced amplitudes (Jordà, Schularick and Taylor, 2013).

Comparing to that theory of credit-driven cycles, Perez (2009) develops the theory of technology-pushed booms, based on the observation of the dotcom bubble building up in the 1990s. She connects the *following credit-driven* bubble which ended in 2007 with the dotcom-bubble by theorizing that both are interrelated. The argument is that the diffusion of information technology created a boom with ever rising expectations about the positive impact of that new technology. Those rising expectations lead to massive increase in credit lending.

### 1.2.2 About The Impact of Stock Market Trade on the Economy

"The dispute about the importance of changes in the stock market revolves around their causal role in economic fluctuation: Are they a source of variation in aggregate demand? Does the causation run solely in the opposite direction? Or do the levels of economic activity and of stock prices simply respond similarly to other, more basic, economic forces, with no direct causal link between the two?" (Bosworth, Hymans, Modigliani, 1975, p. 257.)

The possible ramifications between excessive stock market trade and the real economy take place via demand or supply impacts. Stock market profits are not merely paper profits as they affect "capital supply, distribution and production, and international relationships." (Richter-Altschäffer, 1931, p. 230.) The *composition* of production is affected if purchasing power is diverted to speculation. (See Richter-Altschäffer, 1931, p. 235 ff.). Nevertheless, the demand impact should be rather small if only wealthy people are stockholders in the first place (Hardy, 1937).

Investment can be negatively affected since the "turnover of stock does tie up means of circulation ... [and] reduces the reserve of credit available to entrepreneurs for new productive enterprise." (IBID.) Furthermore, "[t]he panic atmosphere of crash lames many enterprising forces." (Richter-Altschäffer, 1931, p. 238).

Booms in security markets also mean low costs of issuing new securities (Hardy, 1937). There might be an even amplified impact since "effects... psychological in nature ... stimulate[] the spirit of enterprise and increase[] the possibility for new stock issues" (Richter-Altschäffer, 1937, pp. 237,238). The pecking order theory of corporate finance suggests that the potential of issuing securities might not be used exhaustively as bank credit is the major source of financing (Mayer, 1990; DeHaan and Hinloopen, 2003).

Furthermore, if funds for buying those securities come from savings, there is a minor impact on capital goods. If credit is used, it does have a more significant impact (Hardy, 1937). Magdoff (2006) points out that if debt is used for financial transactions, this has no direct impact on the economy, except for leverage. Because of the limited impact of the demand side outlined by Hardy (1937) and evidence from corporate finance literature we focus on the role of speculative behaviour on credit usage in corporate finance.

### 1.2.3 Relevance of Credit

The financing of corporate activity is subject to differences throughout the world. In the USA a market based culture prevails and thus equity plays a huge role while in Europe the use of bank credit is the most common source of funds (Allen and Santomero, 2001). Mayer (1990) points out that although the financial systems differ severely across countries there are stylized facts about corporate finance:

1. Retained profit is the major source of financing.
2. Bank credit is the major source of external funds.
3. The relation between bank credit and retentions is strongly inverse.
4. Small and medium firms rely more on external finance than large firms.

Those findings are backed by other empirical studies. De Haan and Hinloopen (2003) examine 153 Dutch firms and find a clear pattern of financing preferences: most preferred are retained earnings, followed by bank credit, equity and at last bond issuing. Marsh (1982) points out that the choice between equity and (long-term) debt, for instance bonds, relies heavily on the past prices of those. Furthermore, the choice seems to depend more on target debt ratios than on company size, bankruptcy risk or asset composition. The persisting structure of funds also casts doubt about the Modigliani and Miller (1958) model. They postulate that in a frictionless market the financial structure of a firm, that is the source of funds, does not influence the value of the firm.

Basically, there are two competing explanations for the empirically observed financing structures: a tradeoff theory where firms weigh the costs and risk of each source of financing and choose an optimal composition, and a pecking order theory where there are hierarchies among the sources of funds. Graham and Leary (2011) point out that both explanations have some explanatory power which empirically depends on which samples are chosen and whether cross-sectional patterns or within firm financing patterns are examined. For mature firms with a large share of asset value and low growth opportunities the pecking order seems to fit very well while for other firms the tradeoff model fits directionally. Along with the *pecking order* theory there seems to be explanatory power in the culture of the markets by which financing methods would depend more on habit than on an extensive trade-off consideration based on the costs of funding (Myers, 1983).

The process of granting credit involves the assessment of many pieces of information. The creditor needs to know how likely it is that his loan is paid back. The evaluation usually takes the form of a credit rating that includes not only hard figures but also more soft information about the debtor. First of all this is his relation to the creditor and their commercial history. Banks need to provide a rating of their debtors according to the Basel II agreement (Reichling et al., 2007). They can do ratings on their own (internal rating ) or rely on external ratings provided by rating agencies. There are many commonalities between internal and external ratings and external ratings are usually used for large companies above a particular threshold of market value. The crucial differences between pieces of information used for rating are whether they are of quantitative or qualitative nature. Quantitative information can be extracted from financial statements such as the balance sheet. Those pieces of information are backward-looking. Nevertheless, "[a]n assessment that only includes the present must not be decisive - the [firm's] focus on the orientation to the future must be satisfactory." (Kremer and ten Hoevel, 1989, p. 122). In order to assess the likelihood of credit repayment, a forward looking approach is necessary: "[a]ssessing an obligor's resources for fulfilling its financial commitments is primarily a forward-looking exercise." (Standard and Poor's, 2011, p. 5.) This can usually only be achieved by assessing the available information qualitatively, such as market outlook, management quality or brand value. There is an inherent speculative element in qualitative assessment. Furthermore, it is highly subjective. Credit analysts tend to be less optimistic and give a lower rating than credit advisors who actually want to sell the credit (Everling et al. 2009, p. 233 f.). Banks use ratings that are to some extent standardized. There are however, differences in rating models in terms of which model is used for processing the information into a default probability. For an overview, Crouhy et al. (2000) report different approaches from four private companies. There is a rating on the probability that a firms moves from one credit quality to another. Also, the option pricing model as well as an actuarial approach are in use. Last, default probabilities based on macroeconomic variables are applied as well. Furthermore, Reichling et al. (2007) focus on the sources of information that are actually used by banks and rating agencies. Those are not only balance sheet and income statement information, but also inquiries with the management or expert statements.

### 1.2.4 Modelling Approaches

Asymmetric information models rely on the notion that credit and financial markets are not frictionless and thus the source of funding for firms does matter in contrast to the early theoretical approach of Modigliani and Miller (1958). Empirical evidence however, suggests that if there are frictions, the selection process might be disturbed so that not the financially soundest firm but that with the highest collateral may survive (Zingales, 1998). Bernanke, Gertler and Gilchrist (1999) develop an equilibrium model with credit market frictions where a 'financial accelerator' amplifies shocks to the economy. Credit supply is endogenous and in equilibrium firms pay less credit if they have a high value of collateral. Since the collateral value is pro-cyclical the paid interest is countercyclical. In equilibrium, the lender also requires a higher premium for more risk and thus firms pay most when being the most fragile. This mechanism amplifies the cyclical behavior of the system. Greenwald and Stiglitz (1990) develop a model that combines such an accelerator with information asymmetries and risk averse firms. In their framework, firms take into account the risk associated with information imperfections and act more prudent. They therefore reduce production. This affects demand facing other firms and thereby transmits a shock to other firms.

In order to yield results about the impact of financial frictions however, equilibrium models à la Bernanke, Gertler and Gilchrist (1999) or Greenwald and Stiglitz (1990) rely on some assumption about the solvency of the agents. Even if they do not assume perfect capital markets, the borrowing constraint must be assumed for example by collateral assumptions. In practice however, "insolvency of the borrower can arise without the borrower moving up to his or her borrowing capacity." (Semmler 2011, p. 28 f.) This means that actual bankruptcy is highly idiosyncratic and, in conjunction with the granular theory, it does matter who is bankrupt in order to determine the effect on the macro economy. Gabaix (2011) establishes the granular theory and shows that idiosyncratic bankruptcy shocks can trigger business cycles, depending on which company is actually affected by the shock. The limited use of equilibrium macro models is also put forward because of their empirically not justifiable underlying assumptions (Colander et al., 2008; Juselius and Franchi 2007). In order to be analytically tractable important characteristics of the inherent complexity of economies are neglected such that it is assumed that the fate of any single individual is the same as that of the entire economy. Nevertheless, this is a problem since this defies heterogeneity and emergence. Emergence states that the behavior of the aggregate system is different from the behavior of its single components as the Sonnenschein-Mantel-Debreu aggregation problem already suggests (Colander et al., 2008). A way of coping with this shortcoming is the use of so called agent-based models. Those rely on computer simulation of a multiple-agents setup where the development of each individual agent can be tracked as well as the evolution of the aggregate system.

There are some features of economies that agent-based models promise to be able to deal with which equilibrium models cannot: emergence, low level of predictability at a point in time, limited cognition of individual agents and multiple possible histories (Ormerod 2009). Emergence deals with differences in individual dynamics and aggregate dynamics. Since agents make decisions in situations of genuine uncertainty (Knight, 1921; Keynes, 1921) the path of evolution of their decisions and thus the entire economy is hardly predictable, especially since -due to the behavior- several outcomes are possible. Furthermore, "micro behaviors of individual households and firms are very diverse. Thus, we have *distribution* of responses by microeconomic agents as an equilibrium rather than a unique response by a representative agent." (Aoki and Yoshikawa, 2007). Such distributions, if observed in many empirical data examinations are deemed to be stylized facts. Delli Gatti et al. (2007) summarize 28 (!) stylized facts of economic features. Agent-based models can be 'validated' by their ability to replicate those facts.

## 1.3 Contribution of the Thesis

The thesis addresses two features of recent crises. An increasing collateral value, for instance rising asset prices, may lead to increasing usage of credit and leverage. This has been a problem in the 2007-2009 crisis (Dell'Ariccia et al., 2012). Furthermore, speculation at the stock market may have an impact on expectations in the real economy and thus an impact on credit and leverage. The technology bubble in the 1990 was fueled by new technology and rose expectations about a bright future of the economy with ever new possibilities (Semmler, 2011). We address the question to what extent asset prices and boom-bust periods can impact the real economy via credit in the first paper. We also want to address the question to what extent expectations can contribute to the actual advancement of technology when credit is the source of external financing. The second paper addresses this question by focusing on the determinants of individual credit supply and their impact on technological progress. The third paper focuses on the way credit ratings are conducted and its impact on credit supply on firms in different industries who compete for bank credit not only with firms in their own sector, but also with firms in the other sector.

### 1.3.1 Stock Price Related Financial Fragility and Growth Patterns

This part addresses how the mechanism of building up of leverage and financial fragility leading to business cyles is affected by stock price patterns. Leverage can boost output but if financial fragility is too high, firms cannot meet their due liabilities and go bankrupt. This leads to recessions (Minsky, 1970).

Delli Gatti et al. (2005) develop a model based on Greenwald and Stiglitz's (1990) financial accelerator approach which remedies two shortcomings of the financial accelerator model: the dynamics of the variance of financial positions can be analyzed and there is interaction between agents. Furthermore, they show that for instance, the distribution of firm sizes is responsible for the distribution of firm growth rates and that the changing network due to interaction of firms is what contributes to business cycles. Battiston et al. (2007) use such an approach to identify the impact of the structure of firm networks has on the likelihood that firms go bankrupt.

The build up of leverage and the point of bankruptcy are possibly affected by stock prices. The definition of *insolvency* offers two possible cases, either stock insolvency where the value of all assets is insufficient to honour the debt that is due, or flow insolvency where the current cash-flow is insufficient to cover the debit currently due (Wruck, 1991). In the model of Delli Gatti et al., bankruptcy occurs whenever net value is negative, which is the same as stock insolvency where net productive capital is less than bank debt. When the cash-flow expectations are taken into account, the *current* net value might still be negative, but due to the positive expectations, the present value of those expected cash-flows might lead to an overall positive assessment of the firms long-term value. In such a situation we observe insolvency but no bankruptcy. The importance of those expectations is that they first might differ among stakeholders and some might claim that the future earnings are quite meaningless while shareholders, for example, might tend to claim that optimism is reflecting the situation more accurately. The importance of those different expectations is discussed in more detail in Wruck (1991). The recent financial crisis brought forward a notion that its roots lie in parts in a too low capital buffer, that is too much leverage (Roubini and Mimh, 2010; Admati and Hellwig, 2014), which follows Minsky's view but also that there were caveats due to information asymmetry and moral hazard. It is stated that especially bank managers had wrong incentives to conduct business because they could reap the benefits of successful business but would not suffer any losses (Roubini and Mimh, 2010; Admati and Hellwig, 2014)

The main contribution of this chapter is to introduce feedback from stock prices into the model of financing constraints and growth. There are three ways of known feedback channels under examination: credit rating, bankruptcy determination and managerial compensation. Banks take the stock price into account when they process information in order to assess the creditworthiness of firms and thus take advantage of information that stock investors might possess. In bankruptcy processes all stakeholders can file for bankruptcy. If the stockholders value an insolvent firm very high, they might be unwilling to file for bankruptcy and convince other stakeholders to let the company go on. Third, managerial compensation relies often on granting stocks or stock options. Thus, managers are interested in pushing the stock market value of a company as high as possible. This might affect their choices. The second and third channel are examined for the impact of the random stock price on the model dynamics while they are compared with a scenario where a boom-bust cycle represents speculative influences in a stylized way.

Results of the models show that stock market features have a higher effect on the economy when transposed through firm behaviour than by bank behaviour. The reason is that the bank evaluates the firms relative to each other and therefore, market wide patterns do not affect the bank decision too much. Firms however, take different levels of risk, depending on the stock market. In boom times they are less likely to be declared bankrupt and that contributes to higher risks being taken. Also the volatility can play a role if the management is compensated partly in company stocks. The stock market volatility adds to the swings in the real economy. The managers act more sensitively when the volatility is high because price swings are expected to be more severe and their payoff is less forecastable. Furthermore, the leverage of a firm does impact how the managers react on stock price swings because they face different probabilities of bankruptcy. Managers of highly leveraged firms do benefit from volatility because they expect the benefits from further credit to outweigh the increase in the bankruptcy probability.

### 1.3.2 Credit Constrained R&D Spending and Technological Change

There is empirical literature on the effects of financing constraints on innovation. Those constraints are identified as obstacles to innovation and economic growth, for instance because they prevent firms from implementing better technology (e.g. Mina and Lahr, 2013) or disturb the selection process (e.g. Bottazzi et al., 2006, 2010). We contribute to this empirical literature by providing experimental insights on the importance of different interacting factors in the credit granting process for the successful promotion of technology. We introduce financing constraints to the model of evolutionary innovation by Nelson and Winter (1982) and test for the impact of market conditions and behaviour of agents on the long-run development. Several conditions are tested for their impact on the economy: credit supply, interest rate, bank policy, and firm behaviour. Credit supply and the interest rate as exogenous market conditions have the most distinct impact on the evolution of the economy. The higher the credit supply, the better the economy will evolve as it can finance R&D on top of investment and successfully apply better technologies. The impact of credit supply is non-linear. The interest rate has a negative effect on the evolution of the economy as it constitutes costs for the firms which cuts into their profitability and thus the ability to finance investment and R&D.

The bank provides credit to the firms based on a rating process that supplies each firm with a different share of total credit supply. This process takes into account the relative profitability and the market share of each firm. The profitability is a proxy for cash-flow and the ability to repay the credit. The market share is a proxy for collateral which is important if the cash-flow is too low for repayment.

When the bank focuses on market share the economy evolves a bit better than if the focus is on profitability. Firms exert competitive pressure through their technology and through their size.

The firms adaption of R&D effort based on profitability has only a distinct impact if there is credit abundance. Otherwise credit constraints induced by the bank overshadow any firm policy as R&D can only be conducted if investment demand has been fully met.

### 1.3.3 The Impact of Credit Rating on Innovation in a Two-sector Evolutionary Model

This model builds on the model developed in the second paper (chapter 3). It takes up the result that bank behaviour matters more than firm behaviour in the evolution of an industry. This result is developed further by establishing a more sophisticated credit supply policy and introducing a second sector in the economy. The second refinement refers to the fact that accounting based rating is subject to group norms (Altman and Saunders, 1998). That means that for access to credit it matters in which industry the firm is doing business. Usually, innovative sectors are not yet profitable but have the highest return potential. We account for that by the extended credit policy which will take expectations about the sectoral productivity differences into account. There is a tradeoff between risk and prospects that drives access to credit.

We ask how much does the particular characteristic of weighing the pieces of information in the credit decision matter? And furthermore, how much do expectational characteristics matter in the overall decision?

The bank policy that determines whether profits or sector-specific firm features matter more has a distinct effect on the evolution of the economy. There are two sectors, one high-tech sector and a low-tech sector. Firms are evaluated in relation to the entire economy based on their profitability and in relation to their competitors based on market share. The more the bank focuses on the profitability and hence on an economy-wide perspective, the better the high-tech sector will evolve. It has an inherent advantage in its higher probability of finding better technology. This adds to a profitability advantage compared to the low-tech sector. If the bank only cares about profitability the advantage is the most distinct. By taking into account sector-specific information the bank accounts for bankruptcy risk. If there are more bankruptcies in one sector the bank will reduce the supply of credit to this sector. As bankruptcies are a direct result of innovation success due to competition, the high tech sector cannot benefit too much from its inherent advantage as the bank focuses on the bankruptcy risk. In a case where the bank does only focus on sector-specific information, both sectors evolve similarly and the high-tech sector has only a slight advantage that will take much time to unravel. Also, the low-tech sector will grow more compared to a profitability-based credit policy because it gains access to credit due to its low riskiness.

The bank's expectations have an impact on the allocation of credit between the sectors. As technological progress always leads to more exits in a sector it hereby also suffers from credit shifted away to the other sector. This can only be overcome if the expectations about a sector are positive for a longer period of time. In this case, credit is shifted to the successful sector despite the risk of bankruptcies. This persistence in expectations is given if the bank follows a mean-reverting forecast rule. Then positive developments in one sector influence the rating long enough to contribute to an allocation that repeatedly shifts a little bit more credit to the innovative sector and thus supplies it enough to allow for a distinct growth path. If the bank changes its opinion according to short-lived advantages the allocation will not be directed to the more successful sector because then the bankruptcies impact the credit decision more.

There is no distinct impact on aggregate output and concentration because the credit allocation plays only a minor rule in the credit granting process.

## 1.4 Lessons From the Three Chapters

The three chapters of this dissertation tackle links between financial markets and the real economy in both directions. The first paper addresses the impact of large mood swings of stock investors on economic dynamics. Since technological progress can spur optimism or even manias and trigger large investments the impact of financing constraints on technological progress was also explored. A key feature within that relationship was that technological improvement feeds back to financial constraints. The first paper shows that stock market features can impact the real economy because of banks' credit supply or because of firms' willingness to pay for credit. It has a minor effect via bank behaviour: the allocation of credit is influenced but the persistence of the effect is meager. Firms' behaviour has a much more pronounced impact. Banks behaviour is embodied in a set of rules and information so naturally, there is less space for speculation in the decision. For firms the decision is much more exposed to speculative influences. We see in the first paper that when firms react on boom-bust periods the output shows extreme boom-bust patterns as well. When firms react on volatility they take higher risks. As the downside risk plays a role as well, over time there are some more pronounced fluctuations in volatility but no extreme reactions.

Concerning the question how speculative frenzies can build up via financial links and produce innovation which itself is a driver of speculative expectations, we find that it has only a slight impact when rating-bounded banks are the only source of external funds. In general, innovation is affected by financial considerations. We use a rating process to explore the impact of financial constraints with positive feedback on innovation. First, innovation is more likely to happen if the rating focuses on sector-independent features. We find that this holds true for various forms of firm behaviour.

Second, if there are several industries competing for credit the focus on industry specific information can hinder innovation. Even if the prospects of a particular industry are good, this does not suffice to boost innovation if the risk along with it also enters the credit decision. As long as the risk in an industry plays some role, positive expectations do not count enough to offset this risk which emerges from the very positive evolution of the industry through competition.

Chapter 2 shows that when there are huge expectational deviations like those present in speculative manias, those transmit rather by firm behaviour and banks do not play a major role. Chapter 3 and 4 show a complementary picture. In the evolution of differences among firms it is the bank's behaviour that has the most impact. Its expectations play a minor role but its behavioural regimes are highly decisive. Therefore, it is the banks who can seed speculative frenzies but most probably, it takes other agents as well to have them turn into manias and speculative bubbles.

# Chapter 2

# Stock Price Related Financial Fragility and Growth Patterns

## 2.1 Introduction

Economic fluctuations and boom-bust patterns in asset prices occur sometimes in conjunction while crises in financial markets can turn economic contractions into recessions (Minsky, 1970; Kindleberger and Aliber, 2005; Bordo and Lane, 2013). This chapter aims to explore the possible causal contributions of asset prices to economic performance by asking which effect do stock prices and their patterns have on output via the supply side? The model focuses on bank credit as the channel that transmits changes in stock prices to the real economy. This focus on bank credit is based on two observations: firms finance a significant part of their business by relying on external sources of funds (Graham and Leary, 2011) and, although financial systems differ around the world, credit is an important external source of funds (Allen and Santomero, 2001).

Stock prices are part of the financial market. Nevertheless, they are likely to affect real market activity. Their impact might be so severe that they cause financial market breakdowns and recessions (Minsky, 1970). "There are four channels through which stock prices can be considered to affect [real] activity: (1) the wealth effect on consumption, (2) the Tobin's Q effect on investment, (3) the balance sheet effect on private spending (via the credit channel) and (4) the confidence effect on private spending."

(Altissimo et al., 2005, p. 4.) In academic research, effect (1) has been studied the most while also channel (2) got some distinct attention. The other channels are usually not pointed out separately (Semmler, 2011). Many early papers focus on the role of increased (perceived) wealth in times of stock market booms as source of increased consumption which establishes the link between stock markets and the real economy. By this concept, the stock market leads the dynamics of the economy (Semmler, 2011). More generally, the distinction between asset prices and the financial market is in order. While it is shown that asset prices indeed contribute to the real economy, for instance via investment in owned houses (Higgins and Osler, 1998; Semmler, 2011), the link between other assets, traded on the financial market like bonds or stocks is less proven. Nevertheless, stock prices are a good indicator for following investment (Barro, 1990). Morck et al. (1990) examine three theoretic transmission channels by econometric analysis. The first one does see the managers responding to the stock price as source of information on future economic fundamentals like aggregate demand. The second theoretical link states that stock prices affect the cost of external funds and the third link is about pressure on managers by stock investors. This pressure leads them to respond for instance to low stock prices which comprises the threat of a hostile take-over. Morck et al. (1990) use idiosyncratic sentiment differences but also focus on market-wide correlated sentiment. They find that idiosyncratic differences across stock prices are not held up by the empirical evidence for all of the three theories. If investors' sentiment is correlated market-wide their evidence is able to support only the first theoretical link.

In this paper stock prices fluctuate due to real activity but also due to exogenous random deviations on top of that. The paper builds upon a model of Delli Gatti et al. (2005) where excessive leverage in credit financed production may cause bankruptcies. The paper shows that collateral based credit granting may contribute to model output dynamics that exhibit features of real world output dynamics. Also, firm sizes and their growth exhibit patterns which match empirical regularities. The model is agent-based and therefore allowing for enough flexibility to incorporate multiple scenarios about stock market changes. In this paper there will be three variations of the model carried out by computer simulation using the software `Wolfram Mathematica`. Two of the three model extensions comply with the original paper as it is a special case of the extended model. Therefore, the original model will serve as a benchmark case. The third variation is only slightly different and exhibits similar dynamics.

The first influence is that the way credit is granted is depending on the stock prices. When banks estimate the creditworthiness of borrowers they also refer to the stock price as piece of information. Secondly, firms in financial distress might be subject to restructuring and thus survive in cases where the stock market does evaluate its future prospects rather optimistically. The third influence is that managers may act in response to the stock price if their payment is also dependent on the stock price. This influences risk taking. The question addressed is to what extent stock prices have an impact on firms' dynamic and output via those various channels? The analysis will be based on comparing scenarios with varying levels of crucial behaviour parameter values to the baseline case where stock prices do not play a role.

This paper contributes to the investment literature by dealing with the influence of stock prices on the investment behaviour of firms (see ECB, 2013; Ormerod, 2009; Morck et al., 1990). Due to the agent-based structure it can add further insight to the impact of firm level financing to aggregate growth. It relates to Minsky's (1970) approach of leverage and financial fragility due to credit and investment that causes single failures feeding back to the rest of the economy. This two-sided relationship is not greatly covered in classical macroeconomics: "[m]oreover, it is worth noting that in the stochastic growth model there is only a one-sided relationship. Real shocks affect stock prices and returns but shocks to asset prices - or overreaction of asset prices relative to changes in fundamentals - have no effects on real activity." (Semmler, 2011, p. 82.)

The results show that all channels do have a significant impact on the dynamics of the firms and total output. If banks take the stock price into account for their credit offer, this leads to a more similar evolution across firms because leverage does pay off less for them. Therefore, financial health gains a higher importance and this induces more persistence in firms' differences where the pace of growth is comparatively lower. If stock prices matter for legally declared bankruptcy a high bargaining power of shareholders is of almost no effect if stock prices are uncorrelated. If stock prices have a boom-bust pattern the real economy shows correlating patterns over time because all firms act on those prices simultaneously. In the last scenario, where managers react on the stock price, they behave ambivalent: in highly leveraged companies they increase capital demand due to a lower expected remuneration. This is caused by a high bankruptcy risk that makes payment less likely. In healthy firms managers reduce risk by demanding less capital and acting more prudent. Managers of highly leveraged firms have a small downside risk as their payoff is expected to be less certain in the first place.

In the economic literature formal approaches to the causes of crises in economic activity linked to financial market range from failure propagation approaches in networks (Battiston et al., 2007) to asymmetric information concepts (Stiglitz and Weiss, 1981). The particular mutual dependency of credit obligations between -in general banks and firms, but also among firms and banks themselves - might contribute to an amplification of failures. Not only is the effect of idiosyncratic failure of different effect on an economy as Gabaix (2011) points out in his granular model, but the connectedness of economic agents might lead to contagion. Gabaix (2011) shows that it matters which firm is hit by a shock or a crises for the economy, for instance due to the firm size a shock to major players like General Electric might influence the economy more than foreclosure of the neighborhood grocery store. He shows that the empirically proven power law distribution of firm sizes can propagate idiosyncratic shocks in a way such that business cycles emerge (Gabaix, 2011).

According to the Basel II regulations banks need to have their credit engagements rated. They can do this themselves (internal rating) or hire some rating agency to do it (external rating). Ratings will be done using a mix of information consisting of quantitative and qualitative information (Reichling et al., 2007). To the best of our knowledge, there is no literature that assesses the impact of rating strategies at an economy-wide scale. Literature dealing with rating methods is concerned about the predictive accuracy of the method as this is crucial for practitioners such as banks or rating agencies. For instance, Altman coined the "Z-Score" as a bankruptcy predictor (Altman, 1968). This approach is used in many refined ways so that rating agencies and banks have their own slightly different methods of rating (Altman and Saunders, 1998; Crouhy et al., 2000; Reichling et al., 2007). Our approach deals with the impact of actual customs at financial markets in an economy-wide context. We motivate our analysis with rating methods that comprise stock market valuations as piece of qualitative information (Crouhy et al., 2000; Reichling et al., 2007; Standard and Poor's, 2011).

As the legal processes are a major source of political risk in any country the respective bankruptcy laws are important for investment decisions. In our model the degree of the transmission of stock price variation is the main mechanism propelling output fluctuations. The impact of bankruptcy law on business cycles is addressed by Suarez and Sussman (2007). They find that more firm friendly laws ("soft laws"), that is a higher chance of not being declared bankrupt, has a possible adverse long-term effect. While more firms continue to exist in the short run, lenders may require higher levels of collateral in the long-run which diminishes growth. Their idea of soft laws is based also on shareholders' bargaining power which is the transmission channel of stock prices in our model. In a simpler argument Lee et al. (2007) point out that soft laws may be beneficial as they promote a larger variety of firms.

They deem this desirable for the society. In a general equilibrium context, modest levels of bankruptcy punishment can be beneficial because they make both, creditors and lenders better off (Dubey et al., 1995).

Our results indicate that the law is of minor effect if the firms are affected idiosyncratically by stock prices. If there is correlation among stock prices, for instance through boom-bust cycles, a firm friendly ruling would also result in extreme variations and business cycles. Those come however, with no long term growth in the model because there is no further equity injected. Therefore, in the presence of boom-bust cycles at the stock market we would recommend a bankruptcy law that is not too firm friendly.

The compensation of managers can actually consist of several components. Besides from the salary there are performance based payoffs that serve as incentive for the managers. This incentive can differ. Bryan et al. (2000) point out that for instance, granted stocks may lead to more prudent behaviour while stock options might increase the risk taking. This is due to the different payoff structure which is linear in granted stocks but not in stock options where managers do not bear the downside risk.

There is a recent debate as to cap the bonuses of *bank* managers since wrong incentives have been deemed to contribute in the financial crisis of 2007. As a result, the European Union [EU] passed a law with effect of January 1, 2014 that effectively limits the bonus payments of bank managers to 100% of their fixed salary. (EU, 2013: Article 94,1,g,(i) and (ii)). Managers in the United Kingdom even face a claw-back rule put into effect from January 2015 on. According to that, they can be forced to pay back bonuses over a period of seven years after their awarding. This is a form of ex post risk adjustment in order to "align better the interests of staff subject to the Remuneration Code with the long -term interests of the firm." (Bank of England, 2014.) In the model the bankruptcy costs are taken into account by the managers since they suffer from the termination of their contracts. If there is only fixed salary, they loose only their salary which matches with the cost concept of Delli Gatti et al. (2005). However, if part of their salary is also granted stocks in a performance based remuneration scheme, there might be also a loss positively related to the current stock price.

Our model results indicate that there is a complex impact of performance based compensation. For low levels (share is below about 1/2) any increase does hardly increase output but causes a higher interest rate. However, for a share above 1/2 a further increase does increase the interest rate only marginally but boosts output. Policy advise is therefore depending on the current level of performance based compensation and on the particular issue that should be promoted. In comparison to the EU law this means that it makes sense to hold the managers accountable since this induces sensitive behaviour. If managers behave sensitively, volatility cycles at the stock market do not harm the economy very much.

The paper is organized as follows: section 2.2 gives an overview of the model. Then, the impact of bank policy is introduced in section 2.3. The impact of different bankruptcy circumstances is discussed in section 2.4 and last the impact of managerial behaviour with respect to stock prices is examined in section 2.5. Section 2.6 discusses the results.

## 2.2 The Model

The model is based on work of Greenwald and Stiglitz (1990, 1993) and subsequent work of Delli Gatti et al. (2005). A core feature is that firms' managers act in a risk averse manner because bankruptcy of the firm is costly for them personally. Credit financing and leverage exposes the firm to financial fragility. Therefore, they take possible bankruptcy costs into consideration when they use bank loans for financing desired production. The use of credit drives the economy and has an ambivalent impact which induces fluctuations: a higher amount of credit increases leverage which possibly induces higher profits and growth but at the same time also increases financial fragility.

Bankruptcy is costly for the management first of all due to the loss of salary but also the loss of reputation and further reemployment might become more difficult. A further assumption is that the costs of bankruptcy increase in firm size because usually there are more managers involved in large companies (Greenwald and Stiglitz, 1990). Greenwald and Stiglitz also point out that financial distress can occur in different ways and does not always lead to bankruptcy (Greenwald and Stiglitz, 1990, p. 17, footnote 5). While for the company financial distress does not automatically mean the end of the firm, usually one of the first measures undertaken in such situations is to replace management. Therefore, as soon as there is financial distress, managers most probably suffer from a monetary loss which is at least foregone salary. The issue of financial distress and bankruptcy is incorporated in the model by Delli Gatti et al. (2005) in the simple way that financial distress automatically leads to the liquidation of the firm.

### 2.2.1 Baseline Setup

We first recall the model introduced by Delli Gatti et al. (2005). We add equity and stock prices in section 2.2.2. Other extensions are presented in the following sections. Net worth of a firm $i$ at time $t$, that is in general assets minus liabilities due in $t$, is denoted $A_{it}$. This notation refers to the net worth *at the end* of period $t$. It consists of the net worth at the end of the prior period plus *net* profits from the current period. Often, this net worth is also referred to as "equity". If the firm has not issued any shares, net worth is the same as the sum of all retained profits up to the *end of period t*.

$$A_{it} = A_{it-1} + \pi_{it} \tag{2.1}$$

Assume that the firms transform financial means into productive capital without any costs. Productive capital $K_{it}$ is then the sum of net worth taken over from the prior period $A_{it-1}$ and credit taken in the current period, $L_{it}$:

$$K_{it} = A_{it-1} + L_{it} \tag{2.2}$$

Output $Y_{it}$ is produced by applying constant returns to scale $\phi$ to productive capital:

$$Y_{it} = \phi K_{it} \tag{2.3}$$

Profit depends on the price $u_{it}$ that applies to the output and the costs for setting up capital which consists of retooling costs $g > 0$ and rental costs for capital $r_{it}$. Assume that the costs for credit and the real return to capital are the same and apply hence to the entire stock of productive capital:

$$\pi_{it} = u_{it}\phi K_{it} - g r_{it} K_{it} \tag{2.4}$$

with $u_{it}$ being random and uniformly distributed with support between zero and two. Therefore, $\mathbb{E}[\pi_{it}] = (\phi - g r_{it})K_{it}$. A firm is bankrupt when its assets are insufficient to repay the debt at the end of a period:

$$A_{it} < 0. \tag{2.5}$$

This condition states that a firm whose equity (net worth) is below zero will be dissolved and leaves the economy. It is assumed that firms can sell their products at a market isolated from all others ("islands") and that they can sell their entire production. Nevertheless, they face uncertainty in the price $u_{it}$ which is unique on each island and period. This approach is in line with the fact that a lot of financial distress stems from defaulting customers (Reichling et al. (2007), p. 223). Therefore, the random price which yields a random revenue can also be interpreted as the share of sales that is actually paid for. Taking into account the bankruptcy condition and equations (2.1) and (2.4), the price that just sustains a firm is

$$\bar{u}_{it} = \frac{gr_{it}}{\phi} - \frac{A_{it-1}}{K_{it}\phi} \tag{2.6}$$

Assume that the costs of bankruptcy depend on the size of the enterprise in the form $c^f = cY^2$ with $c > 0$ being a constant. Assume further that managers take into account these costs of bankruptcy when deciding about the demand for capital in each period. They base their decision on the expected profit

$$\Gamma_{it} = (\phi - gr_{it})K_{it} - \mathbb{E}(c^f) \tag{2.7}$$

while the expected costs of bankruptcy $\mathbb{E}(c^f)$ are determined by the probability of bankruptcy Prob$(BR)$ = Prob$(u_{it} < \bar{u}_{it}) = \bar{u}_{it}/2$ for $u \sim$ Uniform$[0,2]$. Demand for capital is the result of the maximization of expected profit. Using the first order condition and solving for capital yields $K^d_{it} = \frac{\phi - gr_{it}}{c\phi gr_{it}} + \frac{A_{it-1}}{2gr_{it}}$. Credit demand is the difference between demand for capital and retained profits $L^d_{it} = K^d_{it} - A_{it-1}$, yielding

$$L^d_{it} = \frac{1}{c\phi gr_{it}} \left( \frac{c\phi}{2} A_{it-1}(1 - 2gr_{it}) + \phi - gr_{it} \right). \tag{2.8}$$

The banks' profit $(\pi^B_t)$ depends on the revenue from loans granted minus the costs of raising those funds from equity $E^B_{t-1}$ and deposits $D_{t-1}$:

$$\pi^B_t = \sum_{i \in N_t} r_{it} L^s_{it} - \bar{r}_t[(1-\omega)D_{t-1} + E^B_{t-1}]. \tag{2.9}$$

Here, $\omega$ describes the degree of competition within the banking sector and is a measure for the mark up the bank can charge on interest above deposits. The interest paid on deposit is $\bar{r}_t(1-\omega)$ where $\bar{r}_t$ is assumed to be the weighted average lending interest rate. When a firm goes bankrupt *at the end of a period*, the banking sector as a whole suffers a loss equal to the difference between the amount of credit supplied in period *t* and the relative mortgage (value of assets), which is the same as the (negative) amount of net worth: $B_{it} = L_{it} - (K_{it} + \pi_{it}) = -A_{it}$. The banking sector's equity base evolves according to the law of motion:

$$E_t^B = \pi_t^B + E_{t-1}^B - \sum_{i \in \Omega_t} B_{it}. \tag{2.10}$$

Here, $\Omega_t$ is the set of all bankrupt firms in period $t$. The bank lends a multiple of its prior equity base according to some multiplier $L_t^s = \frac{1}{v} E_{t-1}^B$ which is based on regulatory constraints. Credit supply emerges from the banks equity base inherited from the last period $E_{t-1}^B$ and deposits available from the last period $D_{t-1}$ in the form $L_t^s = E_t^B + D_t$ while deposits are treated as a residual. Write $\alpha_{it} = A_{it} / \sum_i A_{it}$ and $\kappa_{it} = K_{it} / \sum_i K_{it}$. Individual credit supply is then

$$L_{it}^s = L_t^s [\lambda \kappa_{it-1} + (1-\lambda) \alpha_{it-1}]. \tag{2.11}$$

The interest rate $r_{it}$ for each firm is determined by the equilibrium situation where credit demand matches credit supply. From that condition this rate is

$$r_{it} = \frac{1}{2cgL_{it}^s + 2gc(\frac{1}{\phi c} + A_{it-1})} (2 + A_{it-1}) \tag{2.12}$$

Entry depends on the average interest rate $\bar{r}_t$ which determines the number of possible entrants and the features of the entrant is determined by a random draw. The term is:

$$N_t^{entry} = \overline{N} Prob(entry) = \frac{\overline{N}}{1 + e^{d(\bar{r}_{t-1} - f)}} \tag{2.13}$$

where $\overline{N} > 1$, $d$, and $f$ are constants. This assures that the probability of number of entrants is low if the overall interest rate is high. The term is then rounded to an integer. New firms are endowed with capital and net worth randomly. The draw for an entrant's capital endowment is from a uniform distribution with a center at the mode of incumbents' capital. Then, the equity ratio $\alpha_{it} = A_{it} / \sum_i A_{it}$ is determined by the mode of all incumbents' equity base $A_{it}$ and the capital ratio is $\kappa_{it} = K_{it} / \sum_i K_{it}$. Those ratios are needed by the bank in order to determine the credit supply for each new firm.

### 2.2.2 Stock Price

We now include equity and stock prices in the model. If firms have also access to equity markets, they can raise capital by issuing shares. If those are traded at a stock exchange their price can be thought of to consist of a "fair" component, that is the fundamental value $F_{it}$, and a deviation $\theta_{it}$ from that

$$P_{it} = F_{it} + \theta_{it}. \tag{2.14}$$

The fair stock market value depends on net worth and on the overall equity that a firm has

$$F_{it}E_{it} \equiv E_{it} + \Pi_{it} = A_{it}. \tag{2.15}$$

Here $\Pi_{it}$ refers to retained profits up to period $t$. Note that total equity of a firm will consist of the equity raised through issued shares $E_{it}$ and net worth which is accumulated profits $\Pi_{it}$. The above specification is based on the assumption that each share has a nominal value of 1 unit of currency, therefore the number of shares equals the nominal value of shareholders' equity, both denoted by $E_{it}$. Hence there is exactly one share of nominal value 1 for each firm. Furthermore, the fair share price is just the net value over the number of shares issued. In the remainder of the paper we will assume that $E_{it} = 1$ for all $i,t$, implying that $A_{it} = F_{it}$ and $P_{it} = A_{it} + \theta_{it}$.

The actual stock price $P_{it}$ could deviate from the "fair" price because of the expectations of investors:

1. the future inflow of cash is supposed to be significantly large or small;
2. speculators pay premiums (sell at discounts) in order to benefit from expected even larger (lower) prices in the future.[1]

This specification follows the idea that market valuation on average represents the discounted sum of all expected cash flow, represented by profits in this setup. If these expectations are very optimistic, there can be a mark up which is not justified alone by just the actually observable profit. The relation between the mark up on firm value and the error in profit estimation is

$$\theta_{it} = |\pi_{it}|\varepsilon_{it}.$$

[1] Note that 1. affects the fair value of shares while 2. may occur due to speculation (exogenous to the firm) .

This expresses that the markup on firm value (LHS) is just the markup on expected cash flow, here today's profit (RHS).

This markup *on fair market value* is assumed to be a function of profits and a random component. The overall market value of *cash flow* based on profits and the error is supposed to be given by $\pi_{it} + |\pi_{it}|\varepsilon_{it} = \rho(\pi_{it}, \varepsilon_{it})$. This means that a positive error always leads to a more favorable profit estimation, also for negative profits. The sign of the error is preserved in this way. The error might occur for some time span. The persistence in this error can be induced if the error is modeled as a random walk.[2]

$$\varepsilon_{it} = \varepsilon_{it-1} + \eta_{it}\sigma_\eta \tag{2.16}$$

where $\eta \sim \mathcal{N}(0,1)$ and $0 < \sigma_\eta < 1$. Hence, $\mathbb{E}(\varepsilon_{it}) = \varepsilon_{it-1}$.

The complete expression for the stock price is hence

$$P_{it} = A_{it} + |\pi_{it}|\left(\varepsilon_{it-1} + \eta_{it}\sigma_\eta\right).$$

## 2.3 The Role of the Stock Market Value in Credit Decisions

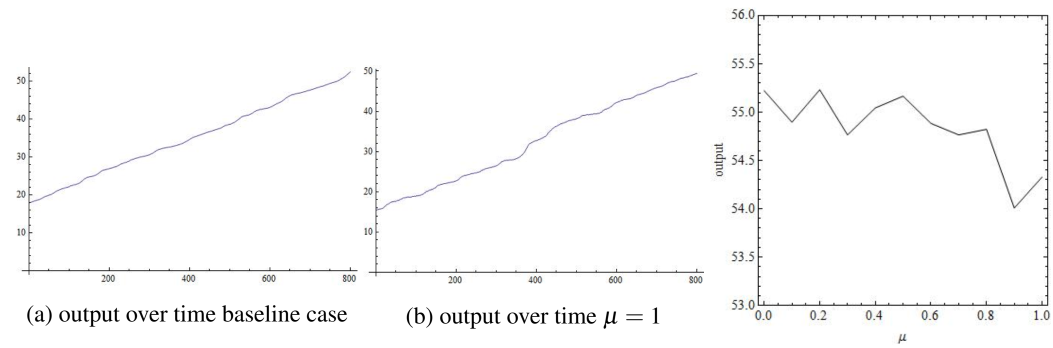
The stock market value of a firm carries information that is valuable for a bank for two reasons. First, the valuation on the stock market might reveal some information about a firm's ability to raise funds from the asset market. Second, it reveals information about the market's estimation of the relative prospect of the firm. The stock market usually indicates changes of firm's prospects earlier than the income statement or the balance sheet (Atiya, 2001; Altman, 1968). Therefore, the stock market value is a piece of forward looking information rather than the backward looking balance sheet analysis. Furthermore, "[s]tock market based information ... has responded more quickly to changing financial conditions than ratings of credit risk agencies." (Bongini et al. (2002), p. 1011.) This is an incentive to free-ride on external information since assessing creditworthiness is costly, as is monitoring.

In order to represent the impact of the stock price on credit supply we shall assume in this setting that credit supply is determined according to:

$$L^s_{it} = L^s_t\left[(1-\mu)\lambda\kappa_{it} + (1-\mu)(1-\lambda)\alpha_{it} + \mu\frac{P_{it}E_{it}}{\sum_i P_{it}E_{it}}\right] \tag{2.11a}$$

[2] If there is also a drift in the random walk, then this would represent general phases of optimism or pessimism.

where $0 < \lambda < 1$ represents the weight put on relative firm size and $0 < \mu < 1$ stands for the weight put on the relative stock market value. The third piece of information used for the decision is the relative net value. We run simulations for increasing values of $\mu$ while for each value there are a number of repetitions. Results are taken from an interval over 51 periods, between $t = 1000$ and $t = 1050$. The average is computed. This is done for each of 100 repetitions for any parameter value and for those 100 results from each parameter value also the average is taken. Note that the simulations for $\mu = 0$ also represent the benchmark case which matches the Delli Gatti et al. (2005) model. The results in our baseline case are in line with the findings of Delli Gatti et al. (2005) as they reproduce business cycles (figure 2.1a) and power-law firm size distributions (figure A.1a, page 49). While Delli Gatti et al. (2005) focus on the distribution of firm sizes and their growth rates we will put emphasis on total output and the average interest rate in our analysis.



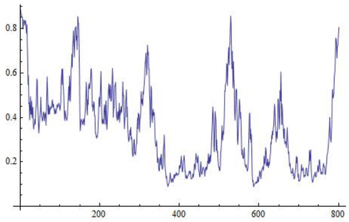

(a) output over time baseline case

(b) output over time $\mu = 1$

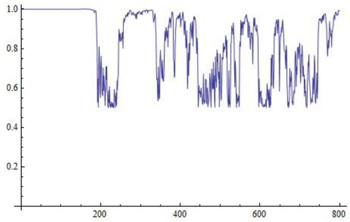
(c) output

Figure 2.1: **Impact of $\mu$ on output**

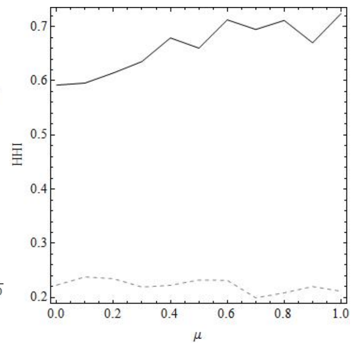
Figure 2.1 shows the effect of the stock price consideration on output. The baseline case shows that over time output is increasing with phases of faster and phases of slower growth (figure 2.1a). This represents business cycles. If the bank would only look at stock prices, those phases would be more intense (figure 2.1b). The overall pace of output growth would be similar, however (figure 2.1c). As a firm's stock price - for given nominal equity - rises in total equity, a firm that possesses more equity has an increasing advantage if the banking sector refers more to the stock price. The impact of relative capital and thus output is decreasing in $\mu$. Therefore, equity has relatively more weight. That is, less fragile firms get relatively more credit offered because the total assets $K_{it}$ are without effect for large $\mu$. This means that only firms with relatively low leverage get access to credit. The total output in the economy however, is lower because firms that otherwise produce at the brink of bankruptcy have less access to credit. Firms that are less fragile get funded over proportionally compared to the case where $\mu = 0$ but only offer a really low interest rate for that. This dampens the evolution of credit supply and thus total output. This low interest rate is the key for their advantage in growth which is visible in the Herfindahl index (figure 2.2c). Comparing representative runs shows that under the stock market relevance regime ($\mu = 1$) there is a fast movement to the dominance of a monopolist (figure 2.2b) while in the baseline case ($\mu = 0$) there are only short episodes of market domination (figure 2.2a). We leave out the first 250 periods in order to avoid transient dynamics. If furthermore, credit is offered less strictly, comparatively many firms survive (figure 2.3) . This is also a reason why total output is lower in this regime: more firms leave the industry and there are less periods where there is no capital lost due to bankruptcy. Differences in firm size are less decisive for credit due to $\mu$ because



(a) Market Power baseline case



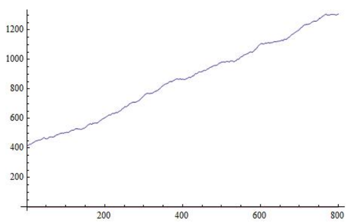
(b) Market Power with $\mu = 1$



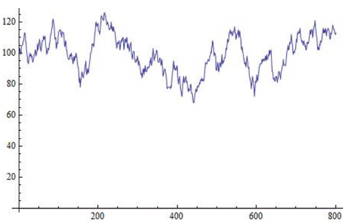

(c) Market Power, dashed line: standard deviation

Figure 2.2: **Impact of $\mu$ on market concentration**

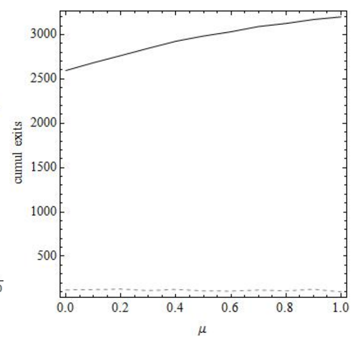
there is additional noise. Also, the distribution of firm sizes does not clearly show a power-law in the tail(figure A.1b on page 49). Nevertheless, we observe that market power increases in $\mu$ (figure 2.2c). Concentration therefore stems from *exiting firms*.



(a) numberof firms baseline case



(b) number of firms $\mu = 1$




(c) no. of exits, dashed line: standard deviation

Figure 2.3: **Impact of $\mu$ on the no. of firms**

Economically, if some firm faces a markdown $\varepsilon_{it} < 0$, it will be offered less credit in the following period.

Nevertheless, as its equity $A_{it}$ is the same, it still demands the same amount of capital. This leads to a higher equilibrium interest rate for that firm in the upcoming period and less leverage which will lead to lower profits. This means, that the markdown also leads to lower credit supply in the *following period*. This effect is even more severe since there is persistence in the markup/markdown. Even for a one time markdown, there is a long term effect in diminished credit supply and hence hindered firm growth.

If some firm faces a mark up ($\varepsilon > 0$) it is offered more credit and thus experiences higher growth and lower interest rates in the following period. It is more leveraged and will grow faster. The growth advantage is however, less pronounced if the bank predominantly puts weight on the stock price. Then the advantage from a markup on profit is less than an advantage from size due to the magnitude of the underlying value.

The additional noise disturbs the selection process in that some fragile firms are offered more credit and some robust firms are constrained for reasons other than their financial situation. If we consider only the balance-sheet situation as a benchmark, stock market expectations are exogenous. We cannot verify whether there would actually be reason to grant more credit due to some positive outlook. The only information from the model is the financial situation. A selection process based on this information is disturbed by the additional noise which hurts total output in the long run compared to a situation where only model internal information is used.

## 2.4 Firm Distress and Restructuring

In this section we distinguish between insolvency and bankruptcy in order to tackle the question how the stock price can influence the fate of a financially distressed firm in a bankruptcy negotiation. The impact may have implications for designing a favourable institutional framework. Mere financial distress may hurt business, but does not mean that a firm will cease to exist. Whether it can resolve financial distress and sustain as a going concern depends very much on the expectations of its creditors and shareholders - along with its capital structure and the legal framework in each particular country.

Consider that the stock *market* value instead of net worth determines bankruptcy of a firm. Most of the large firms are publicly listed firms whose market value is determined at the stock exchanges. Sabry and Hrycay (2014) provide empirical evidence that shows that when a bankruptcy case is filed courts do take the stock market value into account for their ruling about bankruptcy. Usually, the stock market price serves as source of information complementary to the ability to issue bonds and credit ratings based on cash flow projections. Occasionally however, the stock market price is the major determinant of bankruptcy ruling.

Note that mere insolvency already occurs when net worth is negative: $A_{it} < 0$. Since restructuring could take place, insolvency does not automatically mean that a firm cannot continue to exist. For instance, if a firm has a negative cash amount but the evaluation of its future cash flow is still optimistic it can survive. The initial public offering [IPO] of 'Rocket Internet' which took place on Oct. 2, 2014 may serve as example. The IPO collected 1.5 bn Euros which left the internet company with a total market value of 5.5 bn Euros, about the same value as Lufthansa. This is remarkable since 'Rocket Internet' has low revenues and huge losses. Therefore, the market value is "predominantly based on the hope of a glorious future" (Frankfurter Allgemeine Zeitung, 2014). This is also visible in the fact that the shares were issued at the top end of the price range but lost more than 20% of their value within the first days of trading. Accordingly, in the model setup, a stock price mark-up $\theta_{it}$ would be high because investors think that *in the long run* the firm will recover and be able to repay all of its current debt. A bankruptcy condition based on market value hence takes the expectations into account:

$$A_{it-1} + \rho(\pi_{it}, \varepsilon_{it}) \equiv \underbrace{F_{it} + \theta_{it}}_{\text{stock market value}} < 0.$$

The stock market value consists of inherited net value $A_{it-1}$ and the *market valuation* of current profit $\rho(\pi_{it}, \varepsilon_{it})$ which is equivalent to the end-of-period net value $F_{it}$ and a mark-up $\theta_{it}$.

Whether they can be rescued and go on profitably, depends on *all* of its stakeholders. Many parties are allowed to file for bankruptcy: creditors might try to recover part of their loans to a firm and seek foreclosure in order to rescue as much asset value as possible, owners (shareholders) might not be willing to inject further money into the firm and maybe also to limit losses by liquidating the firm, and at last, the firm itself may file for insolvency. Focusing on the interest of the provider of funds, each group has some bargaining power in the restructuring negotiations. While a bank would be willing to file for bankruptcy, optimistic shareholders, who do not want to lose their investment, could be able to convince the bank to roll over the loan once again. They are more likely to be successful if the stock market value of a firm is high. Assume there is a parameter $n^s \in [0, 1]$ representing the shareholders' influence, the firm would be dissolved and leave the economy if

$$A_{it-1} + \pi_{it} + n^s \theta_{it} < 0. \tag{2.5b}$$

If the shareholders have no influence on the bank's decision, the bankruptcy condition is as in Delli Gatti et al. (2005) and the market markup does not play any role. If they have influence, any markup makes actual bankruptcy less likely. Equation (2.5b) covers the different interests of stakeholders. The bank would file for the firm to go in formal bankruptcy if $A_{it-1} + \pi_{it}$, the net worth, is not sufficient. The shareholders have a deviating interest which is expressed in $\theta_{it}$. The parameter $n^s$ determines to what extent this deviation is crucial. In conjunction with $\theta_{it}$, $n^s\theta_{it}$ shows how much the hard facts are influenced by stock market expectation and can be understood as measure for legal circumstances and policies applied in an economy.

Each firm's demand for capital is affected by the new bankruptcy condition. Recall that profit is revenue minus capital costs

$$\pi_{it} = (u_{it}\phi - gr_{it})K_{it}.$$

The new bankruptcy condition is in detail

$$A_{it-1} + (u_{it}\phi - gr_{it})K_{it} + n^s\theta_{it} < 0.$$

This can be solved for

$$\bar{u}_{it} = \frac{1}{K_{it}\phi}\left[K_{it}gr_{it} - (A_{it-1} + \theta_{it}n^s)\right]. \tag{2.6b}$$

Doing the same steps as in the baseline model, this crucial price $\bar{u}_{it}$ is used in the probability of bankruptcy. Firms do not know the mark up on profit at the end of the period and they form naive expectations in the form

$$\mathbb{E}[\theta_{it}n^s] = \theta_{it-1}n^s \tag{2.17}$$

It is assumed that the influence of stockholders $n^s$ is known for example due to the legal institutions and that the management does not know how the stock market forms expectation of future profits. Therefore, the firms do not know how the mark up $\theta_{it}$ actually comes up. They know, however, the deviation of the prior stock price from the net value and it is assumed that they simply expect this deviation to persist. After maximizing profit, capital demand is determined by

$$K_{it}^d = \frac{\phi - gr_{it}}{c\phi gr_{it}} + \frac{A_{it-1} + \theta_{it-1}n^s}{2gr_{it}}.$$

The banking sector also reacts on a distressed firm. It will not take into account the (negative) net worth of distressed firms. Since the capital ratio of a distressed firm is very low, such a firm will be offered little credit via the market share rule. The bank's rule is now

$$L_{it}^{s} = \begin{cases} L_t^s \left[\lambda \tilde{\alpha}_{it} + (1-\lambda)\kappa_{it}\right] \text{ for } A_{it-1} > 0, \\ L_t^s \left[(1-\lambda)\kappa_{it}\right] \text{ else.} \end{cases} \tag{2.11b}$$

Here $\tilde{\alpha}_{it} = \frac{A_{it-1}}{\sum_{i \in \Delta_t} A_{it-1}}$ and $\Delta_t$ is the set of all firms that are solvent in period $t$. This ensures that all individual credit offers sum up to $L_t^s$ again. Compared to a situation where insolvent firms leave the pool of assessment there is less credit supply for the solvent firms. Thus, by construction, if there exist insolvent but not yet bankrupt firms, the solvent ones are comparatively worse off due to a tougher assessment. The equilibrium interest rate is

$$r_{it} = \frac{2 + (A_{it-1} + \theta_{it-1} n^s)c}{2gc\phi(L_{it}^s + A_{it-1} + \frac{1}{c\phi})}. \tag{2.12b}$$

It is easy to see that capital demand and hence equilibrium interest increases in the markup on profit. If the stock market values the firm extremely high, managers can afford to take higher risks as the firm will be less likely to go bankrupt.

It is possible, that the bank credit offer does not suffice to offset the negative net value carried over to the next period. In this case, there would be negative productive capital. This is excluded in the simulation as the productive capital must be at least zero. Therefore,

$$K_{it} = \begin{cases} A_{it-1} + L_{it}, \text{ for } A_{it-1} + L_{it} > 0, \\ 0, \text{ else.} \end{cases} \tag{2.18}$$

Figure 2.4 shows that the credit demand curve contingent on the interest rate shifts upwards in $\theta_{it}$.

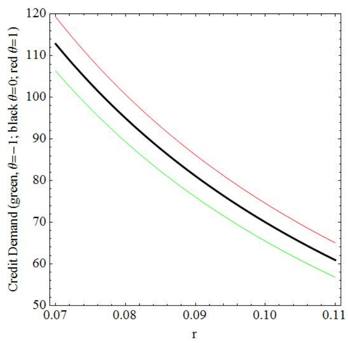
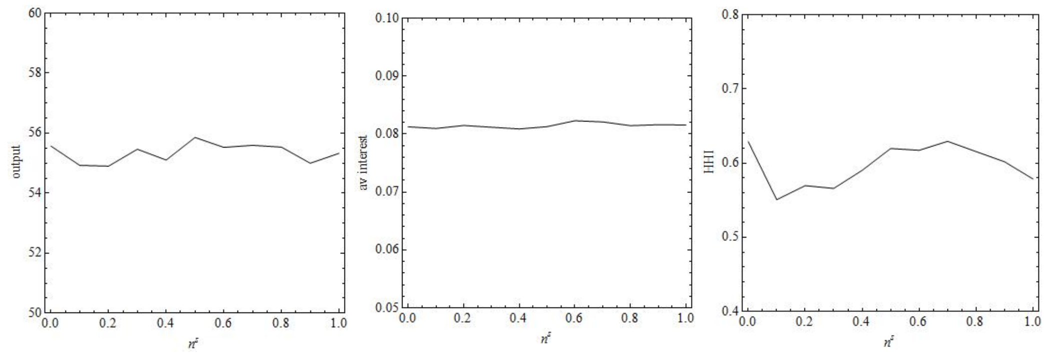



Figure 2.4: Credit demand $n^s = 1$
(black→ $\varepsilon = 0$, red→ $\varepsilon > 0$, green→ $\varepsilon < 0$)

This shift is larger in the influence parameter of the shareholders $n^s$. If there is a positive stock market influence an actual bankruptcy is less likely. Therefore, the expected costs of bankruptcy are lower which boosts credit demand by firms for any given interest rate and vice versa.

### 2.4.1 No Stock Market Mood Swings

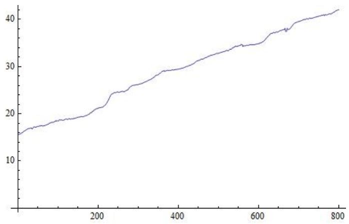
As the firms in the model operate on "isolated islands" which makes their product prices independent, the same is true for stock prices in this section. This adds some further noise to the expected costs of bankruptcy. However, the noise is auto correlated in the short run. The question is whether the firms take more or less risk compared to the initial model and whether this influences the output pattern. The comparative analysis is done for different levels of influence of shareholders in restructuring negotiations $n^s \in [0,1]$. There are 100 repeated simulations for each parameter value while the interval is covered in 10 incremental steps.



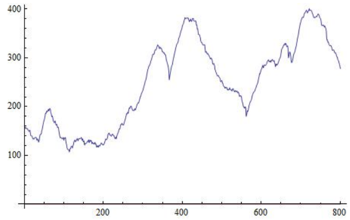

(a) total output (log) (b) average interest rate (c) Market Power

Figure 2.5: **Impact of bargaining power**

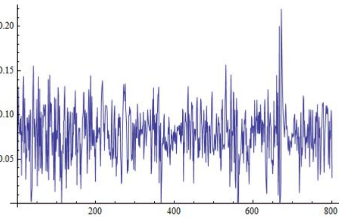
The impact of positive markups is that distressed firms can survive but that might only have a short postponing effect. The distribution of firm sizes is deviating slightly from a power-law in the tail (figure A.1c). Figure 2.5 shows that the bargaining power of shareholders does not have a significant impact on the evolution of the economy. Total output, the interest rate and market power do not change in the bargaining power. The reason is that some firms pay relatively more interest if they face a markup but others pay relatively less. The representative run in figure 2.6 reveals that the dynamics over time are distinct. Especially the interest rate fluctuates severely (figure 2.6c). The output has a pattern of distinct economic booms and recessions (figure 2.6a) while the firm number also is somewhat cyclical (figure 2.6b). There seems to be a clear tendency toward market concentration while this is frequently disturbed (figure 2.6d). This indicates that also large firms are likely to go bankrupt. They could be hit by a severe markdown. On average though, a clear impact of the bargaining power cannot be



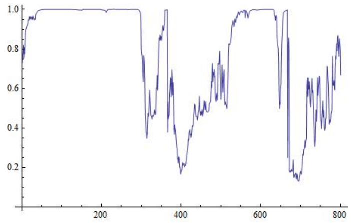
(a) GDP without drift



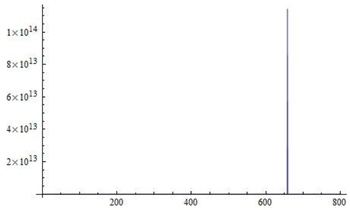
(b) Firm number without drift



(c) Average interest rate, no drift



(d) **Market Power without drift**



(e) Bad Debt without drift

Figure 2.6: **Time series for high bargaining power of shareholders**

distinguished.

The legal framework does not seem to have much of an influence if stock prices are not correlated.

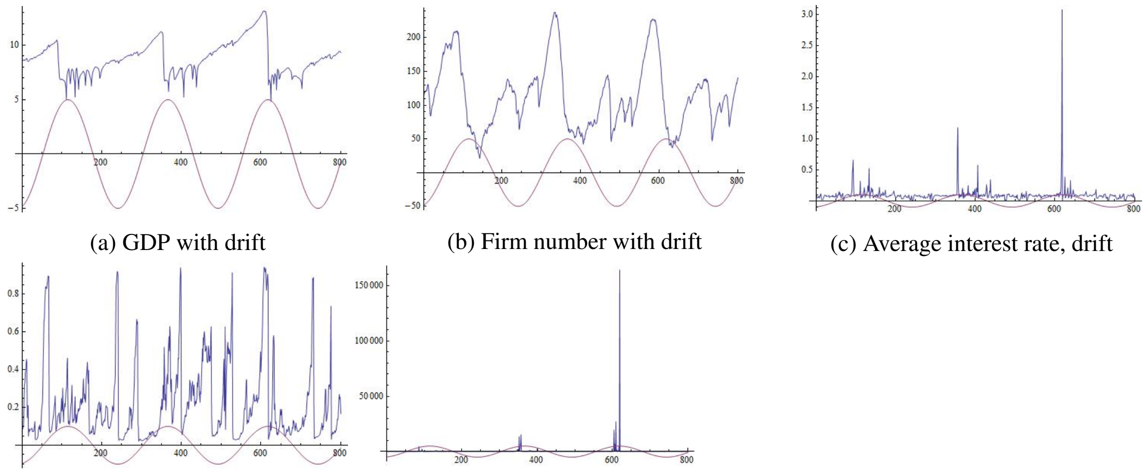
### 2.4.2 Boom Bust Periods

Stock markets exhibit cycles which can be caused by fundamental changes due to real economic cycles. They can also show booms and busts which are are considered to be overreactions not justified by fundamental data (Shiller, 1981; DeBondt and Thaler, 1985, 1987). Those booms and busts can be driven by herd behaviour, for instance. This kind of speculation is exogenous to the stock price. It is introduced by adding a drift to the random walk of $\varepsilon_{it}$:

$$\varepsilon_{it} = \varepsilon_{it-1} + \eta_{it}\sigma_{\eta} + \sin\left(\frac{t}{40}\right).$$

This means that the errors are correlated and the drift lifts all deviations equally or diminishes them by the same amount. If there are phases of booms and busts, as described by the drift in the random walk, the real economy reacts distinctively on stock market mood. Figures 2.7a to 2.7e show the extreme situation where shareholders' bargaining power is $n^s = 1$. The market drift is also depicted, but for graphical reasons amplified in the images.

Total output (figure 2.7a), the number of firms (figure 2.7b) and the average interest rate (figure 2.7c) respond to boom-bust cycles of the stock market. For high mark ups many firms go bankrupt. That



(a) GDP with drift (b) Firm number with drift (c) Average interest rate, drift

(d) Market Power with drift (e) Bad Debt with drift

Figure 2.7: **Time series for high bargaining power of shareholders with stock market drift**

also causes deep recessions. The average interest is generally high in such phases which causes the large number of bankruptcies and the depression times. Market power varies a lot (figure 2.7d) but there is no clear correlation with the stock price swings visible. Large losses due to bankruptcies occur during phases of high mark-ups (figure 2.7e).

If the bargaining power of stock holders is high and there are booms every firm has an increased demand for credit (see also figure 2.4), which is the cause of high interest rates. The reason is that the probability of bankruptcy is comparatively low. If the stock price mark ups are uncorrelated the effects on single firms more or less cancel out each other. If there is correlation there is also correlation in credit demand and all firms face higher interest rates.

Figure 2.7 depicts a drastic scenario where the stock holders have maximum bargaining power. The firm size distribution however, comes closer to a power-law (figure A.2a, page 50). Almost all firms are certain that their shareholders would not let them go bankrupt in times of stock market booms. Therefore, they all have low expected bankruptcy costs which causes them to demand high amounts of capital. As long as the markup increases but is not too high yet, firms pay a high interest rate which induces high credit supply in the following period. Then, leverage will increase and output will grow along with net value. Nevertheless, due to high interest rates, there is low profitability and the capital increase depends more and more on credit than on retained profits. Firm equity remains at a low level. At some point leverage is too high to sustain the high interest payments and there is a deep slump in output because firms go bankrupt.

Over time the total output does not grow and only exhibits cycles. If firms pay high interest rates there is no profit that can be retained and add to the net worth. Capital may increase due to increasing credit supply but the collateral basis does not improve over time on a wider scale. Growth would be credit driven. This is the classical story of Minsky (1970) where leverage builds up over time and interest payments are financed to an increasing extent by new credit rather than profits. Eventually, firms will go bankrupt which constitutes repeated cycles in economic activity and output. In such a scenario it would be good to implement a policy that limits the influence of shareholders in bankruptcy procedures. This, however, is subject to the absence of injecting further equity by the shareholders.

## 2.5 Stock-related Remuneration

In this section we base the managements' payoff on the stock price at the end of a period. Two questions will be addressed: if some share of the management compensation consists of granted shares, how does this affect total output and the average interest rate? And what impact do volatility cycles have in this context? In major corporations the overall payment of managers consists of a package that includes fixed salaries and a performance-based payout. This performance-based payout is linked to the stock price by granting some shares or issuing stock options. This means that the higher the stock price, given a prior benchmark, the higher the managers' salary.[3] We consider a management that is concerned about the likely stock price at the end of a period only. They do not consider any further price increases or decreases since we assume that they could sell the stock immediately.[4] The stock price at the particular point in time is then uncertain also due to the volatility that reigns in the stock market. It is a well established fact of financial markets that volatility is persistent (Bollerslev and Jubinsky, 1999; Lux and Kaizoji, 2007) and that it is also positively correlated with trading volume (Karpoff, 1987; Brock and LeBaron, 1996). The connection between stock market volatility and business cycles is discussed by Fornari and Mele (2010). They find that aggregate stock market volatility explains up to 55% of real growth. Theoretical models of this connection differ in the timing of the correlation. There are models that explain countercyclical influences (Campbell and Cochrane, 1999) while others explain procyclical connections (Bernanke et al., 1999). The countercyclical models assume no feedback from the real economy to asset prices while the financial accelerator approach of Bernanke et al. does (See Fornari and Mele, 2010).

[3] There are different sorts of stock-related compensations which have a contrary effect on risk taking. See Bryan, Hwang, and Lilien (2000) for more details. As for bank managers, this type of compensation has been discussed as contribution to the financial crisis due to subprime lending as banks could benefit from their earnings but their losses were borne by taxpayers through bailouts. The managers had each incentive to take large risks in exchange for the chance of large earnings. See Admati & Hellwig (2013), pp. 122,123 for some more detailed discussion. Since a payment in common stocks is possibly one of the easiest way to look at, this is chosen for this approach.

[4] Usually, there are some minimum holding times before managers can sell the stock granted.

We stick to the latter concept and build in exogenous levels of stock market volatility on top of the real economy feedback. Furthermore, we stay as close as possible to the prior approach and model volatility as sensitivity to profit, that is the level of profit extrapolation in the formation of cash flow expectations.

The Greenwald and Stiglitz (1990, 1993) approach acknowledges that the leverage a (non-financial) firm manager is willing to take in order to finance production is bound by the conditional probability of bankruptcy. The reason is that those managers do bear the downside risk by loss in reputation ("being a bad manager") and loss in salary due to unemployment if the firm goes bankrupt. If the firm is a corporation (i.e. a publicly listed company) the management remuneration is likely to depend also on the stock performance. In that case a manager would take the expected stock price into account for his or her capital demand decision. In the underlying model the stock price affects the manager's decision of how much leverage to accept.

In this context there needs to be some deviation from the former approach. Since there is no labour market in the model, there are also no wages for the management or workers. If the remuneration is tackled as channel of influence, there needs to be a distinction between the acting managers and the owners of the firm. The managers' decision problem under investigation is not to maximize mere expected profit for the firm but to maximize their own expected payoff.

The remuneration package of the management is assumed to consist of the number of company shares $\varphi_{it}$ granted as incentive and a fixed salary $c^M_{it}$ which also depends on the firm size in the form $c^M_{it} = \phi K_{it} c^m$ where $c^m > 0$ is a constant. The value of the compensation $\pi^M_{it}$ depends on the stock price that is realized *at the end* of the period and the share of salary that is paid in granted shares $\beta \in [0,1]$: $\pi^M_{it} = \beta \varphi_{it} P_{it} + (1-\beta) c^M_{it}$. Note that the stock price itself depends positively on profit. Assuming the costs of bankruptcy borne by the management include losses from future salary and reputation, this is captured by $c^f_{it}$. The management can only reap the benefits from granted stocks if the firm is not bankrupt. Denote the probability of bankruptcy as Prob$(BR_{it}) = \mathbb{P}_{it}$. The expected payoff for the management is

$$\mathbb{E}[\pi^M_{it}] = (1-\mathbb{P}_{it})\beta \varphi_{it} \mathbb{E}[P_{it}] + (1-\beta) c^M_{it} - \mathbb{P}_{it} c^f_{it}. \tag{2.19}$$

Stocks are assumed to be traded at the end of each period when investors know whether a firm will continue existing and under which conditions. Therefore, the stock price at period $t$ is not known when the investment decision of the management is due. It is assumed that the number of granted shares is smaller for *single* managers if the share price is high so that the individual performance based remuneration on average does not grow just because the firm is large. On firm level we assume a relation $\varphi_{it} \equiv \frac{E_{it}}{A_{it}}\phi K_{it}$. Furthermore, we again assume that $E_{it} = E = 1$ for all $i,t$. The managers' expected payoff is in detail

$$\mathbb{E}[\pi_{it}^{M}] = (1-\mathbb{P}_{it})\beta\frac{1}{A_{it}}\phi K_{it}\mathbb{E}[P_{it}] + (1-\beta)\phi K_{it}c^{m} + \mathbb{P}_{it}c\phi^{2}K_{it}^{2}.$$

Remember that $\mathbb{P}_{it} = \frac{\bar{u}_{it}}{2}$. Managers are assumed to have some knowledge about the composition of the stock price and they try to maximize their payoff by influencing the stock price. The management knows the prior period deviation of the stock price from the fair value of the company. They also can figure out how much the market over- or undervalued the profit. Therefore, they have some expectation about the deviation. Assume that $\varepsilon_{it}$ still is the market deviation from the value of profit. But assume now that the management does see it as *sensitivity* to profit. Then, $\varepsilon_{it}$ also determines an amplification of negative profits. We specify

$$P_{it} = A_{it} + \pi_{it}\varepsilon_{it} \tag{2.20}$$

The term $\varepsilon_{it}$ can now be understood as markup on the multiplier of profit if we assume that the stock price is supposed to be a multiple of profit or dividend. This refers to the concept that share prices should reflect the present value of the expected stream of dividends.
The managers' payoff depends on the expected valuation of net worth and on the probability that the firm is not bankrupt at the end of the period. The stock price is positive only if the firm is not bankrupt. The expected stock price is

$$\mathbb{E}\left[P_{it}\right] = \left(\frac{A_{it-1}}{E} + (\phi - gr_{it})K_{it} + (\phi - gr_{it})K_{it}\frac{\mathbb{E}[\varepsilon_{it}]}{E}\right)$$

The managers optimize their expected payoff from equation (2.19) by choosing the amount of capital to employ for production:

$$K_{it}^{d} = \frac{\frac{A_{it-1}}{2}\left[(E+\varepsilon_{it-1}+1)\,\beta\,(gr_{it}-\phi) - \beta\phi - E\right] + (\beta-1)E\phi c^{b}}{\beta\left(E+\varepsilon_{it-1}\right)\left(g^{2}r_{it}^{2} - 3gr_{it}\phi + 2\phi^{2}\right) - Egr_{it}\phi}.$$

Then, the equilibrium interest rate becomes:

$$r_{it} = \frac{1}{-4\beta\phi^2 (E+\varepsilon)} \cdot \left(\Lambda_1 - \sqrt{(\Lambda_1)^2 + \Lambda_2}\right) \tag{2.12c}$$

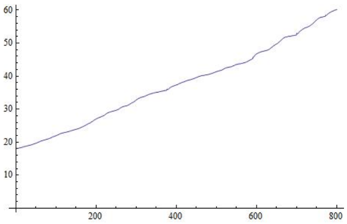
with

$$\Lambda_1 = g\phi \left(2c^b E + 6\beta E_{it} + 6\beta \varepsilon_{it}\right) \frac{A_{it-1} g\beta (1+E+\varepsilon_{it})}{L^s_{it} + A_{it-1}}$$

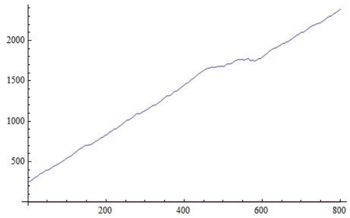
$$\Lambda_2 = 8g^2\beta (E+\varepsilon) - 4g^2\beta (E+\varepsilon) \frac{1}{L^s_{it} + A_{it-1}} \left(A_{it-1}\beta\phi (2+E+\varepsilon_{it}) + c\phi E (-2\beta + 2 + A_{it-1})\right)$$

Details about the computation are provided in Appendix A.1.

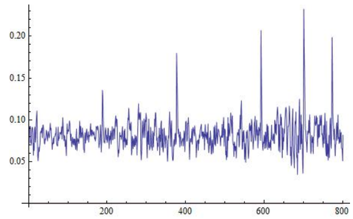
Since this setting deviates slightly from the baseline case we start with examining the case where the management is paid only a fixed salary. Compared to the baseline case of the prior two settings here the



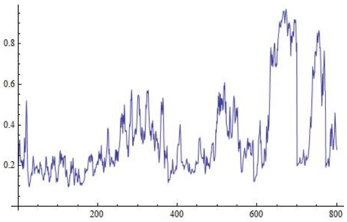
(a) GDP Scen. (3)



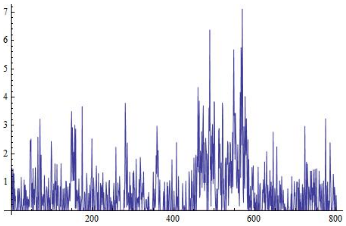
(b) Firm number with Scen. (3)



(c) Average interest rate, Scen. (3)



(d) Market Power Scen. (3) ($\beta$ low)

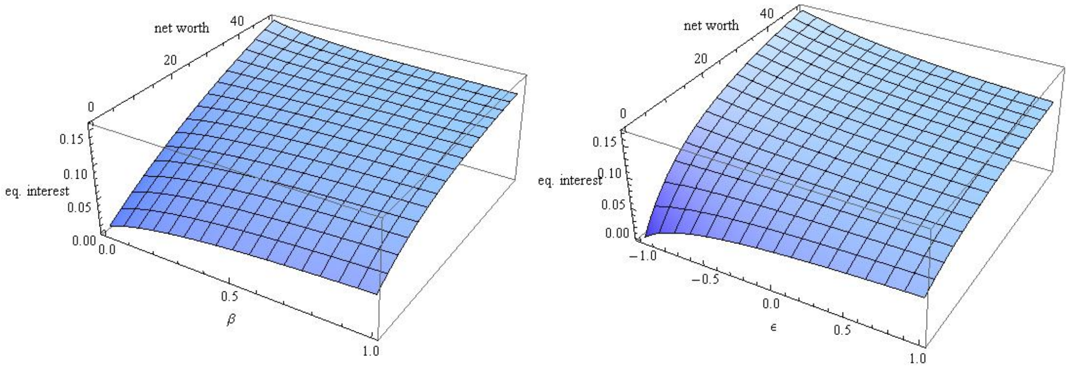


(e) Bad Debt Scen. (3)

Figure 2.8: **Uncorrelated stock prices ($\beta$ low)**

interest rate is slightly higher on average as is total output. Figure 2.8 shows the over time dynamics of a typical baseline scenario. There are business cycle patterns (figure 2.8a) and the number of firms active is increasing (figure 2.8b). The interest rate is fluctuating a lot (figure 2.8c). Due to the increasing number of firms the market power is low but occasionally there is a high market power (figure 2.8d). The bad debt shows that there are frequent bankruptcies but those are usually small firms (figure 2.8e). The tail of the firm size distribution follows a power-law (figure A.1d, page 49) so there is some validity of this variation of the model as well.

The dynamics resemble the baseline scenario of the underlying model except that the interest rate varies more. The reason is that due to the fixed payoff component the payoff is less sensitive to the interest rate. Therefore, for given credit supply the equilibrium interest rate varies more. Figure 2.9a shows




(a) sensitivity to performance-based share

(b) sensitivity to profit extrapolation

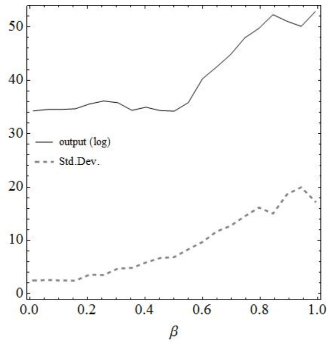
Figure 2.9: **Interest sensitivity**

the equilibrium interest rate depending on net worth and the share of stock based compensation. The amount of credit supply is fixed so that the net worth indicates the leverage of a firm. If the leverage is high, that is, the net worth is low, then an increasing share of stock based compensation leads to a higher equilibrium interest rate. If the leverage is low, then an increasing share of stock based remuneration leads to a *decreasing* equilibrium interest rate (figure 2.9a). This picture also shows that for any distribution of leverage, a higher share of stock price based compensation will result in a narrower distribution of equilibrium interest rates. The interest sensitivity to the amplification of profit shows a similar pattern (figure 2.9b).

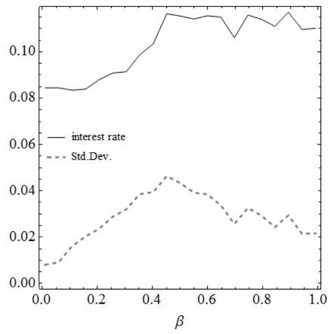
This indicates that managers demand higher capital if their payoff relies on a good performance of the firm but once the firm is financially sound, a higher $\beta$ causes a more prudent behaviour.

### 2.5.1 No Cycles at the Stock Market

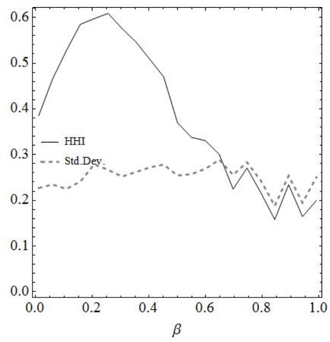
Comparing the long-term impact of various shares of compensation based on stock prices $\beta$, for low values of $\beta$ an increase in performance based compensation does result in a higher interest rate (figure 2.10b) and higher market power (figure 2.10c). Output and credit supply are unaffected (figures 2.10a and 2.10d). For values of $\beta$ above some threshold (about $\beta$=0.5) output and credit supply are higher (figures 2.10a and 2.10d), but here the interest rate is unaffected (figure 2.10b). Market power decreases for higher levels of $\beta$ (figure 2.10c). Credit is supplied to only a few firms for a medium value of $\beta$.



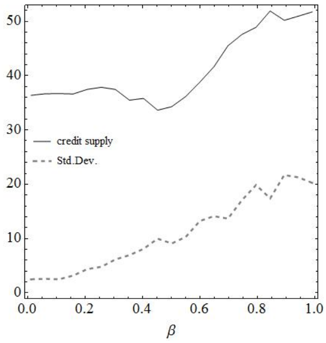

(a) total output



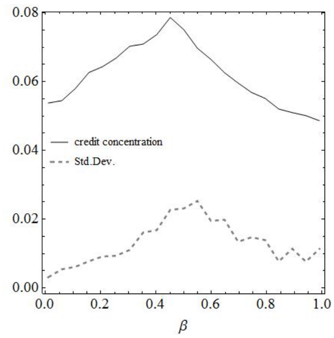

(b) average interest rate




(c) Market Power




(d) Credit Supply



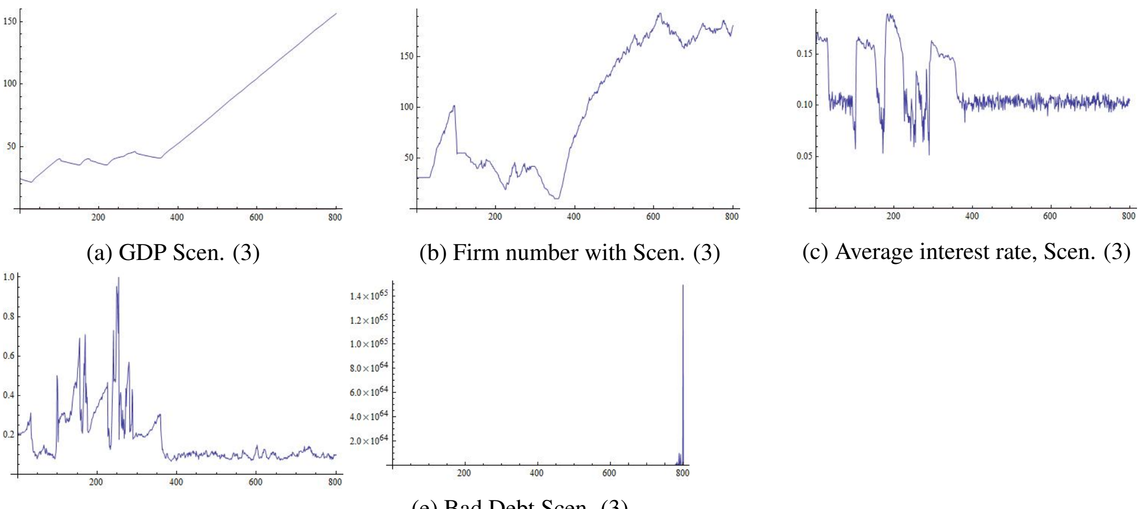

(e) Credit Concentration

Figure 2.10: **Impact of $\beta$**

For low $\beta$, that supply concentration increases but after the peak decreases again as $\beta$ approaches one (figure 2.10e). Representative runs show (figures 2.11) that there is a highly cyclical dynamic effect so that the reliability of those results has to be handled with care. The sensitivity of the interest rate to the performance-based remuneration share (figure 2.9) indicates that for large $\beta$, the interest rates across firms will be less dispersed. Therefore, growth differences among firms will be less dispersed, too. The distribution of firm sizes shows that large 'gaps' in firm sizes for low values of $\beta$ (figure A.1e, page 49) will be less pronounced for larger values of $\beta$ and the tail of the distribution does follow a power-law (figure A.1f, page 49). At the same time, if the firm is financially sound the expected performance based payoff is relatively high through the low bankruptcy probability. Any changes in the payoff weights have a rather large effect through the performance based part because now it may change faster than the fixed payoff. As a result, the optimal capital is lower for stable firms if more weight is put on the performance based part because the possible stock price is then less influenced by capital. Additionally, the probability of yielding that price is relatively sensitive. A lower level of capital might then induce a comparatively higher probability and only a slightly lower possible price whereas the net gain is positive in this case.

The marginal changes in the probability of bankruptcy and the stock price differ in $\beta$ which accounts for its effect on the long run dynamics. For firms any additional unit of capital contributes to the growth perspective and to the probability of bankruptcy at the same time. If a firm is highly leveraged its probability of bankruptcy is high, too. An additional unit of capital however, will increase the profit perspective as the expected stock price increases. This is based on the high probability of bankruptcy that increases less than the stock price perspective increases. Remember that also the expected costs of bankruptcy depending on the job loss increase slowly for highly leveraged firms.

Managers of financially sound firms who rely mostly on performance based compensation will not risk the survival prospects and thus most of their payoff for only small increases in the anticipated amount of payoff. Therefore, as this part of their salary becomes more important, it is optimal for them to reduce capital and therefore the possible stock price by a little if at the same time the survival probability increases significantly. Managers of leveraged firms can afford using more capital because the decrease in survival probability is meager but the potential gain is huge. As performance based compensation becomes more important, the gains by the anticipated price become more important and together with the only slight trade off in the survival probability, it pays off to increase capital. In the long run leveraged firms grow comparatively less because of higher interest rates. Colloquially expressed, leverage is more costly for $\beta = 1$ and financial soundness is rewarded more for high levels of performance based remuneration compared to a regime of fixed compensation.



(a) GDP Scen. (3)

(b) Firm number with Scen. (3)

(c) Average interest rate, Scen. (3)

(d) Market Power Scen. (3)

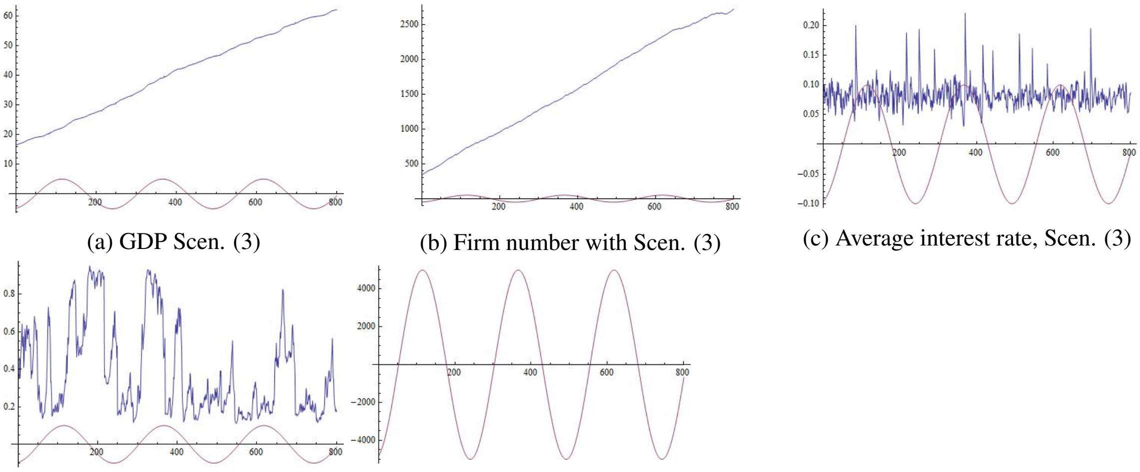
(e) Bad Debt Scen. (3)

Figure 2.11: **Uncorrelated stock prices ($\beta$ high)**

The single run of high $\beta$ reveals that the extreme case leads to unreasonable dynamics since there are no business cycles visible (figure 2.11a). The number of firms is more or less stable (figure 2.11b) and the interest rate fluctuates in a tight corridor but at a relatively high level (figure 2.11c). Also the market power remains relatively stable at a low level (figure 2.11d).

### 2.5.2 Volatility Cycles

In this sub-section we will examine the effects of volatility cycles of the stock prices on the dynamics in a strictly performance based remuneration situation. The volatility cycles are supposed to reflect phases of wide-spread sensitivity of stock investors to news or data. They are included by adding a cyclical drift to the random component of *all* stock prices.



(a) GDP Scen. (3)

(b) Firm number with Scen. (3)

(c) Average interest rate, Scen. (3)

(d) Market Power Scen. (3)

(e) Bad Debt Scen. (3)

Figure 2.12: **Stock Prices with persistent volatility**

In figure 2.12 it is visible that the stock investors' mood has a significant impact on the dynamics. Also, the distribution of the firm sizes only show a power-law in the tail for $\beta = 1$ (figures A.2b through A.2d on page 50). Overall output shows about the same dynamics as with non-correlated stock prices (figure 2.12a). The number of firms increases since there are almost no firms leaving (figures 2.12b and 2.12e). Both, the interest rate (figure 2.12c) and market power (figure 2.12d) show rich dynamics but there are no clear patterns identifiable that would emerge due to the drift in stock prices. Figure 2.13 shows the credit demand conditional on the interest rate and its sensitivity to the stock price extrapolation $\varepsilon$. The demand curve rotates in $\varepsilon$ rather then being shifted. For $\varepsilon > 0$ it becomes flatter, for $\varepsilon < 0$ it is steeper. This explains why there are more fluctuations in the equilibrium interest rate but no clear responses to the cyclical volatility.

Credit demand is not higher or lower for all levels of interest as it would be with a shift of the credit demand curve. The rotation results in more extreme interest rates.

For $\varepsilon > 0$ firms with tight constraints pay less interest but those who have plenty of credit supplied pay comparatively more. For $\varepsilon < 0$ this impact is reversed because the credit demand curve is steeper. Under supplied firms pay comparatively high interest rates and well supplied firms pay comparatively less.

Thus, there are no phases where *all* firms pay relatively more or relatively less interest.

Economically, for extrapolations $\varepsilon > 0$ credit demand is less sensitive, for $\varepsilon < 0$ it is more sensitive to the interest rate. This is because the expected payoff changes due to two things, the probability of bankruptcy and the profit that is expected. For any $\varepsilon$ the probability of bankruptcy changes the same in the interest rate as does the profit that is expected. The stock price that is expected however, changes less if $\varepsilon < 0$ and the extrapolation is low. This is a situation where the probability of bankruptcy increases faster in capital than the possible payoff. Therefore, in times of low volatility the capital demand is more sensitive.

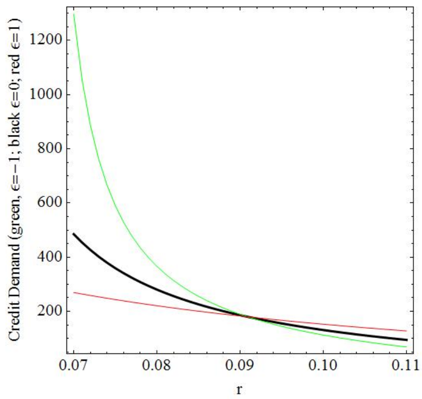



Figure 2.13: Credit demand for different $\varepsilon$
(black$\rightarrow \varepsilon = 0$, red$\rightarrow \varepsilon > 0$, green$\rightarrow \varepsilon < 0$)

This section shows that managers adjust their behaviour to the stock market situation if their payoff depends on it. If they face an asymmetric payoff pattern and bear the downside risk of bankruptcy they have an incentive not to take too much risk. If they can benefit over proportionally from firm profits due to an extrapolation of profit at the stock market they act more accurate in a sense. This accuracy reveals their willingness to pay interest for a given level of credit. In times of volatile stock markets their willingness to pay interest is much less elastic. Therefore, firms evolve more similarly but they pay high interest rates. This hinders capital accumulation and growth. In times of changing volatility the fluctuations lead to a more cyclical output pattern but in times where there are no changing volatility the firms on average pay a high interest. These high average interest rates are beneficial for the development of the economy since the bank makes higher profits and through the monetary multiplier supplies much more credit to the firms. Hence the economy grows fast. Moreover, in this setting it does not show any unusual behaviour over time, neither with stock market volatility cycles nor without it. Therefore, governmental regulation would not need to aim at restricting the share of payoff that depends on the performance. It is to say that this may only hold in a world where the management actually bears some downside risk as well.

## 2.6 Concluding Remarks

The central point of this paper is to assess the impact of three known transmission channels of stock prices to the real economy. One matter of interest is the influence of cyclical stock price patterns in such transmissions. We discuss boom-bust cycles and phases of persistent volatility using a particular transmission example.

This paper abstracts from the typical theory of stock price influences on the real side of the economy. Usually, the focus lies on the demand side: increased output follows increased stock prices because consumers possess a higher wealth and thus consume more. In this paper, the supply side is explored looking at three channels that are known to link stock prices to the real economy. All three channels deal with the influence that stock prices have on credit that firms rely on in order to finance their production: banks use the stock price as proxy for firms' prospects when evaluating creditworthiness, firms in financial distress might continue to exist if the market assessment is good, and last, top managers of listed companies are paid by a remuneration package that relies on stocks. Relying on an agent-based model that employs credit and financial fragility as driver of output and firms' growth dynamics the impact of the stock market is visible in all three channels.

A central point of the examination is the mutual influence, therefore a computer simulation is used. The basis is an existing model by Delli Gatti et al. (2005) that is able to reproduce business cycles and further stylized facts like the distribution of firm sizes. Since individual access to credit is key in this model, it provides a sound basis for introducing the intended links to stock prices and for carrying out a comparative analysis.

The simulation for all three channels shows that all of them have a non-negligible impact: first, the effect of banks' rating policy where it takes stock prices into account is less beneficial as it reduces output and increases concentration. The reason is that the selection is even more concentrated as the firms size matters less than equity which cancels out the advantage of leverage. Leverage has an economy-wide advantage although a larger number of individual firms go bankrupt along the way. There are fewer possibilities for firms to grow by applying leverage. The importance of credit diminishes to the extent with which the bank takes the stock price into account. As financial health exerts more impact in this case, some firms have more persistent advantages and market dominance emerges earlier and is also more persistent. This result relies, however, on the assumption that the stock price reflects to some extent the firm's equity. Second, in cases of financial distress the stock market can determine whether the firm can sustain or whether it will face legally declared bankruptcy. The amount of shareholders' bargaining power does not have a significant impact on the long run development of the economy if firms face idiosyncratic impacts that cancel out on average. If the stock prices are correlated the behaviour of firms becomes correlated, too. Then it matters if the shareholders have a high bargaining power. The cyclical stock prices result in pronounced business cycles but without long term growth. Firms' managers are willing to pay high interest rates in boom times because they regard the probability of bankruptcy to be low. In that situation firms earn only low profits. Because there are almost no profits to be retained in those phases there is no long-term growth. Therefore, if there are boom bust periods on the stock market, it makes sense to consider relying less on shareholders' opinion in bankruptcy rulings.

Third, if managers are paid also in stocks, they are more prudent if stock prices are volatile because they are assumed to be risk averse. Their behaviour impacts the economy in a more complicated way. The impact that an increase in the performance based share has depends on the level of that share. Overall, the economy benefits from the managers having stakes in the company because they act in a more sensitive manner. Even when there are periods of changing volatility at the stock market and their compensation consist only of granted stock they do not take excessive risk. Therefore, it is not necessary to limit the share of compensation based on performance. This holds true in this model because the managers bear a significant downside risk.

All three channels have a significant impact on the dynamics of the economy. It matters not only to what extent the stock price enters the decisions in the real economy but also to what scope those decisions correlate. If there are phases of optimism or pessimism on the stock market there is also correlation in real economy dynamics.

# Appendix A

## A.1 Capital Demand for Stock Related Remuneration

$$\Gamma_{it} = -0.5cK_{it}^2\phi^2\left(\frac{gr_{it}}{\phi} - \frac{A_{it-1}}{K_{it}\phi}\right)$$

$$+\beta K_{it}\phi\left(1-0.5\left(\frac{gr_{it}}{\phi} - \frac{A_{it-1}}{K_{it}\phi}\right)\right)\left(\frac{A_{it-1}}{E_{it}} + K_{it}\left(\frac{\varepsilon_{it-1}}{E_{it}}+1\right)(\phi - gr_{it})\right) + (1-\beta)c^b K_{it}\phi$$

Then, the derivative becomes

$$\frac{\partial\Gamma_{it}}{\partial K_{it}} = -cK_{it}\phi^2\left(\frac{gr_{it}}{\phi} - \frac{A_{it-1}}{K_{it}\phi}\right) - 0.5A_{it-1}c\phi + \beta K_{it}\phi\left(\frac{\varepsilon_{it-1}}{E_{it}}+1\right)(\phi - gr_{it})\left(1-0.5\left(\frac{gr_{it}}{\phi} - \frac{A_{it-1}}{K_{it}\phi}\right)\right)$$

$$+\beta\phi\left(1-0.5\left(\frac{gr_{it}}{\phi} - \frac{A_{it-1}}{K_{it}\phi}\right)\right)\left(\frac{A_{it-1}}{E_{it}} + K_{it}\left(\frac{\varepsilon_{it-1}}{E_{it}}+1\right)(\phi - gr_{it})\right)$$

$$-\frac{0.5A_{it-1}\beta\left(\frac{A_{it-1}}{E_{it}} + K_{it}\left(\frac{\varepsilon_{it-1}}{E_{it}}+1\right)(\phi - gr_{it})\right)}{K_{it}} + (1-\beta)c^b\phi$$

This yields from the first order condition

$$K_{it}^d =$$

$$\frac{A_{it-1}\beta\varepsilon_{it-1}\phi + 2.A_{it-1}\beta\phi + A_{it-1}cE_{it}\phi + A_{it-1}\beta E_{it}\phi - A_{it-1}\beta E_{it}gr_{it} - A_{it-1}\beta gr_{it}\varepsilon_{it-1} - A_{it-1}\beta gr_{it} - 2\beta c^b E_{it}\phi + 2c^b E_{it}\phi}{-4\beta\varepsilon_{it-1}\phi^2 + 2cE_{it}gr_{it}\phi - 4\beta E_{it}\phi^2 - 2\beta E_{it}g^2r_{it}^2 + 6\beta E_{it}gr_{it}\phi - 2\beta g^2r_{it}^2\varepsilon_{it-1} + 6\beta gr_{it}\varepsilon_{it-1}\phi}$$

Define for the numerator:

$$-A_{it-1} g r_{it} \beta \left(1+E_{it}+\varepsilon_{it}\right) =: \Psi_1$$
$$A_{it-1} \beta \phi \left(2+E_{it}+\varepsilon_{it}\right) =: \Psi_2$$
$$c \phi E_{it} \left(-2\beta+2+A_{it-1}\right) =: \Psi_3$$

And for the denomiator:

$$g r_{it} \phi \left(2c^b E_{it}+6\beta E_{it}+6\beta \varepsilon_{it}\right) =: \varphi_A$$
$$-4\beta \phi^2 \left(E_{it}+\varepsilon\right) =: \varphi_B$$
$$-2g^2 r_{it}^2 \beta \left(E_{it}+\varepsilon\right) =: \varphi_C$$

Such that

$$K_{it}^d = \frac{\Psi_1+\Psi_2+\Psi_3}{\varphi_A+\varphi_B+\varphi_C}.$$

Using $K_{it} = L_{it} + A_{it-1} \Leftrightarrow L_{it} = K_{it} - A_{it-1}$ and with the equilibrium condition and capital demand

$$L_{it}^s = \frac{\Psi_1+\Psi_2+\Psi_3}{\varphi_A+\varphi_B+\varphi_C} - A_{it-1}$$

this can be rearranged to

$$\varphi_A+\varphi_B+\varphi_C = \frac{1}{L_{it}^s + A_{it-1}} \left(\Psi_1+\Psi_2+\Psi_3\right)$$

leading to

$$\underbrace{\varphi_C}_{r_{it}^2 a} + \underbrace{\varphi_A - \frac{\Psi_1}{L_{it}^s + A_{it-1}}}_{r_{it} b} + \underbrace{\varphi_B - \frac{\Psi_2+\Psi_3}{L_{it}^s + A_{it-1}}}_{c} = 0.$$

For this expression is of the form $a r_{it}^2 + b r_{it} + c = 0$ for

$$a = -2g^2 \beta \left(E_{it}+\varepsilon\right)$$
$$b = g\phi \left(2c^b E_{it}+6\beta E_{it}+6\beta \varepsilon_{it}\right) \frac{-A_{it-1} g \beta \left(1+E_{it}+\varepsilon_{it}\right)}{L_{it}^s + A_{it-1}}$$
$$c = \frac{1}{L_{it}^s + A_{it-1}} \left(A_{it-1} \beta \phi \left(2+E_{it}+\varepsilon_{it}\right) + c\phi E_{it} \left(-2\beta+2+A_{it-1}\right)\right) - 4\beta \phi^2 \left(E_{it}+\varepsilon\right)$$

this can be solved, e.g. by using the p-q-form such that the known solution is

$$r_{1/2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

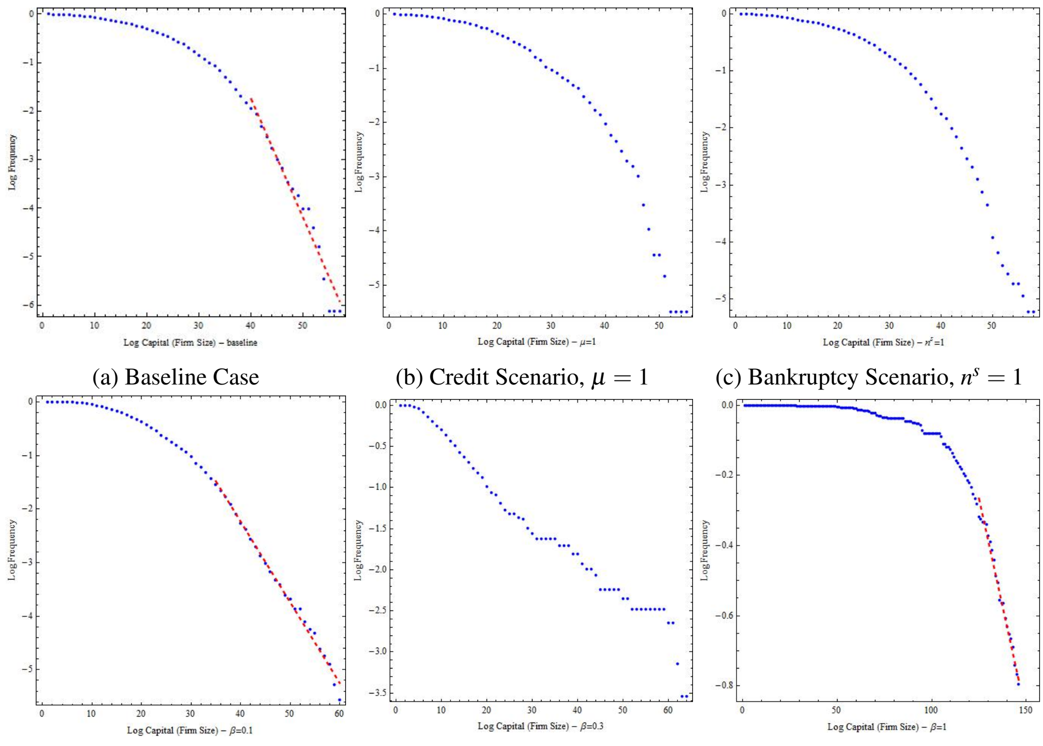
yielding

$$r_{1/2} = \frac{g\phi\left(2c^b E_{it} + 6\beta E_{it} + 6\beta\varepsilon_{it}\right)\frac{A_{it-1} g\beta(1+E_{it}+\varepsilon_{it})}{L^S_{it}+A_{it-1}}}{-4\beta\phi^2\left(E_{it}+\varepsilon\right)}$$

$$\pm \frac{\sqrt{\left(g\phi\left(2c^b E_{it} + 6\beta E_{it} + 6\beta\varepsilon_{it}\right)\frac{A_{it-1} g\beta(1+E_{it}+\varepsilon_{it})}{L^S_{it}+A_{it-1}}\right)^2 + 8g^2\beta\left(E_{it}+\varepsilon\right) - 4g^2\beta\left(E_{it}+\varepsilon\right)\frac{1}{L^S_{it}+A_{it-1}}\left(A_{it-1}\beta\phi\left(2+E_{it}+\varepsilon_{it}\right) + c\phi E_{it}\left(-2\beta+2+A_{it-1}\right)\right)}}{-4\beta\phi^2\left(E_{it}+\varepsilon\right)}.$$

Note that $b = \Lambda_1$ and $-4ac = \Lambda_2$. Since $r_1 > r_2$, $r_2$ is the interest rate that will emerge in equilibrium because firms yield the global maximum profit with it.

## A.2 Firm Size Distributions

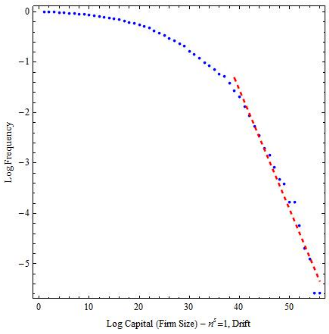



(a) Baseline Case (b) Credit Scenario, $\mu = 1$ (c) Bankruptcy Scenario, $n^s = 1$

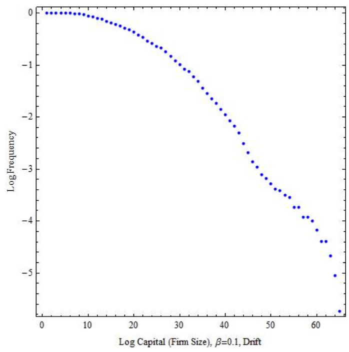
(d) Remuneration Scenario $\beta = 0.1$ (e) Remuneration Scenario, $\beta = 0.3$ (f) Remuneration Scenario, $\beta = 1$

Figure A.1: **Firm size distribution**

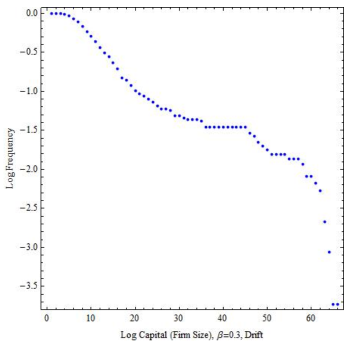
The red dashed lines depict the power-law fit for the tail of the distribution.



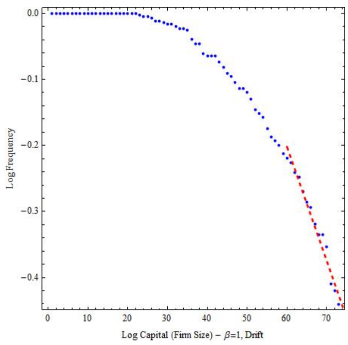

(a) Bankruptcy Scenario with Drift




(b) Remuneration Scenario with Drift $\beta = 0.1$




(c) Remuneration Scenario with Drift, $\beta = 0.3$




(d) Remuneration Scenario with Drift, $\beta = 1$

Figure A.2: **Firm size distribution with drift**

| Parameter Ranges for Robustness Check | | |
|---|---|---|
| productivity | $\phi$ | $[0.05, 0.15]$ |
| bankruptcy costs component | c | $[0.5, 1.5]$ |
| interest spread coefficient | $\omega$ | $[0, 0.004]$ |
| risk coefficient banking sector | $\nu$ | $[0.05, 0.1]$ |

Table A.1: Parameter space for the robustness check

## A.3 Parameters and Variables

| **Control Parameters** | | |
|---|---|---|
| stock price weight in credit supply | $\mu$ | [0,1] |
| influence of shareholders | $n^s$ | [0,1] |
| share of performance based remuneration | $\beta$ | [0,1] |

| **Parameters** | | |
|---|---|---|
| productivity | $\phi$ | 0.1 |
| retooling costs | g | 1.1 |
| bankruptcy costs component | c ($c^b$) | 1 |
| weighing parameter for credit supply | $\lambda$ | 0.3 |
| interest spread coefficient | $\omega$ | 0.002 |
| risk coefficient banking sector | $\nu$ | 0.08 |
| entry parameter | $N$ | 5 |
| entry parameter | $d$ | 100 |
| entry parameter | $f$ | 0.1 |
| initial number of firms | | 100 |

## A.4 Wilcoxon Signed Rank Test

In order to check whether the results are robust, a `Wilcoxon Signed Rank` test is conducted. The Wilcoxon Signed Rank test is performed because it allows for testing samples where a normal distribution cannot be assumed and where the variance is unknown. It is a non parametric test. The following procedure is as described by Sheskin (2011). Basically, the test is whether the medians of two sample populations (data sets) are likely to be the same at a certain level of significance. If so, the two sample populations can be assumed to be drawn from the same distribution. Some assumptions are essential for the test:

1. The observed data either constitute a random sample of $N$ independent pairs of items.
2. The observed data are measured at a higher level than the ordinal scale.
3. The distribution of the population of difference scores between repeated measurements of between matched items of individuals is approximately symmetric.

The Null-hypothesis is that the two populations which the results stem from do not differ in their median $\nu$: $H_0 : \nu_1 = \nu_2$ while the alternative is for a two tailed test $H_{alt} : \nu_1 \neq \nu_2$. that is, the median of population 2 is either below or above the median of population 1. The results are checked for a significance level of 95%, that is $\alpha = 0.05$. Each pair of data is compared and the difference taken $W_i = x_{1i} - x_{2i}$ for all $i = 1, ..., N$. Zero differences $W_i = 0$ are discarded and the sample size left is $n$. Since a two tailed test is conducted, the test statistics is the minimum of the sums of negative and positive differences in the pairs of the samples,

$$W := Min[|W_-|, W_+].$$

If the *sample size* is sufficiently large, $W$ can be assumed to be normally distributed. Then, a $z$-value can be computed using the number of nonzero differences $n$. This can also be done for the continuation of data in order to better compare the continuous normal distribution with discrete data in the form

$$z = \frac{\left|W - \frac{n(n+1)}{4}\right| - 0.5}{\sqrt{\frac{n(n+1)(2n+1)}{24}}}.$$

In this test, the $H_0$ hypothesis can be rejected if $|z| \geq z^{crit}$ where $z^{crit}$ is the critical value at a significance level chosen according to a table. For a significance level $\alpha = 0.05$ the critical value is $z^{crit} = 1.645$.

## A.5 Robustness Check

The robustness check is aimed to see whether the results do hold qualitatively for a wider range of parameters. Therefore,

1. intervals for parameter values are determined,
2. a number of random profiles is generated within the parameter ranges,
3. simulations are run for each setting of the control parameter under investigation for all of the random profiles.
4. Then, the generated results for each different control parameter setup are compared using a Wilcoxon-Signed Rank test. This test reveals whether the output for the random profiles is significantly different under a different control parameter value. If so, the test provides also which output distribution has the higher median and thus provides information for the impact of the relevant parameter.

In particular, the control parameters are $\mu$,$n^s$, and $\beta$. Since $n^s$ has no impact, only robustness of $\mu$ will be tested. Three levels of $mu$ and $\beta$ will be compared. The qualitative difference will then be indicated with ">" if the mode is larger for the first distribution and with "<" vice versa. If there is no significant difference, this will be indicated by "x".

| $\mu$ | | | $\bar{r}_{it}$ | $Herfindahl$ | $Output$ |
|---|---|---|---|---|---|
| $\mu = 0$ | vs. | $\mu = 0.5$ | $>$ | $<$ | $>$ |
| $\mu = 0.5$ | vs. | $\mu = 1$ | $x$ | $<$ | $x$ |
| $\mu = 0$ | vs. | $\mu = 1$ | $>$ | $<$ | $>$ |

Table A.2: Impact of $\mu$

| $\beta$ | | | $\bar{r}_{it}$ | $Herfindahl$ | $Output$ |
|---|---|---|---|---|---|
| $\beta = 0$ | vs. | $\beta = 0.5$ | $<$ | $<$ | $<$ |
| $\beta = 0.5$ | vs. | $\beta = 1$ | $<$ | $<$ | $<$ |
| $\beta = 0$ | vs. | $\beta = 1$ | $<$ | $<$ | $<$ |

Table A.3: Impact of $\beta$

# Chapter 3

# Credit Constrained R&D Spending and Technological Change

## 3.1 Introduction

Empirical research shows that R&D spending is affected by constraints in external funding. The effect is attributed to fluctuations in R&D spending that are accounted for by restrictions in credit markets or access to equity, for example due to lack of financial institutions (Hyytinen and Toivanen, 2003). Another explanation is higher costs of external capital whose impact is identified in Dutch samples (Mohnen et al., 2008), Italian manufacturing samples (Mancusi and Vezzuli, 2010), French manufacturing firms (Savignac, 2007), and US vs. European samples (Ravera and Canet, 2001). Explanations are based on the information shortage of external financiers compared to the researching firm. This disadvantage leads credit or equity providers to require a higher risk premium. Furthermore, even if R&D produces some innovation that can be implemented, this measure does not yield tangible assets that can serve as collateral for a loan. This also contributes to the risk premium (Mohnen et al., 2008, Czarnitzki and Hottenrott, 2011). This view is supported by evidence that considers sub samples of firms that are more likely to be constrained, namely small and medium enterprises and young firms. Because those lack either collateral and/or a proven history of creditworthiness, their ability to pay back a loan is highly uncertain. This finding is consistent with an analysis of Brown et al. (2009) who find that an improved supply of equity can trigger an R&D boom because relatively young firms benefit from that. Consequently, a lack of that supply also can lead to a bust in R&D activity as the R&D cycle in the U.S. in the 1990s showed (Brown et al., 2009, p. 152).

Moreover, firms that have a high R&D intensity suffer comparatively more from constraints because they usually require relatively higher external funding (Piga and Atzeni, 2007). Therefore, firms that show inherently one or more of the adverse features suffer discrimination in access to credit (Canepa and Stoneman, 2008, Hao and Jaffe, 1993, Giudici and Pateari, 2000). The particular role of uncertainty of creditworthiness is pointed out for the case of Finland (Hyytinen and Toivanen, 2003). In this case public subsidies can have a positive effect because they not only allow a research project to take place but also increase the trust in creditworthiness by others and thus may enable external financing in the future (Takalo and Tanayama, 2010).

The aim of this paper is to assess the impact of the described effects in a world where the acting entities react to each other. That is, we ask how much the industry, the R&D undertaken, and the innovation success change if credit restrictions change. More precisely, the impact of changes in behaviour is accounted for to understand why credit shortages have the observed impact. For instance, there might be little demand for credit in general and in this case shortages do not matter. Or there can be a mismatch between those entities that demand credit and those that would have access. This imbalance then determines how an increased supply of credit affects the individual R&D efforts.

The model is embedded in a dynamic agent based framework building on the work of Nelson and Winter (1982) and Winter (1984) which is set in an evolutionary environment under Schumpeterian competition. In each period the bank uses information about the firms in order to determine how much credit it would be willing to lend to each of them. The bank applies a particular routine of assessing creditworthiness based on multiple features. At the same time, each firm produces and conducts R&D to some extent. The outcome is some quantity of a homogenous good which jointly with all other firms determines the market price and automatically the profit of each firm on the one hand. On the other hand the R&D effort might lead to the finding of a better technology which the successful firm can use in the production process of the next period. This leads the successful firm to aiming at more investment for the next round of production. However, this possibility depends on the current profit and available credit. If the firm can exploit that technological improvement it will have better access to credit in the next period. There are two feedback effects at play in the model: a better technology improves access to credit and access to credit improves the probability of finding a better technology. Both effects are however, subject to individual behaviour of both, the bank and the firms. Thus, the effectiveness of the feedback varies in the behavioural routine of the agents. We conduct simulations for variations in credit supply, the interest rate and behavioural characteristics of the bank and the firms.

Results show that an increase of credit supply translates non-linearly to changes in output and industry concentration. First, more credit always is contributing to more innovation, faster growing output and a faster concentrating economy. Nevertheless, if there is either too tight credit or plenty of credit, increasing credit supply has only a marginal effect. There is a threshold of credit supply below which the industry evolves more slowly and above which it evolves with a much higher pace. Second, a higher interest rate cuts into profits and thus economic development. Third, the bank determines credit supply by comparing firms by profitability and by market share the industry grows faster when the focus is on market share. The reason is that firms' innovation success is more directly observable in market share while the increase in profitability depends on its access to credit. Therefore, innovative success is more persistent if the bank offers credit based mainly on the market share. Last, firms can influence their R&D success by adapting their effort only if there is much credit available.

This paper strengthens the role of the lender's information shortages as explanation for R&D spending patterns. The banking sector bases its decision on two observable firm features but does not have any information about the technology that will be applied in the upcoming production period. It does a retrospective evaluation but no forward-looking one. Therefore, it can happen that even the most innovative firms face credit shortages.

This paper contributes to empirical literature that points out that firms with particular features are more constraint in access to external funding. It provides theoretical explanations for those features rooted in the behaviour of the lender.

The remainder of the paper is organized as follows: section 3.2 gives an overview about the relationship between credit constraints and R&D funding. Section 3.3 introduces the model and the experiments. Section 3.4 discusses results while section 3.5 provides conclusive remarks.

## 3.2 Credit Constraints and R&D Effort

According to the empirical literature, constraints in external funding affect R&D efforts of firms (Brown et al., 2009, Mohnen et al., 2008). Hall and Lerner (2009) give an overview of the way R&D and innovation are funded. Small and new innovative firms experience high costs of capital, the evidence for large firms is mixed. Large firms prefer internal funding and manage their cash-flow accordingly. There is evidence that firms are constrained in financing R&D for several reasons. Concerning credit a major aspect is the insecure outcome of R&D in conjunction with relatively high monitoring costs. Therefore, firms might not be able to be granted credit to the amount they would like to (Freel, 2007). For a United Kingdom data-based empirical study, Freel (2007) finds that small firms that are innovative actually experience less credit granting success than their less innovative competitors. Supportive findings for high-tech firms are provided by Guiso (1998) who uses Italian samples. Cross-sectional data shows that manufacturers in high-tech categories have a higher probability of being constrained in credit. The predominant reason might be that there is higher uncertainty related to producing at the edge of technology.

### 3.2.1 Assessing Creditworthiness

The process of granting credit involves the assessment of many pieces of information. The creditor needs to know how likely it is that his loan is paid back. This evaluation usually takes the form of a credit rating which includes not only hard numbers but also more soft information about the debtor, first of all his relation to the creditor and their commercial history. Banks use ratings that are to some extent standardized. The customer adviser rates each of the categories according to some guidelines, but under her own discretion. For instance, the German credit unions (Volks- und Raiffeisenbanken) used the – in the meanwhile replaced – concept: management, market and sector, customer relation, economic situation of the customer, forecasted corporate development. All these factors receive a weight between 1/6 and 1/4. Then, summing up the assigned marks, the bank yields the rating (Reichling et al., 2007, pp. 46-49). The instrument of rating is mandatory because it is required by the Basel II agreement which requires banks to hold equity according to the risk of credits they granted (Reichling et al., 2007, p. 39). Although the probability of default is the crucial figure to estimate, banks do rely mostly on heuristic methods to assess that probability, even if there are also statistical and causal analytical methods, like models of option pricing. One reason is that statistical methods are only meaningful if the data set is sufficiently large (Reichling et al., 2007, p. 55). This particular example of a rating model shows that the current economic situation of the customer plays the most crucial role, along with the customer history. The assessment of the future counts only as much as the management or the commercial sector does. Nevertheless, "[a]n assessment that only includes the present must not be decisive - the [firm's] focus on the orientation to the future must be satisfactory." (Kremer and ten Hoevel, 1989, p. 122.)

### 3.2.2 Adaptive R&D Strategies

There is also some indication that R&D policy reacts to credit constraints. Aghion et al. (2012) find that credit rationing influences the R&D policy of French firms where the effect depends on the degree to which firms are financed externally. Constrained firms in the sample adjust R&D efforts in a more procyclical way. In a theoretical approach, Aghion et al. (2010) establish credit constraints as source of turning long-term investment pro-cyclical because of the liquidity risk involved in external finance when constraints become effective. Constraints have less the impact that projects are not carried out to the full extent but rather that they are not started at all in a sample of Italian small and medium size enterprises (Mancusi and Vezzuli, 2010). Furthermore, firms try to mitigate their dependence on outside funding by building up cash reserves which allows them to smoothen R&D activity over time. This behaviour is encouraged by high adjustment costs because R&D costs consist mainly of high wages for specialised researchers (Brown et al., 2012). Also, R&D investment is a special case because more than 50% of spending is due to high wages for knowledge workers. Therefore, "[f]irms tend to smoothen R&D investment over time in order to avoid having to lay off knowledge workers." (Hall and Lerner, 2009, p.5.)

In a theoretical approach, Yildizoglu (2002) finds that adaptive strategies due to learning outperform static rules for investment. Other insights about firms' R&D strategies are:

- *Ben-Zion (1984)*: Investment in R&D is riskier than investment in production (expansion) since there is more uncertainty about the outcome of research. Therefore, since in good times investment in R&D is easier to justify, research investment increases in economically favourable times.
- *Yildizoglu (2002)*: Investment is not static. Theoretically, learning makes a huge difference. Firms using adaptive research strategies perform better. Also, the higher the share of learning firms in an economy the further upward technology is pushed and so is output. Furthermore, firms who do not experience success of R&D after a while tend to abandon research activities. Also high competition among firms leads to lower R&D.
- *Lee and Harrison (2001)*: Depending on outside firm conditions it is possible to see firms using both, innovative and imitative strategies at the same time or that almost all firms (i.e. the vast majority) tend to either strategy. The important factors for this are the probabilities of payoffs, the distribution of payoff amounts and lag times for payoffs of an investment that had been made.

- *Yildizoglu (2001)*: When discussing the particular way in which firms learn, not only adaptation is important, but also expectations. Expectations are usually overlooked in modeling learning processes.

Furthermore, Ben-Zion (1984) mentions the positive relation between stock and bond market value and investor strategies and the R&D decisions of firms.

## 3.3 The Model

The model is about the evolution of an industrial sector where firms compete in improving their technology used in the production process of a homogenous good. Demand is given and joint output determines the market price and implicitly each firm's profit. In order to improve their technology, firms rely on their retained profits and possibly on external sources of funds for financing their R&D effort. In some situations there might be shortages in available funding. This model tackles the question which role market circumstances and the assessment of creditworthiness plays in the evolution of the sector when there are feedback mechanisms. Furthermore, the impact of the firm strategy of how to conduct R&D on the industrial output is examined. The time-line of events is as follows:

1. The bank has some amount of credit available for lending. According to the firms' features at the beginning of the period, it decides how much credit to grant each firm.
2. Firms have a size equal to their stock of physical capital $K_{it}$. They produce output and *simultaneously* draw for better technology. Joint output determines the market price $P_t$. And the draw determines the available technology in the *next* period.
3. Firms observe their current profits and the success of their past R&D effort. Then, each firm decides about physical investment and R&D spending. If desired total spending exceeds internal funds available, the firm applies for a credit.
4. The credit offered and credit demanded determine the funds available for a firm to invest in physical capital and to additionally perform R&D. The impact of investment and R&D is effective in the *next period*.

This is a model where the firms do not possess exclusive rights for their technology, like a patent. The effect of this legal framework may indeed be that competition might lead to less R&D, at least for innovative activities, since the incentives for cost reduction are lower (Gilbert, 2006). It has to be pointed out that innovation can take many forms, like product or process innovation where in this framework, only process innovation is replicated. The general difference is that product innovation is even less certain than process innovation, partly due to the more incremental character of process innovation.[1] While innovation can also be distinguished by its effect of reducing production costs or increasing the output per unit of input, the following framework assumes that output increases, which is in line with Schumpeter's definition of innovation: "we ... define innovation as the setting up of a new production function."(Schumpeter, 1939, p. 83.)

### 3.3.1 Setup

Output $Q$ is generated by technology $A$ and capital $K$ by each firm $i$ at each period $t$:

$$Q_{it} = A_{it} K_{it}. \tag{3.1}$$

Total output is equivalent to fixed demand so that the market price $P$ follows an inverse demand function

$$Q_t = \sum Q_{it} = \sum A_{it} K_{it} \equiv D \tag{3.2}$$

$$P_t = \frac{D}{Q_t}. \tag{3.3}$$

In case of drawing an imitation the firm adopts the industry's best technology. If drawing an innovation, it gets a sample from a distribution of technical opportunities distributed according to

$$F(\tilde{A}_{it}; A_{it}) \tag{3.4}$$

[1] See Schumpeter (1939, 1942) for a detailed discussion of the degree to which new techniques trigger readjustments of or even setting up capital and processes.

while $\tilde{A}_{it} \sim$ LogNormal$(A_{it}, 1)$. This implies that any innovation that is found is actually better than the currently employed technology. Successful draws are indicated by

$$\chi_{it}^{im,in} = \begin{cases} 1, \text{ if there is a successful draw of imitation (im) or innovation (in)}, \\ 0, \text{ else.} \end{cases}$$

For a firm the productivity level of following periods is given by

$$A_{i(t+1)} = Max(A_{it}, \chi_{it}^{im} \hat{A}_t, \chi_{it}^{in} \tilde{A}_{it}). \tag{3.5}$$

Here $\hat{A}_t$ is the highest (best practice) productivity level in the industry in period $t$, and $\tilde{A}_{it}$ is a random variable that is the result of the innovation draw. A firm's desired expansion or contraction is determined by the ratio of price to production cost $\frac{P \cdot A}{c}$ or, equivalently, the percentage margin over cost, and its market share. A firm's ability to finance its investment is constrained by its profitability, which is affected by its R&D outlays as well as by revenues and production costs. Capital is subject to depreciation at rate $\delta$ and investment $I$. Profitability $\pi$ is determined by the productivity cost difference per unit of capital and the spending on last periods loan, which is determined by the interest rate $i$ and the loan $l$ taken in the last period by the firm:

$$K_{i(t+1)} = I\left(\frac{P_t A_{i(t+1)}}{c}, \frac{Q_{it}}{Q_t}, \pi_{it}, \delta\right) K_{it} + (1-\delta) K_{it} \tag{3.6}$$

$$\pi_{it} = P_t A_{it} - c - i_{t-1} l_{it-1} \tag{3.7}$$

$$\Gamma_{it} = P_t A_{it} - c \tag{3.8}$$

where $\Gamma_{it}$ represents a firm's gross profit and $\pi_{it}$ denotes net profit after interest paid. The probabilities of drawing better technologies are due to imitation and innovation respectively and depend positively on the firm size, i.e. the amount of capital, some positive factor $a^{im}, a^{in}$, and the usage of R&D spendings $\Phi$

$$\begin{aligned} Prob(d_{imt} = 1) &= 1 - e^{-a^{im} K_{it} \Phi_{it} \kappa_{it}} \\ Prob(d_{in} = 1) &= 1 - e^{-a^{in} K_{it} \Phi_{it} (1-\kappa_{it})} \end{aligned} \tag{3.9}$$

where $\kappa_{it}$ is the share which allocates funds to imitation.[2] Assume that a firm does either imitation search or innovation search only. Let this depend on whether it actually employs the best technology

[2] These probabilities are inspired by Dosi et al. (2011).

already or whether it uses less efficient technology. The rationale is that a technology leader has nothing to copy from and thus can devote all financial means of research to innovative search.[3] Firms with less efficient technology would then *strictly* search any possibility to copy existing technology. This is a drastic statement but also very simple. A precondition for this action is that there is common knowledge about the highest technology.[4] Therefore,

$$\kappa_{it} = \begin{cases} 0, \text{ for } \hat{A}_t = A_{it} \\ 1, \text{ else.} \end{cases} \tag{3.10}$$

Credit would be demanded (only) if investment cannot be financed otherwise, that is by using net profit $\pi_{it}$ and savings from the end of the prior period $S_{it-1}/K_{it}$. A firm desires *physical* investment (capital) according to the function

$$I^d_{it} = 1 + \delta - \frac{\mu_{it}}{\frac{P_t A_{i(t+1)}}{c}} \tag{3.11}$$

$$\mu_{it} = \frac{\varphi - (\varphi - 1)s_{it}}{\varphi - \varphi s_{it}}. \tag{3.12}$$

where $\mu_{it}$ is the markup power a firm could exert. This markup consists of some positive parameter $\varphi$ and the current market share of a firm $s_{it}$. The higher the market share, the higher is the markup (Winter, 1984, p. 319). The investment desire then depends negatively on the markup and positively on the price-over-cost margin of the firm. That is, the higher the market share, the less investment in physical capital is desired and the higher the profitability, the higher the desired investment since the profitability directly depends on the price-over-cost margin. Together with R&D demand $\Phi^d_{it}$ the firm has demand for expenditures $E^d_{it} = \Phi^d_{it} + I^d_{it}$. Denote $C_{it} = \pi_{it} + S_{it-1}/K_{it} - l_{it-1}$ as liquidity per unit of capital. It consists of net profits, accumulated savings and recent credit to be paid back. By *assuming a strict hierarchy* in financing, a firm would first use profit to finance investment and then refer to its savings. If investment desire exceeds liquidity, i.e. net profit minus old debt obligations plus savings, there is demand for additional cash in the form of credit. Credit demand is the difference needed for

[3] The particular role both, innovation and imitation play in economic growth is subject to a lot of discussion and research. While innovation breaks ground to better techniques, the diffusion of this techniques as firms reorganize usually leads to the real push in economic activity. See for example, Fagerberg and Verspagen (2002) for some discussion.

[4] Other models employ a more sophisticated and incremental choice between imitation and innovation effort which then does not require common knowledge. See, for instance, Colombo et al. (2012).

financing

$$l_{it}^{d} = \begin{cases} E_{it}^{d} - C_{it} \text{ for } C_{it} < E_{it}^{d} \\ 0 \text{ else.} \end{cases} \tag{3.13}$$

The bank might offer credit based on a set of firm features. There is supply for credit $l^s$ per unit of capital in the economy. It is assumed to be constant which leads to supply in absolute terms $l_t^s = l^s \cdot \sum_i K_{it}$. The bank supplies credit to each individual firm in units of capital based on profitability and market share.

$$l_{it}^{s} = \begin{cases} \frac{l_t^s}{K_{it}} \left( \lambda \frac{\pi_{it-1}}{\sum \pi_{t-1}^{pos}} + (1-\lambda) \frac{Q_{it-1}}{\sum (Q_{it-1})} \right) \text{ for } \pi_{it-1} > 0 \\ \frac{l_t^s}{K_{it}} (1-\lambda) \frac{Q_{it-1}}{\sum (Q_{it-1})} \text{ else,} \end{cases} \tag{3.14}$$

where $0 \leq \lambda \leq 1$ and $\sum \pi_{t-1}^{pos}$ is the sum of all profits from firms that yielded positive profits. The first part of the term refers to the average credit supply per unit of capital and the second one determines an increase or decrease for an individual firm according to its profitability and market share. This concept hence avoids some potential problems for the case that -due to negative profits- some firms' profits are huge relative to the average profit. Thus, the bank takes into account relative profitability and relative technology level. Assuming that the credit supply per unit of capital is fixed, the absolute amount of credit offered will grow in the total amount of capital in the industry. Starting with a fixed supply of credit, the credit is allocated among the firms *applying* for it. Then,

$$l_{it} = Min \left[ l_{it}^{d}, l_{it}^{s} \right] \tag{3.15}$$

This means that even if profits are negative and there is no liquidity, investment can be conducted up to the amount of credit. The investment constraint is

$$I_{it}^{c} = C_{it} + l_{it}. \tag{3.16}$$

Actual physical investment is then determined by this constraint and the desired investment. Actual R&D investment is furthermore determined by the amount of liquidity not used for physical investment and the R&D desire $\Phi_{it}^{d}$

$$I_{it} = Min[I_{it}^{c}, I_{it}^{d}] \tag{3.17}$$

$$\Phi_{it} = Min[I_{it}^{c} - I_{it}, \Phi_{it}^{d}]. \tag{3.18}$$

The firms save money not invested. Savings evolve according to (Colombo et al., 2012, pp. 88, 89)

$$S_{it} = S_{it-1} + (\pi_{it} + l_{it} - I_{it} - \Phi_{it})K_{it}. \tag{3.19}$$

Note that savings are noted in absolute numbers and cannot be negative. Firms determine their R&D effort according to prior success of research and in boom times the firms tend to increase R&D. Denoting $\Phi_{it}$ the per unit of capital R&D spending of a firm $i$ at $t$, the firm changes R&D spending according to the factor $\Omega$. Desired spending on R&D is

$$\Phi_{it}^{d} = Max\left[\Phi_{it-1}(1+\Omega_{it}), b^{RD}\right] \tag{3.20}$$

with

$$\Omega_{it} = \lambda^{F}(\pi_{it-1} - \pi_{it-T-1}) \tag{3.21}$$

where $T$ is the number of periods that the firm is looking back and $\Omega$ increases in the evolution of profits, the R&D success history, and market share as that is directly incorporated in profitability. Furthermore, $b^{RD}$ is some basic R&D activity always desired to be undertaken. This behavioural rule is intended to capture increases in R&D if times are good (Ben-Zion, 1984). and the abandoning of R&D if it lacks success or if competition is too tight which reduces profitability (Yildizoglu, 2002). Note that there will be always a non-zero level of desired R&D which does not completely match with the statement of Yildizoglu (2002) that firms without R&D success will abandon research *completely*. Note also that, compared to the Nelson-Winter approach it is just profit and savings that determine investment possibilities. In the Nelson-Winter approach the constraint includes depreciation. However, it is not clear where the funds may come from. Therefore, the pure constraint seems reasonable from that perspective. Note also that possible R&D spending is already accounted for in the (net) profit.

Entry takes place according to a two-stage process. First, there is exogenous activity and thus the number of potential imitators and innovators is determined. Then, those draw a random technology. A constant for innovation $N = 0.05$ and imitation $M = 0.05$ determines the number of potential entrants for innovation and imitative behavior. After drawing an individual technology, entry takes place if the potential entrant has drawn at least the currently average technology. The other features of the entrants like capital are then further determined randomly under a uniform distribution within the range of existing firms' features. A special case applies to the R&D policy since a new firm does not have a history yet. Assume that entrants also apply the strategy $\Phi^{ini}$ as well.

### 3.3.2 Main Driver of the Model

The driving force of the model is the difference in technology which determines the relative profitability. According to an adjustment in firm sizes and therefore output, firms face market pressure due a decrease in price as a result of the change in output.

- R&D fosters the productivity level $A_{it}$ for firm $i$ at time $t$.
- $A_{it}$ improves the price-over-cost margin *for the next period*.
- A better anticipated p-o-c margin spurs the *desired* expansion.
- In the following period, the firm will increase output ceteris paribus. This contributes to overall output and drives down the market price. The firm with better technology benefits because the technological advantage always outweighs the price decrease for non-monopolists. Other firms suffer from the lower price under given individual technology.
- The firm with improved technology gains market share and higher profits.
- According to credit supply rules, the improved technology firm is offered more credit. Hence it can grow. Other firms are offered less credit and have also less desire to invest and shrink. Both, the credit constraint and the lower amount of capital decrease the firm's probability of finding a technological improvement.
- The longer there is a gap in technology, the more concentrated the industry will become.

Those events are subject to sufficient financial means. Due to the hierarchy, R&D is only possible after *all* physical investment that is desired is satisfied. Therefore, if there are any funding shortages, R&D is impossible. This is in line with findings that R&D reacts the most sensitive of all investment to funding shortages (Mohnen et al., 2008). If there is enough funding available, either due to retained profits or credit, a given change in a firm's technology triggers more pressure on the competitors if this is a very big firm. Since output increases relatively more in this case the price is driven down significantly. There are *two channels* at work in the dynamics of the model: firm size via investment and technology via R&D. Both determine a single firms' output and thus the overall price level in the industry.

### Converging and Diverging Forces

The main mechanism in the Nelson-Winter model would lead to a steady state market which means that the behavioural rule of investment desire has a converging effect. This is due to the influence of the market share: the higher the market share, the less investment is desired. Furthermore, a better technology always increases investment desire because it always improves the price-over-cost margin, except in the monopoly case where it has no effect. Given the linear price structure, for a firm in a non-monopoly market, increasing technology always increases profitability.

$$\frac{\partial \pi_{it}}{\partial A_{it}} = \mathscr{M}\left(\sum Q_{-it} + K_{it}A_{it}\right)^{-1} + \mathscr{M}A_{it}\left(\sum Q_{-it} + K_{it}A_{it}\right)^{-2} \cdot (-1)K_{it} > 0$$

$$\Leftrightarrow \left(\sum Q_{-it} + K_{it}A_{it}\right) = Q_t > A_{it}K_{it} = Q_{it}$$

since $(\sum Q_{-it} + K_{it}A_{it})^{-2}$ is positive with $\mathscr{M}$ as market size. In case of a monopoly, $Q_t = Q_{it}$ and $\frac{\partial \pi_{it}}{\partial A_{it}} = 0$.

Also, in a non-monopoly situation, higher technology always increases the market share of a firm. This can already intuitively seen as the change in output due to higher technology always is bigger relative to the change in aggregate output. Thus, for the market share calculation $\frac{A_{it}K_{it}}{\sum A_{it}K_{it}}$, the numerator increases to a larger extent than the denominator and the entire term will thus increase. In the monopoly case the change is zero.

The finding of a better technology has a positive effect for the successful firm. Nevertheless, the availability of credit determines how severe the positive impact will be. This is an important feature of this model and in line with the findings of Lee and Harrison (2001) who claim that the benefits from R&D and even innovation often are effective after some time lag and which then influence further R&D behaviour. A better technology found in period $t$ leads to immediately increased desired investment in $t$. Then, this leads to a higher level of capital in $t+1$. Both, better technology and more capital boost output of the finding firm in $t+1$ with an increased market share. Because also total output will increase, the market price decreases. Then, the availability of credit determines how much the market share and profitability change until $t+1$. Furthermore, market share and profitability in $t+1$ determine the further availability of credit from period $t+2$ on. If there is enough credit available in $t$ the increase in output will be large because desired investment is completely satisfied. At the same time, the profitability following in $t+1$ will be comparatively low due to the price mechanism. If there is a credit shortage and investment cannot be done to the full extent desired, the impact on output will be lower; but because the price decrease is not as severe the increase in profitability is more pronounced. Therefore, *the availability of credit in $t+2$ is influenced by the availability of credit in $t$*. In $t+2$ then, the bank policy ($\lambda$) matters because it is crucial whether the emphasis is on market share or profitability.

Thus, financing constraints *at the time of a successful innovation/ imitation* can hinder the economic success of R&D and henceforth set back *further* increases in the R&D effort.

#### Small Firms vs Large Firms

Small firms react less on improvements of technology in *absolute* terms because their markup ($\mu_{it}$) is smaller. Their desired investment changes less if the market share is low. Furthermore, since investment is in terms of per unit of capital, the absolute change for any given rate of desired investment is lower for small firms. Therefore, due to their low level of capital, even a large investment per unit of capital is only of limited effect on output and price. However, via this price mechanism the profitability of small firms improves more significantly compared to large firms. This has a direct effect on the following R&D desire of the small firm.

Therefore, smaller firms tend to improve their profitability rather than their size compared to large firms as a direct result of a successful innovation/ imitation.

## 3.4 Simulation Results

The common features of the experiments are given by the parameter setup

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $D_t$ | 1000 | $\delta$ | 0.03 | $b^{RD}$ | 0.002 | $\Phi_{it}^0$ | 0.004 | $a_{it}^{in}$ | 0.007 |
| | | $c$ | 0.16 | $\varphi$ | 3 | $K_{it}^0$ | 140 | $a_{it}^{im}$ | 0.02 |

where there are 100 runs for each value of a varied parameter. The initial number of firms is 10, the interest rate is 2% , the bank policy $\lambda = 0.5$ and firms' policy $\lambda^F = 2$. The results are taken from an average between the periods $t = 280$ to $t = 300$. For the experiments, the credit supply is chosen according to a critical level of credit supply that might just cover credit demand. In order to find an appropriate level, credit surplus for the above setting is looked at for a range of credit supply. Figure 3.1

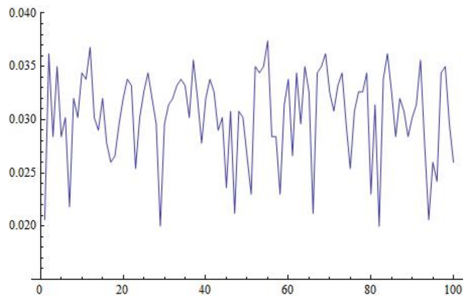



Figure 3.1: **Lowest level of credit supply that generates positive *excess* credit supply.**

shows the lowest level of credit supply that yields positive excess credit supply for 100 simulations where for each repetition $l^s \in [0.02, 0.05]$. The mean is 0.030404 with a standard deviation of 0.00422135. Results range from 0.02 to 0.0374. For the experiments concerning market conditions, credit supply is fixed to $l^s = 0.03$ which is credit supply per unit of *total* capital in the industry. For the policy experiments this level is refined a little bit more to $l^s = 0.027$.

In a situation without any external financing opportunity, technology does not improve at all since the firms earn just the depreciation rate and can only replace written off capital. If entry does take place, competition increases and firms earn even less than depreciation. There is no improvement at all but the firms decrease in size over time as the market is fixed. In either situation there is no funding for R&D available.[5] In this section the effects of credit supply and the interest rate are examined first. It will be interesting to look at the concentration of output, that is monopoly power which is measured by the Herfindahl Index. Also, the evolution of overall industry output gives insight on the effects under investigation. For comparison, we will manipulate parameters of importance and check whether long run results differ according to that changes. First, the effect of credit supply and the interest rate are examined, then the firms' and banks' behaviour is subject to examination.

[5] It is debatable whether firms with credit shortages will do no R&D whatsoever for all times. It might occur that they shift to an R&D priority after a while in order to improve somehow, even if the company must shrink severely initially.

### 3.4.1 Market Conditions

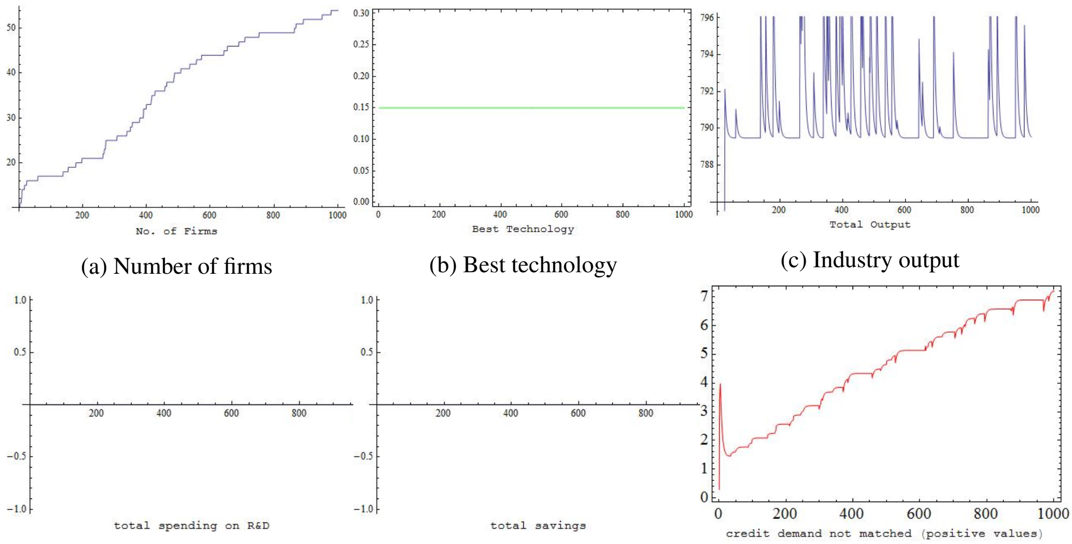
The market conditions that govern the outcome are credit supply, interest rate and demand. Demand determines the severeness of competition in an industry but is not really a constraint like credit supply or the interest rate. We focus on the latter two. Constraints of financing can originate in

- no source of financing,
- a slow setting up of financing or
- a too high interest rate (Savignac, 2007, p. 6).

For a French sample, from all restraint firms, as much as 88% had no financing source for their project, and 22% faced a too high interest rate to conduct a successful implementation of their project (Savignac, 2007, p.7). Schumpeter (1939, 1941) points out that in a competitive environment, probably no firm does yield enough profit as to perform R&D. It is only the monopolist who can set aside enough money and thus take research action. In this model, a monopolist or the sole user of state-of-the-art technology can exert pressure via the productivity of her capital. Her productivity increase will exceed costs more the higher his technology out-stands his competitors' one. Increased production lowers the price and therefore the technological monopolist has a comparative advantage which yields above average profits.

#### Credit Supply

The expected impact of credit supply is that the more credit is available, the easier is financing investment and the better the industry can evolve.
A representative run for a time span of 1000 period shows that if there is no credit whatsoever, neither innovation nor imitation takes place (figure 3.2b). This is due to the fact that the competitive market does not allow for abnormal profitability in a situation where every firm is the same in the first place.

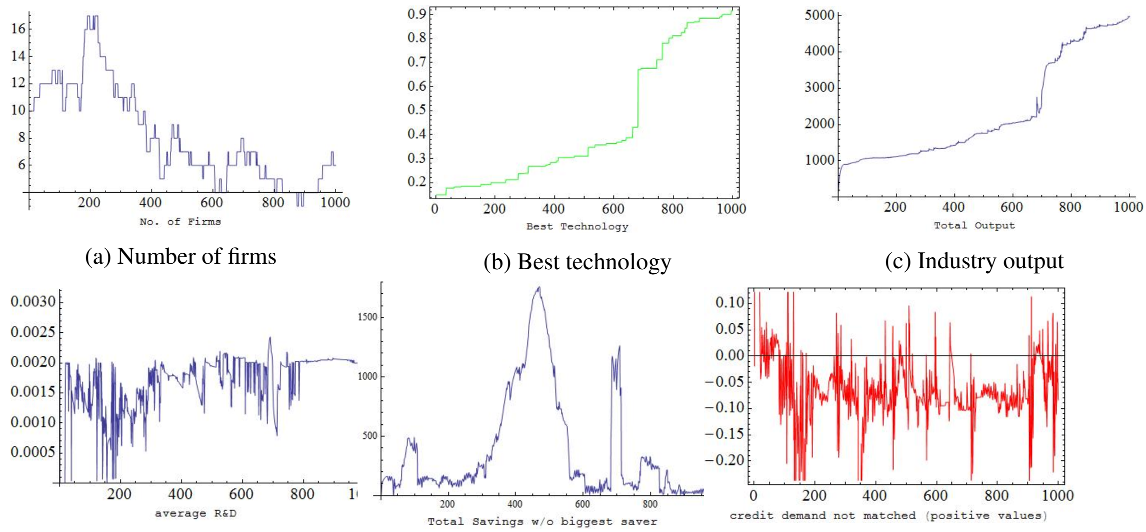



(a) Number of firms (b) Best technology (c) Industry output

(d) Average R&D spending (e) savings (total) (f) unsatisfied credit demand

Figure 3.2: **Representative over time evolution with no credit available.**

Firms need all their profits to reinvest into physical capital in order to counter depreciation. Thus, there is no R&D conducted whatsoever (figure 3.2d) and consequently no technological improvement (figure 3.2b). Entering firms with the same technology then add more pressure to the price by their output and firms can only downsize. However, the price pressure is not large enough to drive many firms out of the market (figure 3.2a). There is a steady state situation where the firms have just the size that joint output yields a price that ensures a price-over-cost margin of the amount of depreciation (figures 3.2c and 3.2e). The increasing number of firms and the low profitability increases the need of credit (figure 3.2f). If no firm would enter, technology would be fixed as would be firm size, output, and price.




(a) Number of firms (b) Best technology (c) Industry output

(d) Average R&D spending (e) savings w/o biggest saver (f) unsatisfied credit demand

Figure 3.3: **Representative over time evolution with credit available $l^s = 0.3$.**

A *representative run* for a high level of credit supply ($l^s = 0.3$) reveals that innovation takes place more often and the phases of diffusion where concentration slowly decreases are interrupted many times. Technology is improved (figure 3.3b) which boosts output (figure 3.3c). This is possible because there is actually some spending on R&D (figure 3.3d). Some firms are profitable and can retain profits (figure 3.3e). Then, there is less credit demand unsatisfied (figure 3.3f). Competition and price pressure drive many firms out of the market (figure 3.3a).

If less credit is available *at the time of a successful draw $t$*, then the increased desire for investment might not be met fully and neither does the firm grow too much nor does it conduct any R&D in the following period. Hence, the impact on market share is humble but the change in profitability is rather high. Consequently, R&D desire in $t+1$ will be high but investment desire might be comparatively low because of the increased market share and the higher price-over-cost-margin. Credit supply, at this point is still not influenced fully because it looks back one period and will thus only be effective in response to profitability in $t+2$.

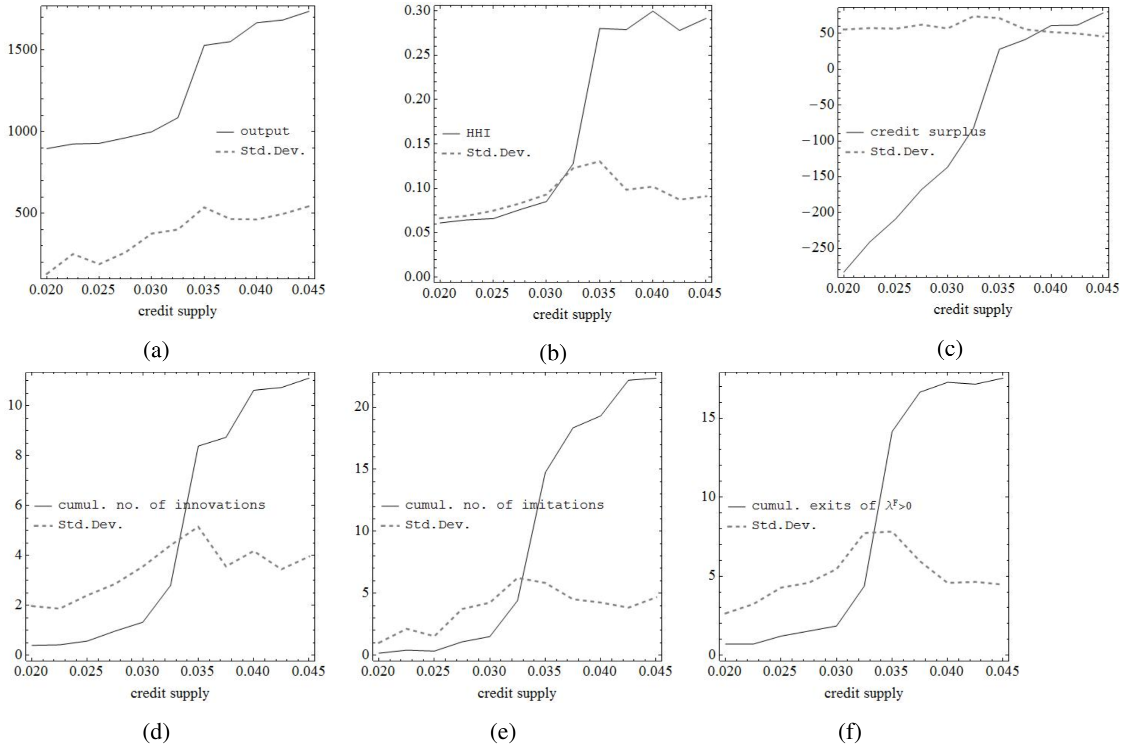
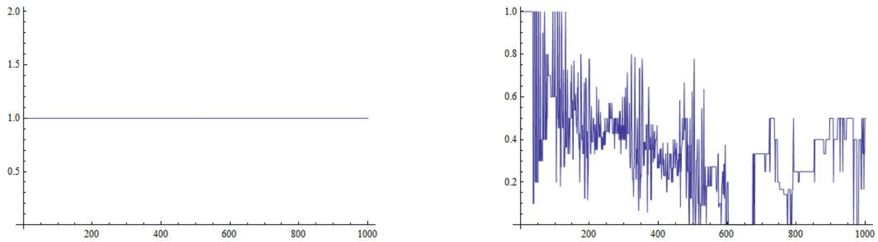



Figure 3.4: **Impact of credit supply**

The experiment of the impact of credit supply levels is done for incremental values of credit supply for $l^s \in [0.02, 0.045]$. Results are shown in figure 3.4. The effect of higher credit supply is nonlinear and distinct. As more credit is available, the level of technology is increasing faster and the overall output is higher (figure 3.4a). There is an emergence of fewer but larger firms (figure 3.4b) as a result of productivity improvements. Larger firms also absorb more of the credit supplied in total which also hurts laggard firms' ability to spend funds on R&D.

The negative credit surplus in the same figure (figure 3.4c) indicates that firms very well would invest more but are effectively constrained. As they only outbalance their depreciation, no firm grows and as new firms keep entering the economy, competition becomes tougher and brings down prices and hence profit. Therefore, firms find it harder over time to outbalance depreciation and the result is that firms shrink and concentration decreases (figure 3.4b). If firms can access the funding they desire, which is indicated by more and more credit surplus (figure 3.4c), R&D can effectively be conducted and there are technological improvements (figures 3.4d and 3.4e). Figure 3.5 confirms that credit supply results in a lower relative number of firms that are actually constrained in credit. This is partly due to some firms accumulating savings and thus not demanding credit and partly due to a shake out period leaving only the more successful firms.




(a) $L^s = 0$ (b) $L^s = 0.027$

Figure 3.5: **Share of firms that face constraints in financing over time**

This creates firms that have a better price-over-cost margin than other firms and those firms hence yield more profit and grow. They also gain market share. This puts further pressure on firms with inferior technology as the price is pushed down. Hence, more firms leave the economy (figure 3.4f). Specifically, the impact of credit supply is non-linear. Abundant credit supply allows the economy to evolve much different, i.e. there is a jump in the dependent value. Without credit supply firms have demand for R&D but cannot do it because their investment in capital does not leave any funds for additional investment in R&D. With the strict hierarchy in place that physical investment comes first, there is almost never any funding of R&D and thus technology does not improve (see figure 3.2b).

**Interest Rate**

The next experiments are conducted using incremental levels of interest for $i \in [0, 0.2]$. Figure 3.6 depicts the impact of the credit interest rate on economic performance. The intuitive effect of the rate is that the higher the interest rate is, the less profitable are firms. As credit supply is given but varying for firms, lower profits mean a more effective constraint in financing on average. Furthermore, a high interest rate leaves firms spending more and more on the credit and less funds are left for conducting R&D and investment. Thus, output and the frequency of technological improvements should be lower as the demand for credit is met to a lesser extent.

The experiment shows that output actually is lower in the interest rate (figure 3.6a). As profits are lower, the firms demand credit in order to finance their endeavors. Therefore, due to financial constraints, credit surplus is decreasing in the interest rate (figure 3.6c). The image about the Herfindahl index (figure 3.6b) delivers evidence for market shares being more equal in higher interest rates. The costlier credit is, the less imitation and innovation actually is observed (figures 3.6d and

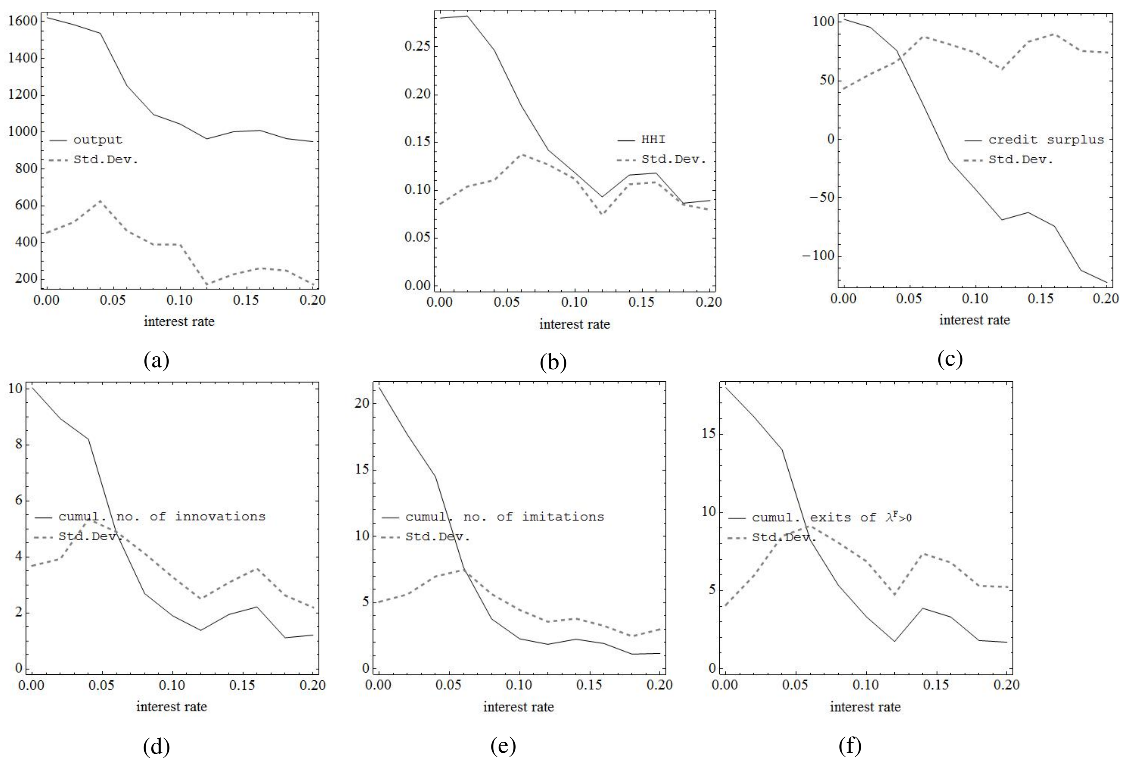



Figure 3.6: **Impact of the interest rate**

3.6e). Therefore, less innovation and imitation takes place economy-wide. Nevertheless, less innovation and imitation leaves the firms to be more equal. No firm is able to exert enough pressure to drive competitors out of the industry, which is visible in the lower exit rates in the interest rate (figure 3.6f).

### 3.4.2 Policies

There are two ways in which the behaviour of the agents can influence the dynamics: the bank's weighing of firm features in offering credit and the intensity of change of the firms' R&D adaptation rule. It affects the determinant of adaptation $\Omega$. The bank's policy is the main matter of interest. It determines the financial constraint any individual firm is facing. Although the overall credit supply does influence the individual access to credit, it is the bank's policy that accounts for the differences among credit supply for individual firms. The key question addressed is to what extent the bank's policy promotes a particular outcome, that is, whether it has only a small influence or whether it can change the dynamics of the industry rather completely. While the empirical evidence mentioned in section 3.2.2 indicates that firms are behaving pro-cyclical in setting their R&D rule, it is possible to see which effect a counter-cyclical behaviour can have. Furthermore, it is possible to account for the impact that the intensity of their behaviour can have. Empirical evidence also points at rather static rules due to relatively high costs of change in R&D settings. It is hence possible to check whether a higher flexibility in adapting to financial conditions would be likely to benefit the industry as a whole.

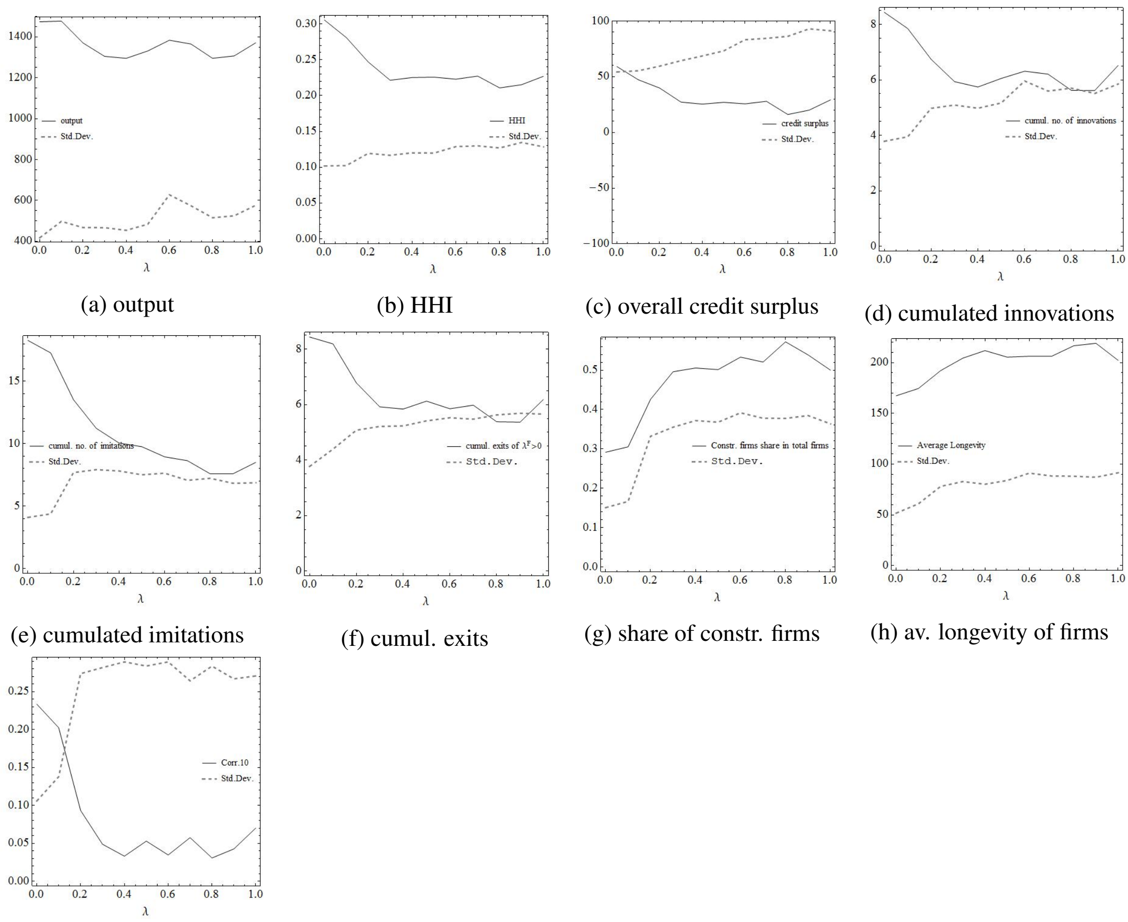
#### Bank's Policy

The bank assesses creditworthiness according to two pieces of information in this model: collateral and expected cash-flow. Collateral provided by the firm is represented by the market share and profitability is a proxy for expected cash flow. Market share can represent collateral if the stock of products would be considered to be pledged. This relies less on the machinery as collateral but on the final product. The cash flow expectation is represented here in the simplest possible fashion. Since banks also use heuristic concepts for the assessment of the firm prospects (Reichling et al., 2007), this is captured by the one-period focus on profitability. In reality, several periods of profit would be taken into account. As the bank's policy is a mix between evaluating the collateral amount by looking at the market share and forecasting cash flow by looking at the profitability, its policy can be described by the weighing parameter ($\lambda$) that determines the impact of each piece of information on the credit decision.

Theoretically, access to credit promotes output rather than profitability because the firm translates technology improvements in physical investment first. In case the following output is significantly higher, the price mechanism dampens the increase in profitability.

The availability of credit at the time of finding a better technology is decisive. If there is sufficient credit supply at the time a new technology is found, there is a huge impact of the finding on further credit availability in case the bank puts emphasis on collateral. Since the access to credit at the time of the finding allows for a significant investment and thus increase in capital, the firm will grow significantly. Therefore, firm size at $t+1$ is relatively large as is market share. A crucial feature for the likelihood of drawing a technology improvement is the firm size (see eq. (9)). Also, the firm size is the crucial feature for market share. The bank hence promotes mostly firms that are already doing well. Then, in $t+2$ this matters for the further availability of credit. If the bank focuses on profitability, the following credit supply is comparatively low because the massive increase in output and market

share pulls the market price down which limits profitability increases in $t+1$. As the bank evaluates profitability, *further* credit supply in $t+2$ will be comparatively modest.
Comparatively, if there is credit shortage in $t$, the increase in market share at $t+1$ is relatively low which leaves a higher market price in $t+1$ and a comparatively lower price-over-cost margin.
Then, if the bank looks only at collateral, credit supply in $t+2$ is relatively low and if the bank looks only at profitability, it will offer comparatively more credit in $t+2$.




(a) output (b) HHI (c) overall credit surplus (d) cumulated innovations

(e) cumulated imitations (f) cumul. exits (g) share of constr. firms (h) av. longevity of firms

(i) Correlation Profit(t)-Firm Size (t+10)

Figure 3.7: **Impact of bank policy**

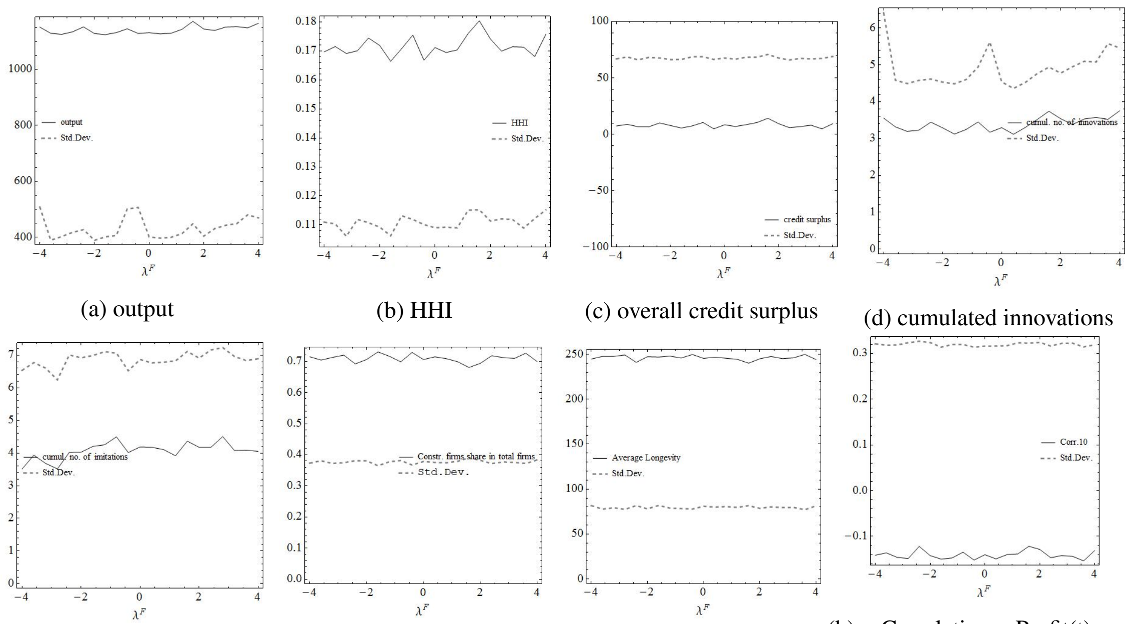
The experiment results are depicted in figure 3.7. Output decreases in the weight the bank puts on profitability (figure 3.7a). If the bank puts emphasis only on the market share ($\lambda = 0$) there is a high concentration evolving (figure 3.7b) because there is a higher probability for an innovating / imitating firm that it actually can do even more research (figures 3.7d and 3.7e). This results in a higher credit surplus as indicated by figure 3.7c.

The credit shortage for the non-technology-improving firms reinforces the financial disadvantage. These firms are driven out of the industry relatively quickly which is indicated by the low longevity of firms (figure 3.7h) and the high number of exits for the collateral focused bank policy (figure 3.7f).
This is supported by the indicator of the share of firms that is actually constrained in credit. This share is bigger for the profitability based bank policy (figure 3.7g). For this profitability based policy only technology propels a faster firm growth via the aid of credit supply. For the collateral based approach both factors contribute to the growth advantage of a technology improving firm. Therefore, we observe a higher correlation between profits and firm size for a policy that focuses on firm size, *not* on profitability (figure 3.7i).
The experiment supports the prior theoretical explanation and emphasizes the role of bank behaviour in the evolution of the industry.

**Firms' Policy**

Firms decide individually how much they want to spend on R&D. According to empirical evidence they adjust their R&D effort to their business situation (see section 3.2.2). In this model this situation is represented by productivity. If productivity increases, so does the R&D desire of firms. If there were no constraints in financing R&D there would be an inherent force that would create a wedge between firms and lead to concentration. Firms who are successful would even do more R&D and thus expand their lead. The opposite is true for less successful firms: they even would reduce their R&D activity and therefore would be even less likely to catch up. With financing restrictions in place this drift is less severe as firms' expansion of R&D might be dampened. The tighter credit constraints are, the less technological improvement will take place in general. Nevertheless, even if firms pursue a different policy for R&D according to profitability, they all increase physical investment in profitability. Along with a given technology, this already is a driving force of concentration because of the price mechanism. A higher profitability in $t+1$ after technology improvement in $t$ has an impact on the desired spending on R&D. If the reaction of the firm is positive, any higher profitability will lead to a higher desired R&D spending compared to the last period. Nevertheless, if following R&D desire over two periods after an innovation, a lack of funding might set back actual R&D spending. An increased profitability always leads to a positive tendency in the R&D desire, but the desire also depends on the actual spending from the prior period. Therefore, a funding restriction on investment at $t$ leads to a higher desired change in R&D investment, but not to a higher level because in $t+1$ actual R&D was set back. For a full funding situation, as profitability is comparatively lower, the desired change in R&D spending is lower but the actual level is higher. If the firms react negatively on profitability, the effect is vice versa. We expect that under a regime with credit scarcity the firm behaviour has not much impact while in a regime with abundant credit available a more drastic reaction should boost output.

The experiments conducted track differences out of the firms' adaptation behaviour. Results under a *scarce credit supply* regime are shown in figure 3.8. Results for a regime with abundant credit supply are shown in figure 3.9.

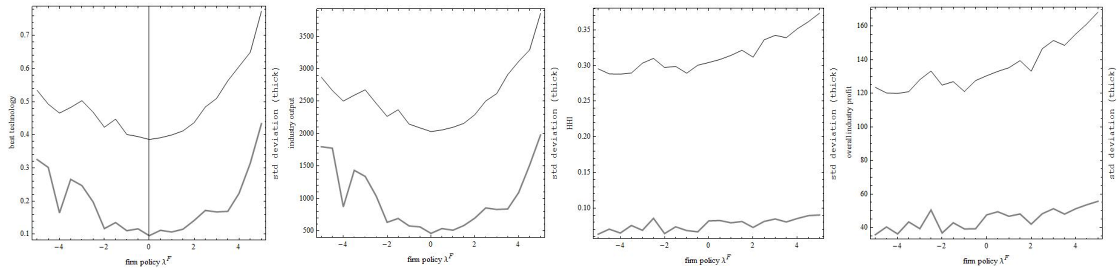



(a) output (b) HHI (c) overall credit surplus (d) cumulated innovations

(e) cumulated imitations (f) share of constr. firms (g) av. longevity of firms (h) Correlation Profit(t)-Firm Size (t+10)

Figure 3.8: **Impact of firm rule**

The credit scarcity regime depicted in figure 3.8 shows that there is no distinct impact of neither the basic strategy of the firms nor the magnitude of reaction. The reason is that once a credit shortage was effective, R&D desire is set back to the basic level. Then, it does not matter too much whether the change in desire ($\Omega$) might be high or low. Figure 3.9 shows the impact of firm policy if there is credit abundance. The dashed line depicts the standard deviation. The comparative experiment with an abundance of credit available reveals that the firm policy would have an impact if there was sufficient credit (figure 3.9). Then, the severeness of reaction ($\lambda^F$) would positively influence technology (figure 3.9a) and output (figure 3.9b). Concentration and total profits would depend on the direction of the policy (figures 3.9c and 3.9d), that is whether the firm increases desired R&D spending in economically favourable times ($\lambda^F > 0$) or whether is has a contrariwise policy ($\lambda^F < 0$). If a contrariwise firm policy is in place, technological leaders will cut spending on R&D while laggard firms will try to catch up.



(a) best technology (b) output (c) HHI (d) overall profit

Figure 3.9: **Effect of firm rule with abundant credit supply**

If credit supply is abundant they can actually spend money on R&D and so imitation is possible. As technology more and more diffuses by imitation, the leading firms suffer in profitability and again increase their R&D spending desire. Overall output is higher if the reaction is stronger, but concentration is lower because the laggard firms do not suffer from funding shortages and diffusion is more pronounced. Since there is more equality among firms and less advantages for single firms, more firms stay in the industry but earn less. If credit supply is large enough, the less profit does not hinder R&D effort as Ponzi-financing can emerge. Ponzi-financing means that credit and interest is repaid by new credit instead of returns to investment. Nevertheless, if credit supply is large enough, this situation can be sustained for a long time.

For a positive reaction on profitability, leading firms try to take off even further. Due to sufficient external funding they can do so and have a high probability of drawing better technology also in the long run. Other firms cut desired spending on R&D and diffusion is less likely. Many firms leave the industry and the concentration is higher. Overall profits and output are higher because the technological frontier is shifted significantly, but this is due to only a few (or even only one) firms.

The comparison of firm behaviour in the two credit regimes supports the prior theoretical approach. There are three factors that explain the different results for the two regimes. First, scarcity of credit does not allow for R&D conducted on top of investment. Therefore, the firm behaviour does not matter much. Second, the intensity of reaction does matter. A higher intensity leads to higher output because firms want to push R&D effort more distinctly. Third, concentration is stronger the more positive firms react on their profit history. The reason is that profits positively affect investment which is also crucial for competition and growth.

### 3.4.3 Joint Effects

The previous experiments showed the single effects of market and policy characterizations in a particular environment. These observations can be combined to a larger picture of the effects in particular circumstances. In order to check the robustness of those observations, a Wilcoxon-Signed-Rank test is used. This non-parametric test is done for the impact of the bank policy under 100 random market and firm policy setups for a significance level of 95%. As market conditions cannot be influenced by the agents in this model, the focus is on policies. Furthermore, since the impact of credit constraints is the matter of interest, the results obtained are checked for robustness by focusing on the bank policy and comparing three levels of it. It is checked whether the results obtained from the comparative analysis hold in broader, randomly chosen parameter setups, that is, in a broader environment. The Wilcoxon-Signed Rank Test confirms the qualitative findings so that those are concluded to be robust at a 95% significance level (see appendix B.2).

As the model is intended to capture the effects of credit shortage, the level of credit supply turns out to be the most influential part of the model. If there is a shortage, no R&D is conducted because investment in replacement and additional machinery has priority. If there is abundance of credit, firms can conduct a lot of R&D which pushes the technological frontier forward. The way credit supply is allocated is hence crucial only if credit is scarce. Then, credit is offered to a fraction of the firms while other firms are almost excluded from credit. This is the environment where behaviour has the highest impact. The bank determines which features are important for access to credit. If it puts most weight on market share, the firm policy does not have a significant effect because the firm R&D policy only responds to profitability. Its response to market share is fixed in the investment desire function. However, as soon as the bank puts some weight on profitability, the firm policy gains importance. In this case both, the bank and the firm react positively to profitability, thus, there is a twofold positive feedback on profitability. In a situation of scarce credit supply and credit allocation based (also) on profitability it pays off for a firm to adjust R&D desire according to profitability because the bank also reacts positively on it. It can be observed that the firm policy is more effective if credit supply is high with respect to output and concentration (see figure 3.9), however, this impact does not change very much due to bank policy as long as there is some weight put on profitability by the bank (- see Wilcoxon-Test results in the appendix B.2). If there is plenty of credit available, firms can finance almost every investment and R&D desire and the distinction by the bank still leaves enough credit supply for the least supplied firm. Additionally, firms only demand a limited amount of credit, even in periods of high intended investment and R&D. Therefore, the bank policy does not have a significant

impact in such a situation. The same is true if credit supply is too low. Then, even the best firm is not being offered enough credit to conduct R&D on top of investment.
Thus, there is a minimum level of credit supply that is necessary to enable firms to develop over time below which, neither the bank policy nor the firm policy is of much impact. Once this level is passed, the bank policy becomes crucial. It exerts the most effect if credit supply is not large enough to allow for Ponzi-financing. Nevertheless, the firm policy is most effective in a situation of Ponzi-financing because then it is assured that it actually will be able to carry out its policy.

## 3.5 Conclusion

The purpose of this work was to examine in what way credit shortages can influence the evolution of an industry if technological improvement relies very much on credit and at the same time echoes back to credit availability. In a model where firms decide how much they want to invest in capital due to their market situation and how much on top they want to spend on research based on profit history it turns out that this hierarchy is sensitive to credit shortages. Market conditions - such as credit availability and interest rates - are checked for their impact on technological evolution and market concentration as well as total output. There are two policies taken into account: the bank's decision rules about creditworthiness and the firms' rule about adapting R&D effort. The approach is based on an evolutionary model by Nelson and Winter. This heterogeneous agents based model is examined by using a computer simulation.
The main findings are that the most crucial factor is overall credit supply available in the industry. A higher credit supply is always beneficial to some extent but there is some critical level of credit supply where the impact changes dramatically, i.e. there are jumps in the dependent numbers. This is due to the fact that if there is sufficient credit supply at the time a better technology is found there is also further credit supply in the longer run. The interest rate has an intuitive effect in that a higher interest rate always hinders the evolution of the firms and thus the industry which is simply due to the fact that interest is costly for the firms.
The bank influences the evolution of the industry by its internal routines because it can reinforce the positive effect of a new technology on the firm size via investment. The better technology is visible for the bank later than for the firm that found it and therefore it matters to what extent that technology is visible in the firm's balance sheet two periods later. If the bank considers predominantly firm size, it fosters further growth because firm size is directly affected by better technology. Thus, the impact of

the better technology is more significant via firm size. If the bank looks predominantly on profitability, the impact of the better technology can be diluted. Therefore, the correlation between profitability and later firm size is bigger if the bank values firm size relatively more. Also, smaller firms will improve more on profitability than on size in comparison to large firms. Thus, if the bank values profitability more, it gives an advantage to smaller firms. This however, reduces the probability of further improvements compared to a situation where mainly large firms benefit from credit because the probability of finding better technology is positively influenced by firm size.

Firms can adapt their R&D behaviour. This however, only influences their situation if there is plenty of credit available. In that case a positive feedback rule is more effective on the technological evolution but brings along a monopoly situation. This is due to the fact that in a negative feedback scenario, innovators stop innovating and other firms try harder to catch up. It is an inherent convergence behaviour. Nevertheless, the heftiness of reaction promotes technological evolution in both scenarios because any desire can be met if there is enough funding and profitability does not matter too much in such a situation.

This model considers only a single industry where a homogenous good is produced. Furthermore, the bank is strictly backward-looking in its assessment of creditworthiness. There might be further insights if different industries compete for funding where the bank again assesses the probability of bankruptcy for each firm. Furthermore, it would be interesting to consider some exogenous policies, like the monetary policy of a central bank which would be effective in the model as credit supply shocks. The trajectory of the industry in response to those changes could provide insights about the effects of a particular policy on technology, market power and individual access to credit.

# Appendix B

## B.1 Parameters and Variables

| **Control Parameters** | | |
|---|---|---|
| interest rate | $i$ | 0.05 |
| average credit supply in unit of capital | $l^s$ | 0.027 |
| bank's weighing parameter for credit offer | $\lambda$ | 0.3 |
| firms' R&D adjustment policy parameter | $\lambda^F$ | 2 |

| **Parameters** | | |
|---|---|---|
| Demand | $D$ | $1,000$ |
| initial no. of firms | | 10 |
| initial capital | $K_{it}^{0}$ | 100 |
| initial technology | $A_{it}^{0}$ | 0.15 |
| initial R&D spending desire | $\Phi_{it}^{0}$ | 0.004 |
| minimum R&D spending desire | $b^{RD}$ | 0.002 |
| innovative R&D success probability | $a_{it}^{in}$ | 0.007 |
| imitative R&D success probability | $a_{it}^{in}$ | 0.02 |
| depreciation rate | $\delta$ | 0.03 |
| production costs | $c$ | 0.16 |
| lower capital barrier for bankruptcy | $crit$ | 1 |
| time horizon for looking back | $T$ | 3 |
| markup parameter for investment desire | $\varphi$ | 3 |

The intervals that the parameters for the test are chosen from are:

| | |
|---|---|
| $\delta$ | $\in [0.025, 0.035]$ |
| $c$ | $\in [0.15, 0.17]$ |
| $a^{im}$ | $\in [0.018, 0.022]$ |
| $a^{in}$ | $\in [0.0065, 0.0075]$ |
| $b^{RD}$ | $\in [0.0015, 0.0025]$ |
| $\varphi$ | $\in [2.5, 3.5]$ |

Table B.1: Parameter space for the robustness check

## B.2 Robustness Check

The following tables depict the result of the Wilcoxon Signed Rank test for 100 random samples of above parameter space. If the Null Hypothesis cannot be rejected, $''ns''$ is depicted. If it can be rejected, then the direction of difference between sample medians is shown.

$\lambda = 0$ **vs.** $\lambda = 0.5$

| *firm rule* | *credit supply* | $A^{Max}$ | *Herfindahl* | *Output* |
|---|---|---|---|---|
| $\lambda^F$=0 | $Ls = 0.02$ | $>$ | $>$ | $>$ |
| | $Ls = 0.03$ | $>$ | $>$ | $>$ |
| | $Ls = 0.05$ | $>$ | *ns* | *ns* |
| $\lambda^F$=1 | $Ls = 0.02$ | $>$ | $>$ | $>$ |
| | $Ls = 0.03$ | *ns* | $>$ | *ns* |
| | $Ls = 0.05$ | *ns* | $>$ | *ns* |
| $\lambda^F$=2 | $Ls = 0.02$ | $<$ | $>$ | $>$ |
| | $Ls = 0.03$ | *ns* | $>$ | *ns* |
| | $Ls = 0.05$ | *ns* | $>$ | *ns* |

$\lambda = 0.5$ **vs.** $\lambda = 1$

| *firm rule* | *credit supply* | $A^{Max}$ | *Herfindahl* | *Output* |
|---|---|---|---|---|
| $\lambda^F$=0 | $Ls = 0.02$ | $<$ | *ns* | $>$ |
| | $Ls = 0.03$ | *ns* | *ns* | *ns* |
| | $Ls = 0.05$ | *ns* | *ns* | *ns* |
| $\lambda^F$=1 | $Ls = 0.02$ | $>$ | $>$ | $>$ |
| | $Ls = 0.03$ | $>$ | *ns* | $>$ |
| | $Ls = 0.05$ | *ns* | *ns* | *ns* |
| $\lambda^F$=2 | $Ls = 0.02$ | $>$ | $>$ | *ns* |
| | $Ls = 0.03$ | $>$ | $>$ | $>$ |
| | $Ls = 0.05$ | *ns* | $<$ | *ns* |

$\lambda = 0$ **vs.** $\lambda = 1$

| *firm rule* | *credit supply* | $A^{Max}$ | *Herfindahl* | *Output* |
|---|---|---|---|---|
| $\lambda^F$=0 | $Ls = 0.02$ | $>$ | $>$ | $>$ |
| | $Ls = 0.03$ | $>$ | $>$ | $>$ |
| | $Ls = 0.05$ | *ns* | $>$ | *ns* |
| $\lambda^F$=1 | $Ls = 0.02$ | $>$ | $>$ | $>$ |
| | $Ls = 0.03$ | $>$ | $>$ | $>$ |
| | $Ls = 0.05$ | *ns* | *ns* | *ns* |
| $\lambda^F$=2 | $Ls = 0$ | $>$ | $>$ | $>$ |
| | $Ls = 0.03$ | $>$ | $>$ | $>$ |
| | $Ls = 0.05$ | *ns* | *ns* | *ns* |

Table B.2: Results of the Wilcoxon-Signed-Rank Test

# Chapter 4

# The Impact Of Credit Rating On Innovation In A Two-Sector Evolutionary Model

## 4.1 Introduction

Firms suffer from discrimination in access to credit (Canepa and Stoneman, 2008; Hao and Jaffe, 1993; Giudici and Pateari, 2000). This pattern of constraints can reinforce disturbances in the selection process. For example, those firms that are less profitable and less innovative are expected to grow at a comparatively low rate or to exit the market under an efficient mechanism in place. This is however, not observed in an Italian sample when there are financial constraints (Bottazzi et al., 2006, 2014; Bottazzi et al., 2010). Public subsidies can remedy constraints as they not only help most those firm in dire need of external funding (Hyytinen and Toivanen, 2003) but also increase the trust in credit-worthiness by others and thus may enable external financing in the future (Takalo and Tanayama, 2010).

The aim of the paper is to explore which role the determinants of lender behaviour play in the evolution of a diversified economy. Therefore, we employ a rating process that determines the credit supply for

each individual firm in two sectors. We examine the role of weights put on various pieces of information used for the rating like cash flow or market share. We also examine the impact of different ways of expectation formation about the prospects of the sectors.
We ask first what is the impact of the bank routines for credit supply on innovation and technology diffusion? The focus is on gaining insight about the dynamic of the bank decision in response to risk and furthermore in response to rather optimistic or conservative expectation formation.
In order to grasp insights we consider the following more detailed questions: to what extent does the bank policy determine whether one of the two sectors benefits? And which effect does the funding of the more innovative sector have on the low-tech sector?

We use a two-sector approach in order to bundle firms in an innovative and in an less innovative sector. We call the more innovative sector 'high-tech' and the less innovative one 'low-tech'. Banks that use internal rating/ scoring systems evaluate the creditworthiness of a firm in comparison to its rivals. Therefore, even if a firm does better than all firms in another sector, it might still be seen as an under-performing entity. The particular importance that the bank shifts to the sector-specific and economy-wide indicators in measuring creditworthiness may lead to different economic dynamics.

Innovation is subject to sufficient funding. However, firms are constrained in financing R&D for several reasons. The explanations are based on the information shortage of external financiers compared to the firm. This disadvantage leads credit or equity providers to require a higher risk premium. Furthermore, even if R&D leads to some innovation that can be implemented, it does not yield tangible assets that can serve as collateral for a loan. This also contributes to the risk premium (Mohnen et al., 2008; Czarnitzki and Hottenrott, 2011). Furthermore, the outcome of R&D projects is highly insecure and monitoring them is costly. Therefore, firms might not be able to be granted credit for R&D to the amount they would like to (Freel, 2007). For a United Kingdom data-based empirical study, Freel (2007) finds that small firms that are innovative actually experience less credit granting success than their less innovative competitors. In a sample of US and UK small and medium-sized enterprises [SMEs] more innovative firms face a higher probability of not being financed externally although they are not more likely to apply for it (Mina et al., 2013). Supportive findings concerning high-tech firms are provided by Guiso (1998) who uses Italian samples where cross-sectional data shows that manufacturers in high-tech categories have a higher probability of being constrained in credit. The explanation refers to higher uncertainty related to producing at the edge of technology.
Furthermore, it is reported that the availability of external finance is more constrained for *very* innovative

firms, more precisely, the relation between innovative ability and access to credit is inversely u-shaped (Czarnitzki and Kraft, 2004). This is supported by the evidence mentioned above that considers sub samples of firms that are more likely to be constrained, namely small and medium enterprises and young firms. Because those lack either collateral and/or a proven history of creditworthiness, their ability to pay back a loan is highly uncertain.

Bank credit is the major source of external financing (Hall and Lerner, 2009). Banks across the world need to provide a rating for their debtors according to the Basel II agreement. They can do ratings on their own (internal rating) or rely on external ratings provided by rating agencies (European Parliament, 2006). In fact, for granting credit to SMEs in Europe, banks use mostly internal rating systems (Centre for Strategy and Evaluation Services [CSES], 2014). There are many commonalities between internal and external ratings and external ratings are usually used for large companies above a particular threshold of market value. The crucial differences between pieces of information used for rating are whether they are of quantitative or qualitative nature. Quantitative information can be extracted from financial statements such as the balance sheet. Those pieces of information are backward-looking. Although the probability of default is the crucial figure to estimate, banks do rely mostly on heuristic methods to assess that probability, even if there are also statistical and causal analytical methods, like models of option pricing. One reason is that statistical methods are only meaningful if the data set is sufficiently large (Reichling et al., 2007, p. 55). In order to assess the likelihood of credit repayment, a forward looking approach is necessary: "[a]ssessing an obligor's resources for fulfilling its financial commitments is primarily a forward-looking exercise."(Standard and Poor's, 2011, p. 5.) Moreover, "[a]n assessment that only includes the present must not be decisive - the [firm's] focus on the orientation to the future must be satisfactory." (Kremer and ten Hoevel, 1989, p. 122.) The prospect requirement is also an explicit demand of the European Union for internal rating methods to be approved: "[i]nformation shall be current and shall enable the credit institution to forecast the future performance of the exposure." (European Parliament, 2006, Annex VII, Part 4, Paragraph 18.) An important part in the assessment of creditworthiness is the evaluation of the market growth, because that represents the prospect of the particular industry the firm does business in (Reichling et al., 2007; Czarnitzki and Kraft, 2004). This can usually only be achieved by assessing the available information qualitatively. For evaluating European SMEs, the reportedly most important pieces of information are management quality, project quality or market sector (CSES, 2014). Usually, banks use 20-40% of qualitative information and the rest quantitative while for banks *specialized* in servicing SMEs the share of qualitative information may be in the range of 60-80% (CSES, 2014).

There are however, differences in rating models in terms of which model is used for processing the information into a default probability. For an overview, refer to Crouhy et al. (2000) who report different approaches from four private companies or Reichling et al.(2007) who give an overview about the pieces of information used by banks and rating agencies.

This paper contributes to explaining empirical findings about financial constraints and innovation by assessing the role of bank routines on financing constraints and heterogeneity found in constraints. By modeling bank routines in an evolutionary framework it provides one possible explanation of the observed phenomena for instance, that highly innovative firms being even more restricted for some types of bank behaviour. The model builds upon literature about risk management and R&D behaviour and on the theoretical approach of innovation embedded in an evolutionary context.

The model is set in a dynamic agent based framework building on the work of Nelson and Winter (1982) and Winter (1984) which is designed in an evolutionary environment under Schumpeterian competition. In each period the bank uses information about the firms in order to determine how much credit it would be willing to lend to each of them. It has a particular routine of doing so by relying on the assessment of creditworthiness based on multiple features. There are two sectors and each firm produces and conducts R&D to some extent. The outcome is some quantity of a homogenous good in each sector which jointly with all other firms in the sector determines the market price. Any firm does exist in one sector only. Also the profit of each firm is determined automatically on the one hand. On the other hand the R&D effort might lead to the finding of a better technology which the successful firm can use in the production process of the *next period*. This leads the successful firm to wanting to invest more for the next round of production. However, this possibility depends on the current profit and available credit. If the firm can exploit that technological improvement it will have better access to credit in the next period.

There are two feedback effects employed in the model: a better technology improves access to credit and access to credit improves the probability of finding a better technology. Both effects are however, subject to individual behaviour of both, the bank and the firms. Thus, the effectiveness of the feedback varies in the behavioural routine of the agents. The bank uses information that applies in comparison to *all* other firms and it uses pieces of information that are sector-specific like market share. Furthermore, the bank needs to form expectations if it wants to assess the prospects of the respective industry.

Results indicate that the more the bank supplies credit based on information distinguished by sector the less innovation and output growth will take place. The reason is that innovative firms cannot benefit to the full extent from their superior productivity. That is, their success is recognized only with respect to their sector and not economy-wide and therefore they cannot gain as much from their advantage.
Furthermore, the way that the bank forms expectations about productivity only matters when all other pieces of information for the rating decision are taken into account in a rather marginal way. If they are of some importance it almost does not matter how the bank assesses the future productivity because the magnitude is too low. Predominantly, expectations are overshadowed by information about current cash flow and survival ratios in an industry. Nevertheless, the expectations have an impact on the shifting of credit between the sectors. The positive impact of higher average productivity growth however, does lead to a shift of funds to the other sector. The reason is that more trend-following expectations also exhibit more short-term variation as they follow the current and ever-changing trend. This trend is more short-lived and works in both directions as occasionally high growth will hardly be sustained in the next period. If the expectations focus more on the long-term average occasionally high growth has a more persistent impact. Therefore, under conservative expectations, the bank shifts more funds to the more successful sector.
The remainder of the paper is organized as follows: section 4.2 introduces the model and section 4.3 establishes a baseline case. In section 4.4 the impact of the rating procedure on the sectoral evolution is examined. In section 4.5 we discuss the role of expectations on the bank's decision and the possible impact in this framework. Section 4.6 concludes.

## 4.2 Setup

Output $Q$ is generated by technology $A$ and capital $K$ by each firm $i$ at each period $t$:

$$Q_{it} = A_{it} K_{it}. \tag{4.1}$$

There are two sectors $I$ and $J$, where $I$ is considered to be a low-tech sector and $J$ is considered to be a high tech sector. Total output per sector is equivalent to demand in each sector

$$D_I \equiv \sum Q_{it} \ \forall i \in I \tag{4.2}$$

$$D_J \equiv \sum Q_{it} \ \forall i \in J. \tag{4.3}$$

We assume that the goods are completely non-rival such that demand for each good is independent of the other sector. The inverse demand function determines the price

$$P_{I,t} = \frac{D_I}{\sum_i Q_{it}}, \ \forall \ i \in \ I \tag{4.4}$$

$$P_{J,t} = \frac{D_J}{\sum_i Q_{it}}, \ \forall \ i \in \ J. \tag{4.5}$$

Capital is subject to depreciation at rate $\delta$ and investment $I$.

$$K_{i(t+1)} = I\left(\frac{P_t A_{i(t+1)}}{c}, s_{it}, \pi_{it}, \delta\right) K_{it} + (1-\delta)K_{it} \tag{4.6}$$

A firm's *desired* investment is determined by the ratio of price to production cost $\frac{P_t \cdot A_{it+1}}{c}$ or, equivalently, the percentage margin over cost, the depreciation rate $\delta$ and its market share $s_{it}$. A firm's ability to finance its investment is constrained by its profitability. Profitability $\pi_{it}$ is determined by the productivity cost difference per unit of capital and the spending on last periods loan, which is determined by the interest rate $i$ and the loan per unit of capital $l_{it-1}$ taken in the last period by the firm:

$$\pi_{it} = \begin{cases} P_{I,t} A_{it} - c - i_{it-1} l_{it-1}, \ \forall \ i \in \ I \\ P_{J,t} A_{it} - c - i_{it-1} l_{it-1}, \ \forall \ i \in \ J. \end{cases} \tag{4.7}$$

Firms try to obtain better technology. They spend some amount $\Phi_{it} K_{it}$ on R&D. The probabilities of finding (drawing) new technologies are determined by imitation and innovation respectively and depend positively on the firm size, i.e. the amount of capital, some positive factor $a^{im}, a^{in}$, and the usage of R&D spendings $\Phi_{it} K_{it}$

$$Prob(d_{im} = 1) = 1 - e^{-a^{im} K_{it} \Phi_{it} \kappa_{it}}$$

$$Prob(d_{in} = 1) = 1 - e^{-a^{in} K_{it} \Phi_{it} (1-\kappa_{it})} \tag{4.8}$$

where $\kappa_{it}$ is the share that determines the allocation of funds to imitation.[1] Assume that a firm does either imitation search or innovation search only. This depends on whether it actually employs the best technology already or whether it uses less efficient technology. The rationale is that a technology leader has nothing to copy from and can thus devote all financial means of research to innovative search.[2] Firms with less efficient technology would then *strictly* search any possibility to copy existing technology. This is a drastic statement but also very simple. A precondition is that there is common knowledge about the highest technology.[3] Let $\hat{A}_{It}$, $\hat{A}_{Jt}$ be the best technology of the respective sector. The choice of R&D investment policy also is depending on the sector such that

$$\kappa_{it} = \begin{cases} 0, \text{ if } \hat{A}_{I,t} = A_{it}, \ \forall\ i \in\ I \\ 0, \text{ if } \hat{A}_{J,t} = A_{it}, \ \forall\ i \in\ J \\ 1, \text{ else.} \end{cases} \tag{4.9}$$

Each firm may conduct some R&D in a period. This is a two stage process where it first may or may not draw an innovation or imitation. In case of drawing an imitation the firm adopts the industry's best technology. Successful draws are indicated by

$$\chi_{it}^{im,in} = \begin{cases} 1, \text{ if there is a successful draw of imitation (im) or innovation (in),} \\ 0, \text{ else.} \end{cases}$$

If the firm draws an innovation, it gets a sample from a distribution of technical opportunities determined by $F(\tilde{A}_{it};A_{it})$ where $\tilde{A}_{it} \sim$ LogNormal$(A_{it},1)$. This implies that any innovation that is found is actually better than the currently employed technology. The technology that a firm can use in the next period is the best technology available to that firm. That is, it is the best technology among the current individual technology, the best technology in the sector if an imitation was drawn or the innovation that was drawn

$$A_{i(t+1)} = \begin{cases} Max(A_{it},\ \hat{A}_{I,t}\chi_{it}^{im},\ \tilde{A}_{it}\chi_{it}^{in}), \ \forall\ i \in\ I \\ Max(A_{it},\ \hat{A}_{J,t}\chi_{it}^{im},\ \tilde{A}_{it}\chi_{it}^{in}), \ \forall\ i \in\ J. \end{cases} \tag{4.10}$$

[1] These probabilities are inspired by Dosi et al. 2011.

[2] The particular role both, innovation and imitation play in economic growth is subject to a lot of discussion and research. While innovation breaks ground to better techniques, the diffusion of this techniques as firms reorganize usually leads to the real push in economic activity. See for example, Fagerberg and Verspagen (2002) for some discussion.

[3] Other models employ a more sophisticated and incremental choice between imitation and innovation effort which then does not require common knowledge. See, for instance, Colombo et al. (2012).

Given the anticipated technology of the upcoming production round a firm demands capital investment according to the functions

$$I^d_{it} = 1 + \delta - \frac{\mu_{it}}{\frac{P_t A_{i(t+1)}}{c}} \tag{4.11}$$

$$\mu_{it} = \frac{\varphi - (\varphi - 1)s_{it}}{\varphi - \varphi s_{it}}. \tag{4.12}$$

where $\mu_{it}$ is the markup power a firm could exert. This markup consists of some positive parameter $\varphi$ and the current market share of a firm $s_{it}$. The higher the market share, the higher is the markup (Winter, 1984, p. 319). The investment demand then depends negatively on the markup and positively on the price-over-cost margin of the firm. Firms determine their R&D effort according to prior success of research and in boom times the firms tend to increase R&D. Denoting $\Phi_{it}$ the per unit of capital R&D spending of a firm $i$ at $t$, the firm changes R&D spending according to the factor $\Omega_{it}$. Desired spending on R&D is

$$\Phi^d_{it} = Max\left[\Phi_{it-1}(1+\Omega_{it}), b^{RD}\right] \tag{4.13}$$

with

$$\Omega_{it} = \lambda^F(\pi_{it-1} - \pi_{it-T-1}) \tag{4.14}$$

where $T$ is the number of past periods taken into account and $\Omega_{it}$ determines the change in R&D demand. Assuming that firms adapt their target R&D spending by reacting positively on profit changes, $\lambda^F > 0$ is a parameter of the adjustment speed. Furthermore, $b^{RD} > 0$ represents a basic R&D target which the firm always wants to conduct. This behavioural rule is intended to capture increases in R&D spending in economically favourable times (Ben-Zion, 1984) and the reducing of R&D activity if the firm's success decreases or if competition is too tight which reduces profitability (Yildizoglu, 2002). Note that there will be always a non-zero level of desired R&D This feature does not completely match with the statement of Yildizoglu (2002) which indicates that firms without R&D success will abandon research *completely*. Note also that, compared to the Nelson-Winter approach it is just profit and savings that determine investment possibilities.

Together with R&D demand $\Phi^d_{it}$ the firm has demand for expenditures $E^d_{it} = \Phi^d_{it} + I^d_{it}$. Denote $C_{it} = \pi_{it} + S_{it-1}/K_{it} - l_{it-1}$ as liquidity per unit of capital. It consists of profitability and accumulated savings minus the last periods credit that has to be repaid. By *assuming a strict hierarchy* in financing, a firm would first use profit to finance investment and then refer to its savings. If investment demand exceeds liquidity there is demand for additional cash in the form of credit. Credit demand is the difference needed for financing

$$l_{it}^{d}=\begin{cases}E_{it}^{d}-C_{it} \text{ for } C_{it}<E_{it}^{d}\\ 0 \text{ else.}\end{cases} \tag{4.15}$$

The average credit supply per unit of capital $l^{s}$ is assumed to be constant. Total credit supply in absolute terms is $l_{t}^{s}=l^{s}\cdot\sum_{i}K_{it}$. Given its capital share in the economy the per unit of capital credit supply for any firm is ex ante $\frac{l_{t}^{s}}{K_{it}}$.

The bank supplies credit by distinguishing the two sectors via setting the weight factor $\lambda_{t}^{s}$. This applies via $\omega_{it}$

$$\omega_{it}=\begin{cases}\lambda_{t}^{s}, \text{ for } i\in I\\ (1-\lambda_{t}^{s}), \text{ for } i\in J.\end{cases} \tag{4.16}$$

The bank supplies credit to individual firms by ranking them according to their profitability and their market share. This represents the rating process in this model. The relative importance of profitability and market share is determined by setting $\lambda\in[0,1]$. The credit supply rule that the bank applies is

$$l_{it}^{s}=\begin{cases}\frac{l_{t}^{s}}{K_{it}}\left(\lambda\frac{\pi_{it-1}}{\sum\pi_{it-1}^{pos}}+\omega_{it}(1-\lambda)\frac{Q_{it-1}}{\sum(Q_{it-1})}\right), \text{ for } \pi_{it-1}>0\\ \frac{l_{t}^{s}}{K_{it}}\left(\omega_{it}(1-\lambda)\frac{Q_{it-1}}{\sum(Q_{it-1})}\right), \text{ else.}\end{cases} \tag{4.17}$$

This applies to both sectors, where $\sum\pi_{t-1}^{pos}$ is the sum of all profits from firms that yielded positive profits. Therefore, firms with positive profitability get credit supplied according to their relative position in the set of all profitable firms. This specification hence avoids some potential problems for the case that -due to negative profits- some firms' profits are huge relative to the average profit. Thus, the bank takes into account relative profitability and relative technology level. The parameter $\lambda_{t}^{s}$ shows the weight the bank puts on each sector. This weight may be adaptive and depend on the expected return, possibly through the survival and thus repayment ratio, from each sector. If the sectors are different, then the expected return can be very different. The allocation choice should be such that $\lambda_{t}^{s}\in[0,1]$. Determine

$f_t$ as the deficit ratio in a sector which expresses a proxy for non-recoverable credit

$$f_t = \frac{\#Exits_t}{\#Firms_t} \tag{4.18}$$

and the average over $H$ periods

$$\overline{f}_t = \frac{1}{H}\sum_{h=0}^{H-1} f_{t-h} \tag{4.19}$$

in the respective industry. Choosing $a_\lambda \in [0,1]$ as an adaptation speed parameter, the bank's choice is made according to

$$\lambda_t^s = Min[1,\ Max[0,\ \lambda_{t-1}^s + a_\lambda\left(\overline{f}_{J,t-1} - \overline{f}_{I,t-1}\right)]]. \tag{4.20}$$

If for example, the default rate in industry $I$ is higher than in industry $J$, the last term is negative and the bank shifts more credit to sector $J$ by reducing $\lambda^s$. This rule is inspired by actual bank rating practice as reported by Reichling et al. (2007). They state that banks classify firms in categories and then assess the risk of credit default by looking at past default ratios of firms having been in the respective category. Since in this model, risk is accounted for by rationing credit, less credit is supplied to the sector that is perceived to be riskier by the bank. The bank proxies this risk by the drop-out rate in the industry.

Some sectors of the economy are regarded to be R&D-intensive, like pharmaceuticals or the aerospace industry (Deutsches Institut für Wirtschaftsforschung [DIW], 2009). Therefore, we assume that the so-called high-tech sector $J$ in our model is aiming at conducting a basic level of R&D that exceeds the one of the so-called low-tech industry $b_J^{RD} > b_I^{RD}$. We also assume that the high-tech sector has a better chance of drawing an innovation/ imitation given the same spending on R&D such that $a_J^{im,in} > a_I^{im,in}$.[4]

Credit is allocated among the firms *applying* for it. Then,

$$l_{it} = Min\left[l_{it}^d, l_{it}^s\right]. \tag{4.21}$$

The investment constraint is

$$I_{it}^c = C_{it} + l_{it}. \tag{4.22}$$

Actual capital investment is then determined by this constraint and the desired capital investment.

[4]See Marsili and Verspagen (2002) on differences between 'technological regimes'.

Actual R&D spending is furthermore determined by the amount of liquidity not used for physical investment and the R&D desire

$$I_{it} = Min[I_{it}^{c}, I_{it}^{d}] \tag{4.23}$$

$$\Phi_{it} = Min[I_{it}^{c} - I_{it}, \Phi_{it}^{d}]. \tag{4.24}$$

The firms save money not invested. Savings evolve according to:

$$S_{it} = S_{it-1} + (\pi_{it} + l_{it} - I_{it} - \Phi_{it})K_{it} \tag{4.25}$$

as in Colombo et al. (2012). Note that savings are noted as absolute numbers and cannot be negative.

Entry takes place according to a two-stage process. First, there is exogenous activity and thus the number of potential imitators and innovators is determined. Then, those draw a random technology. A constant for innovation $N = 0.05$ and imitation $M = 0.05$ determines the number of potential entrants for innovation and imitative behavior in each of the two sectors. After drawing an individual technology, entry takes place if the potential entrant in a sector has drawn at least the currently average technology in the sector. The other features of the entrants like capital are then further determined randomly under a uniformly distributed probability within the range of existing firms' features. Assume that entrants also apply the strategy $\Phi^{ini}$ as well.

The driving force of the model is the difference in technology. It determines the relative profitability in each sector. According to an adjustment in firm sizes and therefore output there is a decrease in the market price. This puts pressure on all other firms in the industry and provokes selection.

If there is enough funding available, either due to retained profits or credit, a given change in a firm's technology triggers more pressure on the competitors if this is a very big firm. Since output increases relatively more in this case the price is driven down significantly. There are *two channels* at work in the dynamics of the model: firm size via investment and technology via R&D. Both determine a single firms' output and thus the overall price level in the industry (indirect feedback).

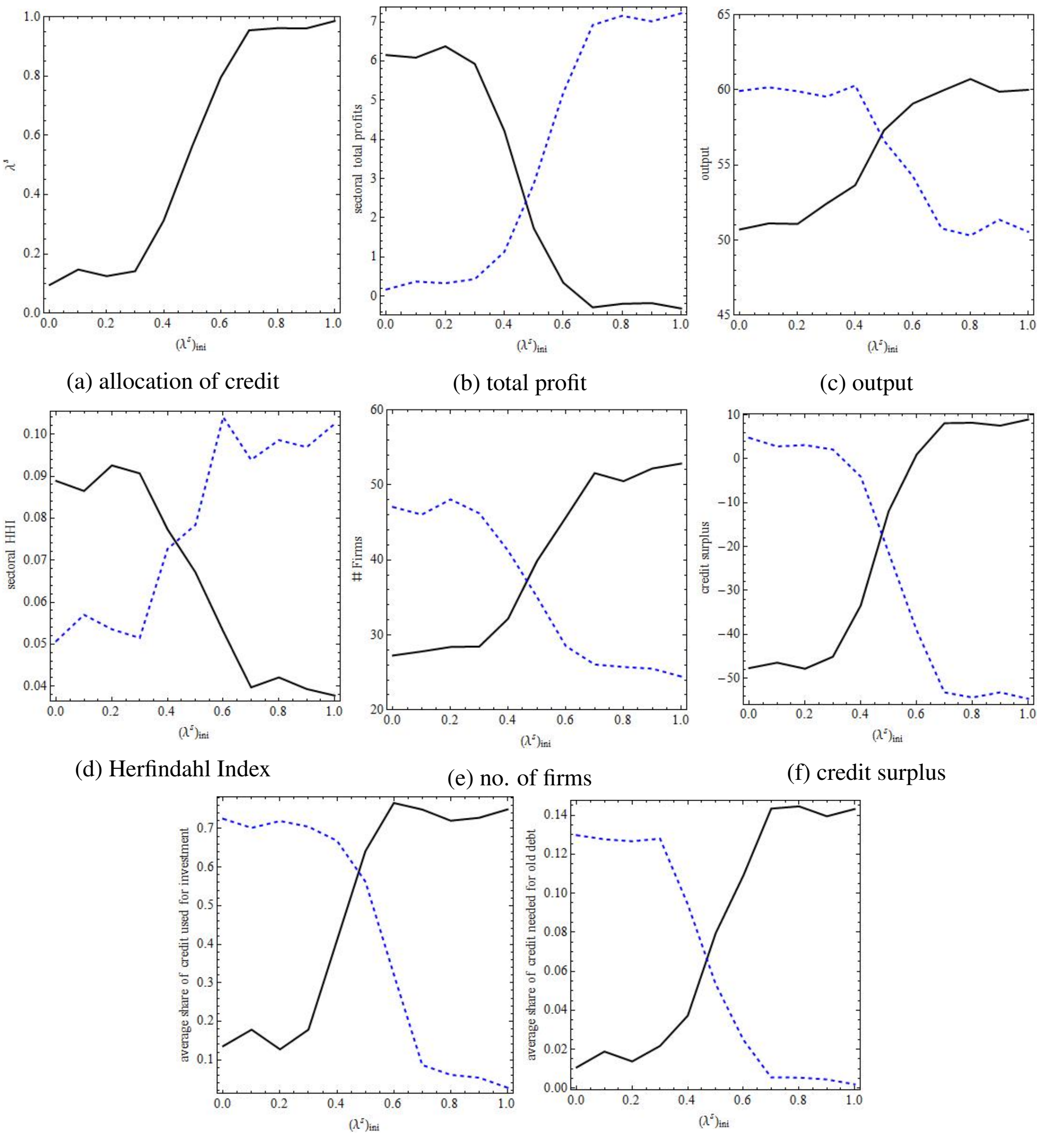
The main mechanism in the Nelson-Winter model would lead to a steady state market which means that the behavioural rule of investment demand has a converging effect. This is due to the influence of the market share: the higher the market share, the less investment is desired. Furthermore, a better technology always increases investment demand because it always improves the price-over-cost margin, except in the monopoly case where it has no effect. Nevertheless, the availability of credit determines how severe the positive impact will be. This is an important feature of this model and in line with the findings of Lee and Harrison (2001) who claim that the benefits from R&D and even innovation often are effective after some time lag and which then influence further R&D behaviour.

## 4.3 Baseline Case

For the baseline case the bank will only regard market specific features ($\lambda = 0$). We will first examine a situation where there is no R&D conducted whatsoever ($\Phi^d = 0$). Recall the credit supply rule

$$l_{it}^s = \begin{cases} \frac{l_t^s}{K_{it}} \left( \lambda \frac{\pi_{it-1}}{\sum \pi_{it-1}^{pos}} + \omega_{it} (1-\lambda) \frac{Q_{it-1}}{\sum (Q_{it-1})} \right), & \text{for } \pi_{it-1} > 0 \\ \frac{l_t^s}{K_{it}} \left( \omega_{it} (1-\lambda) \frac{Q_{it-1}}{\sum (Q_{it-1})} \right), & \text{else.} \end{cases}$$

Note that according to the European Union's requirements for rating methods to be approved, the condition $\lambda > 0$ is sustaining in practice since "consistency shall exist across lines of business, departments and geographic locations" (European Union, 2006, Annex VII, Part 4, Paragraph 17.(a) ) which means that comparability of *all* firms requires also information that is not market specific. The other parameters in this setting are credit supply $l^s = 0.05$ and reaction intensity on default rate $a_\lambda = 0.5$. For $\lambda_{ini}^s \in [0,1]$ we examine the long run evolution of the economy. Then, we will introduce R&D. Since there is no technological improvement in the baseline case we will only observe allocation effects as total output is relatively constant. Furthermore, as the two sectors only differ in their R&D effort and success probabilities, in this baseline case they are the same. We look at economic features after some time period contingent of $\lambda_{ini}^s$. We take results of periods $t \in [980, 1000]$ where the model has evolved enough in order to distinguish for different long-term influences. We compute the average of that time span. We repeat this 100 times and take the average of those repetitions. This is done for each of ten different levels of $\lambda_{ini}^s$. Results are depicted in figure 4.1.




(a) allocation of credit

(b) total profit

(c) output

(d) Herfindahl Index

(e) no. of firms

(f) credit surplus

(g) share of credit demanded in financing investment

(h) share of credit demanded in serving old debt

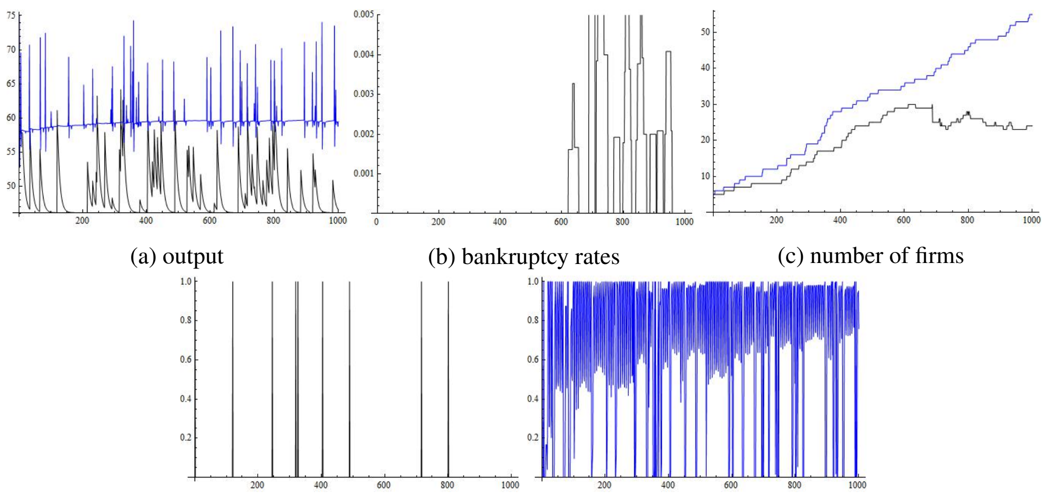
Figure 4.1: **Impact of initial credit allocation - baseline case**

`(Black → Low Tech; Blue, Dashed → High Tech)`

### 4.3.1 Baseline Case Without R&D

In the baseline case it is observable that the sector that gets credit supplied in the beginning will be supplied still in the long run (figure 4.1a). Furthermore, the supplied sector will have some investment and low concentration. This is indicated by output (figure 4.1c) and the Herfindahl-Index (figure 4.1d). Also, the number of firms is higher in that sector (figure 4.1e). Without improving technology the increased number of exits due to under supply of credit takes away capital and output. This is not offset by higher average productivity. Therefore, the initially supplied sector is less concentrated and its output is higher.

The use of credit also increases in initial credit supply (figures 4.1g and 4.1h). However, due to exiting firms and lower output the prices are higher for the remaining firms which leaves those better off. They have a higher profitability and thus require less credit for financing (figure 4.1f). This is indicated by total profits (figure 4.1b). In the simulation the low tech sector makes negative total profits for higher $\lambda^s_{ini}$. That means that it is likely that firms are Ponzi-financed and need to pay a lot of interest for credit which cuts into profits. This is indicated by figure 4.1h. Firms in the low tech sector need furthermore an increasing amount of credit just to pay back old credit so that credit supply induces the need for further credit if there are no productivity gains.

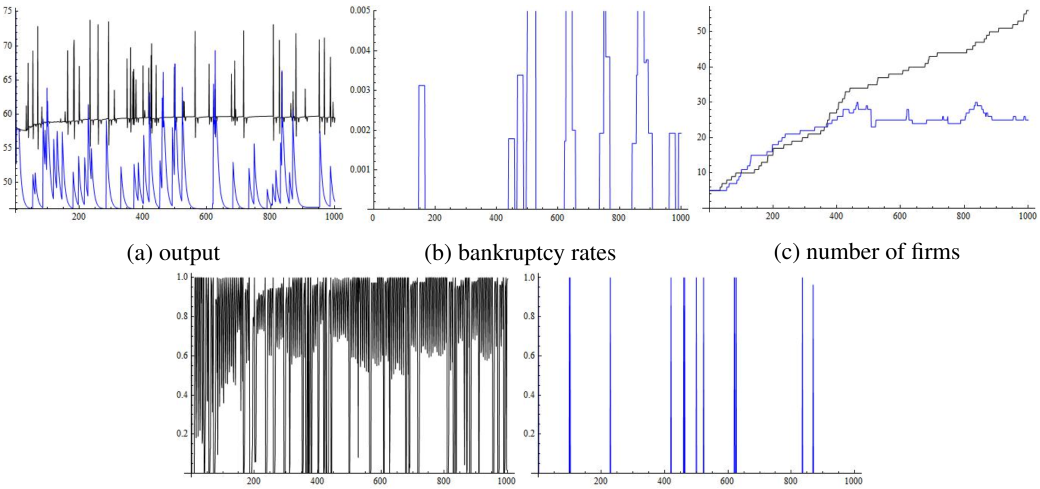


(a) output (b) bankruptcy rates (c) number of firms

(d) share of credit needed for investment low tech (e) share of credit needed for investment high tech

Figure 4.2: **Over time dynamics for baseline case without R&D and $\lambda^s_{ini} = 0$**
(Blue → high-tech sector)

Figures 4.2 and 4.3 show the dynamics over time of the economy for different initial allocation



(a) output (b) bankruptcy rates (c) number of firms

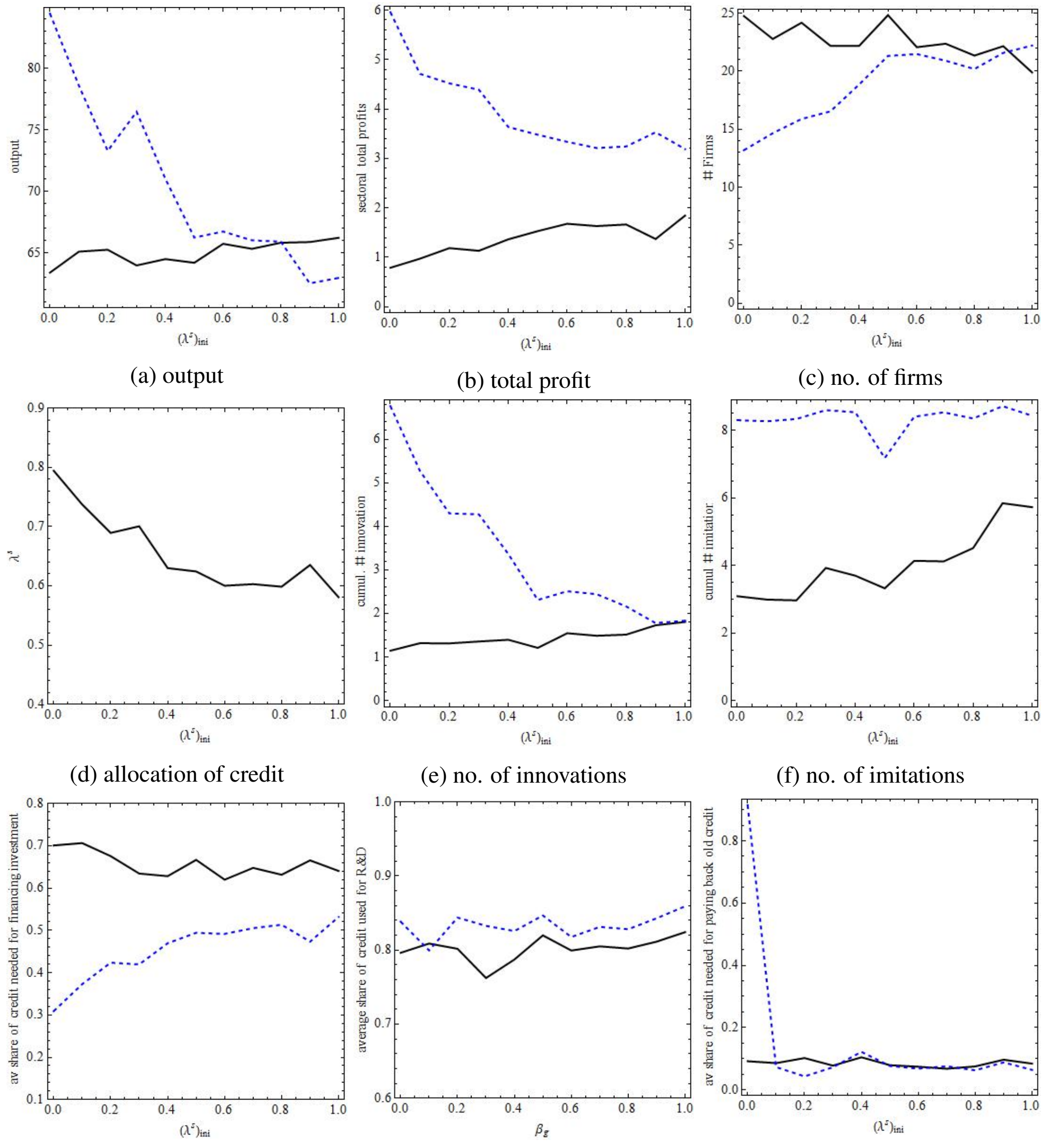
(d) share of credit needed for investment low tech (e) share of credit needed for investment high tech

Figure 4.3: **Over time dynamics for baseline case without R&D and** $\lambda^s_{ini} = 1$
(Blue $\rightarrow$ high-tech sector)

parameters. If the initial supply of credit is higher the credit supply for this sector is comparatively higher and lower in the other sector. In both cases of initial credit supply, the supplied sector evolves the same. A comparison of figures 4.2a and 4.3a shows that the economy evolves the same in both cases and the sectors are just interchangeable. Therefore, the supplied sector output is comparatively higher and at the same time, the market price is lower. This has implications for the profitability in the sectors. The supplied sector has a comparatively lower profitability since there are no technological improvements. This means that at the same time its share of external funds in financing investment is high (figures 4.2d and 4.2e as well as figures 4.3d and 4.3e) but investment itself is at a high level as well. Therefore, there is a larger number of firms able to stay in the industry which drives down concentration (see figures 4.2b and 4.3b or figures 4.2c and 4.3c). Heterogeneity among firm sizes occurs due to random entry with heterogeneous firm sizes. Only the market share matters for the relative supply of credit within the sector. Large firms therefore can drive small firms out of the industry just because of their collateral. For the well supplied sector this is not a problem since also the small firms have enough access to credit. The under supplied sector shows high concentration because credit is scarce. Nevertheless, total profits are low in the supplied sector because firms have to pay large amounts of interest for their funding which hurts profitability. Therefore, credit supply sustains the number of firms in the sector but not its profits.

### 4.3.2 Baseline Case With R&D

We now ask whether the credit allocation has a similar impact if R&D matters ($\Phi^d > 0$).



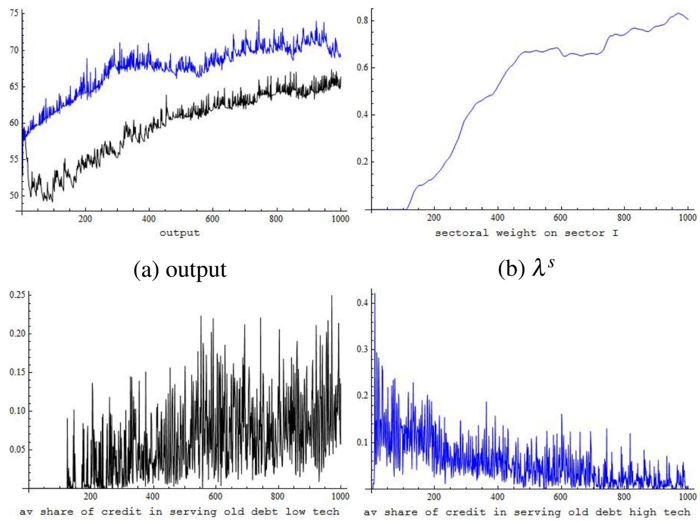

(a) output (b) total profit (c) no. of firms

(d) allocation of credit (e) no. of innovations (f) no. of imitations

(g) share of credit needed for financing investment (h) share of credit needed for financing R&D (i) share of credit needed for serving old debt

Figure 4.4: **Impact of initial credit allocation with R&D**
(Black → Low Tech; Blue, Dashed → High Tech)

Figure 4.4 shows the impact of the initial allocation parameter $\lambda^s_{ini}$ when the high tech sector is willing to conduct more basic R&D, $b^{RD}_J > b^{RD}_I$ and has a higher probability per unit invested than the low tech sector as well ($a^{im,in}_J > a^{im,in}_I$). The high-tech sector with a high R&D intensity is much better off when it is supplied credit in the first place. The output of the low-tech sector changes only marginally but the output of the high-tech sector decreases significantly in the initial allocation of credit (figure 4.4a). The lack of credit also hurts profits more in the high tech sector than its supply benefits the low-tech sector (figure 4.4b). Figure 4.4c indicates that a lack of credit is followed by a higher number of firms exiting the industry. This has implications for the long-term allocation of credit. Since the high-tech sector can grow because it has an initial high supply of credit, increased price pressure drives firms out of the industry. This raises bankruptcy rates and the bank shifts away credit to the low-tech sector (figure 4.4d). The number of innovations and imitations supports this view (figures 4.4e and 4.4f). The lower sectoral profits for the high tech sector require that a higher share of investment needs to be financed by credit as figure 4.4g confirms. Also, figure 4.4i indicates that initial allocation of credit does not matter if firms can improve by conducting R&D. The share of credit needed to set off old debt is low and does not vary in the initial allocation. There is only the exception when all credit is initially allocated to the high-tech sector. Because the high-tech sector starts with using a lot of credit and only diminished that usage over time when some firms improve upon technology sometimes the ratio may be high after 1000 periods. Compare figures 4.5d and 4.6d as well.




(a) output

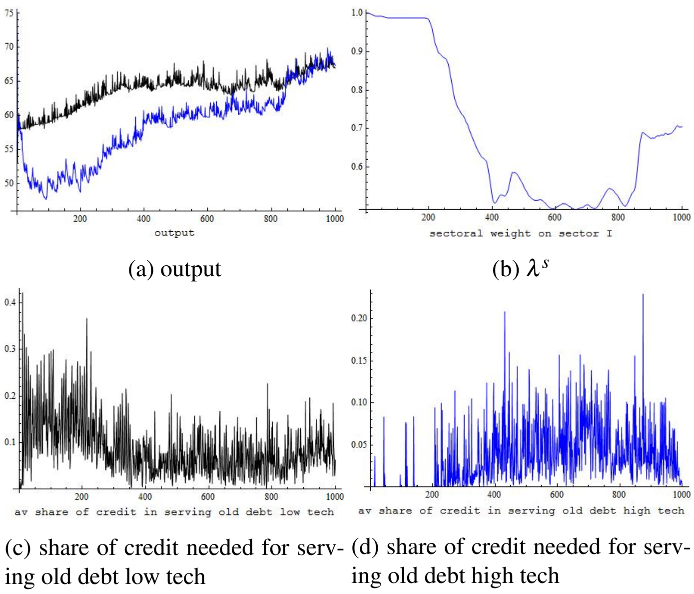
(b) $\lambda^s$

(c) share of credit needed for serving old debt low tech

(d) share of credit needed for serving old debt high tech

Figure 4.5: **Over time dynamics for baseline case with R&D and** $\lambda^s_{ini} = 0$
(Blue $\rightarrow$ high-tech sector)

Figure 4.5 shows the dynamics over time for the baseline case with R&D and initial allocation parameter $\lambda^s = 0$ where the R&D intensive sector is supplied all the credit. The images are averages taken from 10 runs. This supplied sector is able to innovate and hence increase output (figure 4.5a) and the allocation parameter shifts to the low-tech sector over time (figure 4.5b). The reason is that the high-tech sector is exposed to many exiting firms. The shift of credit to the low tech sector is clearly visible in the amount that firms need to refinance old debt (figures 4.5c and 4.5d). The low tech sector lacks credit supply but at the same time does not need to repay any loans which would cut into profits. After a while, this changes due to the allocation parameter of the bank and firms of the low-tech sector need to take a loan just to repay old debt. The same is observed in the opposite direction for the high tech sector. It initially has access to credit which leaves it in need of further credit for repayment. As there is no further credit supplied, this liability vanishes as well.




(a) output

(b) $\lambda^s$

(c) share of credit needed for serving old debt low tech

(d) share of credit needed for serving old debt high tech

Figure 4.6: **Over time dynamics for baseline case with R&D and** $\lambda^s_{ini} = 1$
(Blue $\rightarrow$ high-tech sector)

Figure 4.6 shows why an initial high supply of credit for the low tech sector leaves the sector being supplied even after a period of non-supply. The periods when firms rely on credit to repay old debt do match with the allocation parameter again (compare figures 4.6c and 4.6d with 4.6b). The initial advantage of credit supply is more beneficial for the low tech sector which is able to evolve more quickly (figure 4.6a). This evolution also causes the credit to shift to the low tech sector more quickly than in the opposite scenario. Nevertheless, the initial advantage of full supply lets the high tech sector evolve fast enough to be less reliant on credit. Figure 4.6d compared to figure 4.5c indicates decreasing need to refinance old credit which confirms that view.

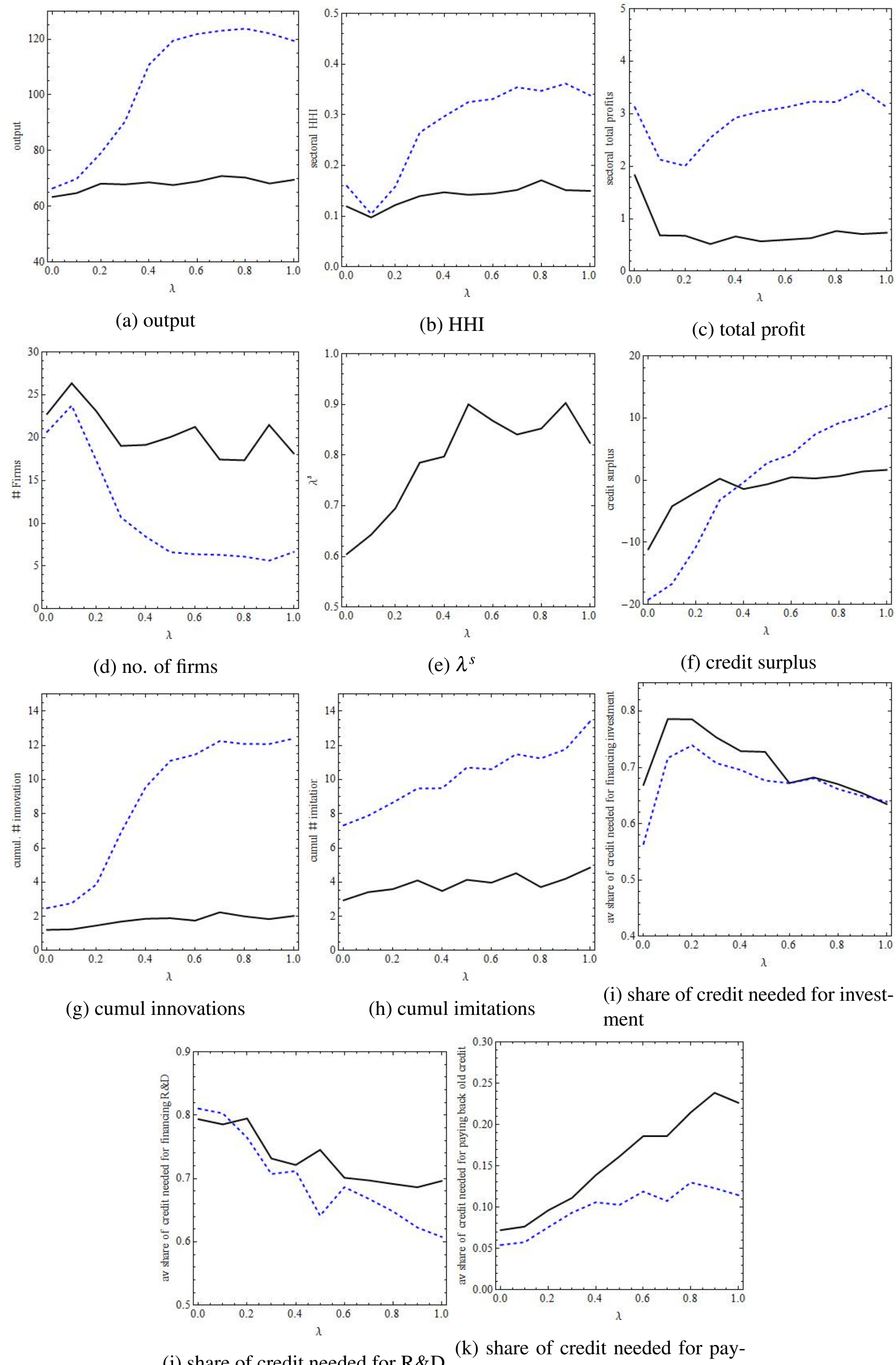
## 4.4 Bank Policy

The bank can affect the dynamics of the industries by the weight $\lambda$ it puts on profitability. Recall that the bank policy is inspired by risk management literature where lenders estimate the creditworthiness of their borrower. They are giving it a rating classification number and then base their decision on it. The effect of this policy is that the sector that is more innovative will get relatively more credit for the better profitability of its member firms on the one hand, but will suffer from less credit supply due to the higher drop out rate that stems from increased competition in that sector.

Figure 4.7 depicts the results for an experiment of the impact of the weight on information in the rating process fixed by the bank. The results indicated are for incremental values of that weight $\lambda \in [0,1]$. The figure shows that the high tech sector prospers most in a situation where sector specific features do not matter ($\lambda = 1$). If the bank puts nevertheless, much weight on sector specific information ($\lambda = 0$) the evolution of both industries is slower with the exception that the low-tech sector has higher total profits (figure 4.7c).

Output is affected much more for the high tech sector (figure 4.7a) than for the low-tech sector, where it is almost constant. As the industry concentration increases in both industries (figure 4.7b), it seems that it is mostly the exit of firms that leads to lower total profits in the low - tech sector. Although the number of exits is much higher in the high tech sector (figure 4.7d) total profits increase. Also, credit surplus increases for *both* sectors (figure 4.7f). This is due to the much higher number of innovations and imitation in the high tech sector (figures 4.7g and 4.7h). The bank allocates more credit to the low-tech sector (figure 4.7e) which reduces negative credit surplus due to the increased supply. The high-tech sector makes more profits and due to less credit demand its credit surplus increases.

Furthermore, the technology gap between sectors widens and the weight put on the less innovative sector increases in $\lambda$. This is indicated by the number of innovations and imitations in figures 4.7g and 4.7h. This happens although the bank allocates more credit to the low-tech sector. This allocation of credit induces a higher use of credit and a higher further dependence on credit (figures 4.7i through 4.7k). Thus, the bank policy does have a distinct influence on the evolution of the economy: as it puts more weight on global competition, that is the profitability, it promotes the firms with the best cash flow and does not take into account credit defaults by exiting firms. It has to be pointed out however, that the credit supply is constant in units of capital, that is, as firms do leave the economy, credit supply in absolute terms is lower in the next period. As firms with better cash flow are promoted, there is more credit surplus as those firms do not require external funding. At the same time, the firms




(a) output

(b) HHI

(c) total profit

(d) no. of firms

(e) $\lambda^s$

(f) credit surplus

(g) cumul innovations

(h) cumul imitations

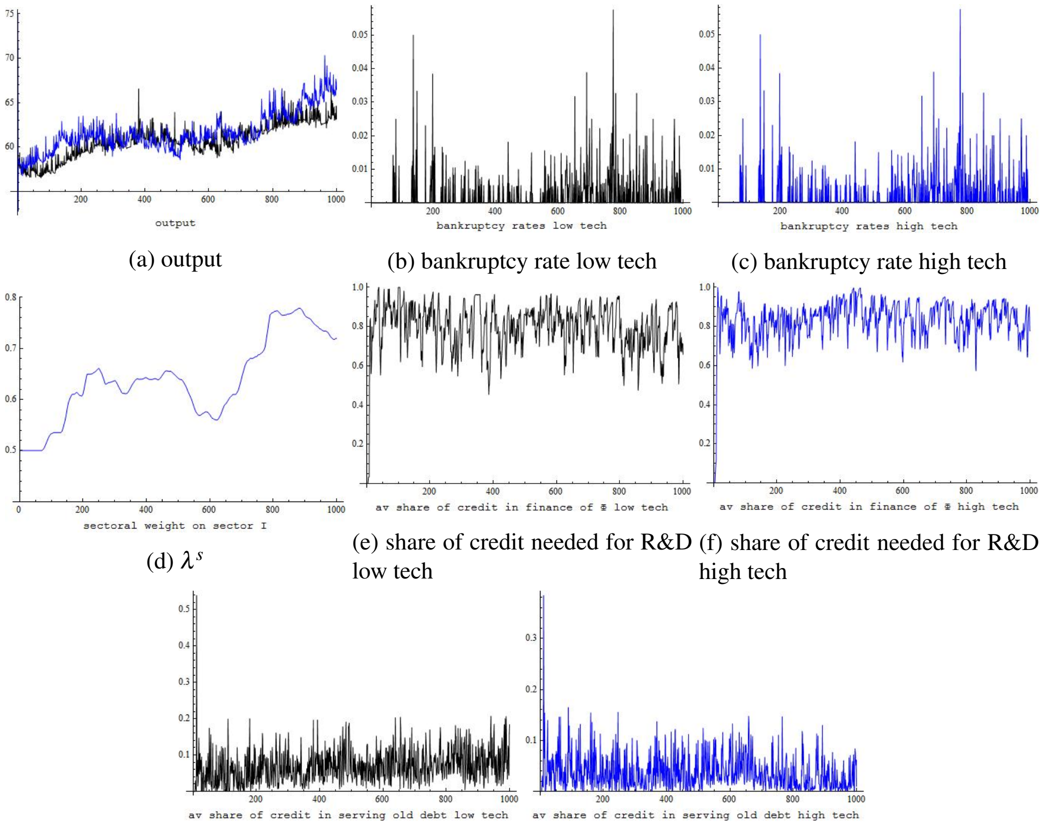
(i) share of credit needed for investment

(j) share of credit needed for R&D

(k) share of credit needed for paying off old debt

Figure 4.7: **Impact of rating weights in the two sector setup**

`(Black → Low Tech; Blue, Dashed → High Tech)` relying on external funding are offered comparatively less credit. There are more bankruptcies and a higher tendency toward monopolistic sectors. Furthermore, as $\lambda$ increases, the impact of $\lambda^s$ and $a_\lambda$, the default quota adjustment speed becomes more negligible. Innovation becomes more crucial since it has only a global effect. The disadvantage of innovation for a single sector due to increased competition, increased bankruptcies, vanishes for $\lambda = 1$.



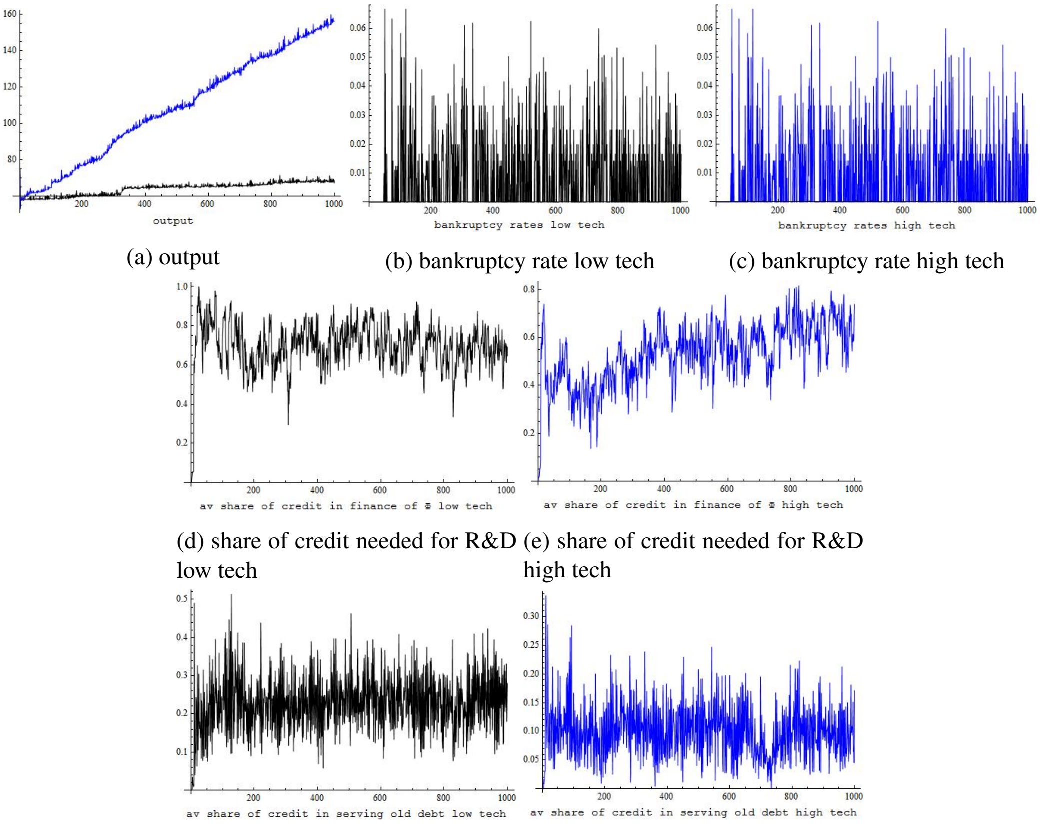

(a) output (b) bankruptcy rate low tech (c) bankruptcy rate high tech

(d) $\lambda^s$ (e) share of credit needed for R&D low tech (f) share of credit needed for R&D high tech

(g) share of credit needed for serving old debt low tech (h) share of credit needed for serving old debt high tech

Figure 4.8: **Over time dynamics for $\lambda = 0$**
(Blue $\rightarrow$ high-tech sector)

The parameter $\lambda_t^s$ is without meaning in this scenario. Figure 4.8 depicts the over time dynamics for $\lambda = 0$ and figure 4.9 shows the dynamics if $\lambda = 1$ for an average of 10 runs. If only market share matters ($\lambda = 0$) firms stay rather identical in each of the sectors. Furthermore, they are supplied with the same amount of credit since they all have the same market share. Both effects reinforce each other. Both sectors can grow almost equally with slight advantages for the high tech sector (figure 4.8a). The allocation parameter $\lambda_t^s$ increases a bit (figure 4.8d) which is the reason that the low tech sector has access to credit and is able to grow at about the same pace as the high tech sector. Figures 4.8b and 4.8c show that both sectors face similar bankruptcy rates. The similar need of credit in order




(a) output

(b) bankruptcy rate low tech

(c) bankruptcy rate high tech

(d) share of credit needed for R&D low tech

(e) share of credit needed for R&D high tech

(f) share of credit needed for serving old debt low tech

(g) share of credit needed for serving old debt high tech

Figure 4.9: **Over time dynamics for $\lambda = 1$**
`(Blue` $\rightarrow$ `high-tech sector)`

to finance R&D is visible in figures 4.8e and 4.8f while figures 4.8g and 4.8h show that also the credit needed in order to repay old debt is similar and at a low level. The high tech sector is constrained in its growth because credit is shifted away to the low tech sector. If the bank puts all weight on sector specific issues the bankruptcy rate information will exert its equalizing effect to the maximum extent. If the bank puts weight on profitability only it does react on the different levels of profitability between the high tech and the low tech sector. Figure 4.9 shows that the high tech sector is able to fully benefit from its inherent advantage of a higher probability of innovating and imitating. It grows very fast (figure 4.9a). The low tech sector hardly grows as all the high tech firms are more profitable as the low tech firms and hence the low tech sector has not much access to credit. Figures 4.9b and 4.9c indicate that in both sectors there are more bankruptcies than in the regime where $\lambda = 0$. Furthermore, also the credit needed in financing R&D is a little bit different. While for the low-tech sector there is no clear difference (figure 4.9d), the high tech sector is in increasing need of credit for R&D over time (figure 4.9e). Additionally, the rate of credit needed to repay old debt is higher for both sectors in this scenario (figures 4.9f and 4.9g). The equalizing impact of the bankruptcy ratios is without any effect here. A better technology is not punished due to credit supply in this scenario. The high tech sector benefits from that. The remaining firms will keep up wanting to conduct R&D which is why the share of credit needed for that increases over time. Both sectors use credit more as it is not shifted away by the bank. Nevertheless, as the high tech sector evolves faster those firms will be allocated most credit due to their high profitability. This is visible in the slow evolution of the low tech sector (figure 4.9a). Thus, the bank policy determines to what extent competition will impact credit supply. The more the bank focuses on sector-specific information, that is market-share and risk, first of all, the more similar will the evolution of both sectors be. If the bank does not distinguish between sectors it does not take risk into account and competition *across* sectors is not important. Then, the more innovative sector will attract most of credit supply because the most innovative firms are much more profitable. Therefore, the high tech sector will be able to evolve much faster while the low-tech sector has hardly any access to credit and thus evolves almost not at all.

In order to check for the robustness of the results a Wilcoxon-Signed-Rank Test is conducted. This non-parametric test is done for the impact of the bank policy under 50 random market and firm policy setups for a significance level of 95%. As market conditions cannot be influenced by the agents in this model, the focus is on policies. Furthermore, since the impact of credit constraints is the matter of interest, the results obtained are checked for robustness by focusing on the bank policy and comparing three levels of it. It is checked whether the results obtained from the comparative analysis hold in broader, randomly chosen parameter setups, that is, in a broader environment. The Wilcoxon-Signed Rank Test confirms the qualitative findings of this section and of the following one as well, so that those are concluded to be robust at a 95% significance level (see appendix C.2).

## 4.5 Market Outlook and Expectation Formation

In this section we examine the impact of different kinds of expectation formation by the bank on the evolution of the sectors. The bank chooses how much credit to allocate to each sector by setting $\lambda_t^s$ according to a mix of financial data and technological growth expectations. Financial data analysis is backward looking. We want to assess the ramifications of rather forward-looking market analyses and whether they have the potential to become self-fulfilling. The financial data is covered by the cash flow and the survival ratios. Growth expectations aim at forecasting the average productivity of each sector. Expectations are formed by adapting to the history of average productivity levels of the sectors. The variation of a single parameter in the expectation formation rule can yield outcomes for three different mindsets of the bank affecting the rating. By changing this parameter $\beta_g$ over a range of negative and positive values, a fundamental view, naive expectations and trend extrapolation are incorporated in the simulation. A fundamental bank view prevails if $\beta_g$ is negative. If it is zero, there are naive expectations and for positive values the bank follows the current trend.
The bank first computes the average growth of average productivity in each sector for a particular period $H$. In more detail the average productivity of industry $I$ at *period t* is

$$\overline{A}_{I,t} = \frac{\sum_{i \in I} A_{it} K_{it}}{\sum_{i \in I} K_{it}} \tag{4.26}$$

The growth rate of average productivity in industry $I$ at period $t$ is

$$g_{I,t} = \frac{\overline{A}_{I,t}}{\overline{A}_{I,t-1}} - 1 \tag{4.27}$$

The *average* productivity growth *over a period of length $H$*, where the current period is included, is then

$$\Theta_{I,t} = \frac{1}{H} \sum_{h=0}^{H-1} g_{I,t-h} \tag{4.28}$$

The bank does not know the productivity of the upcoming period when it is making the credit decision, therefore it forms the expectation

$$\hat{g}_t = g_t + \beta_g \left(g_t - \Theta_t\right) \tag{4.29}$$

which applies to both sectors the same. If the adjustment speed and strategy parameter $\beta_g = 0$, the expectation is naive. The larger $\beta_g$ is, the more speculative is the nature of the expectation. If $\beta_g$ is negative, the bank believes that the growth rate will converge to its long-term average. Here, the term $\Theta_t$ can be understood as the moving average of growth rates for the last $H$ periods. Suppose that the bank translates their expectation about sector $I$ into a scoring number $\sigma_t^I$ according to

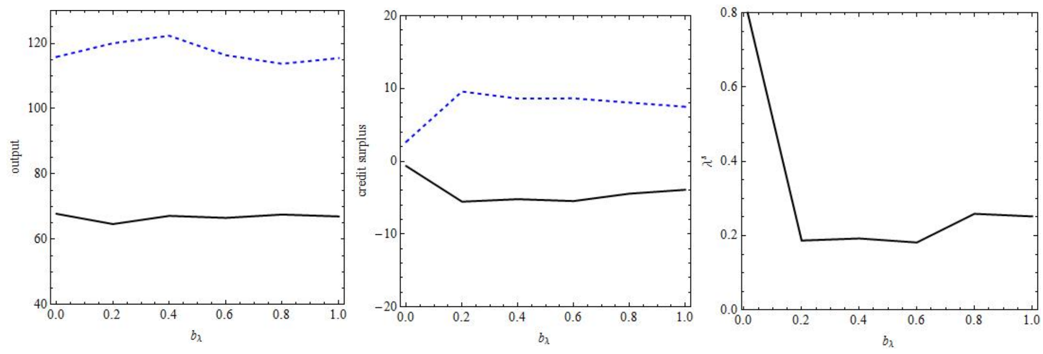
$$\sigma_{I,t} = \frac{1}{1 + e^{-(\xi \hat{g}_{I,t})}} \tag{4.30}$$

with $\xi > 0$ and which assures that $\sigma_t^I \in [0,1]$. This has advantages for comparing it with the impact of the survival ratios which are also between zero and one. Then, the new allocation rule is

$$\lambda_t^s = Min[1,\ Max[0,\ \lambda_{t-1}^s + a_\lambda \left(R_{I,t-1} - R_{J,t-1}\right) + b_\lambda \left(\sigma_{I,t} - \sigma_{J,t}\right)]] \tag{4.20b}$$

with $b_\lambda \geq 0$.

First, we examine how much of an impact the market outlook may have. We compare different levels of importance between $b_\lambda \in [0,1]$ for $\lambda = 0.375$ and for a conservative, mean reverting rule of expectations $\beta_g = -1$ to illuminate the effect. Figure 4.10 shows the result for the experiment about the importance



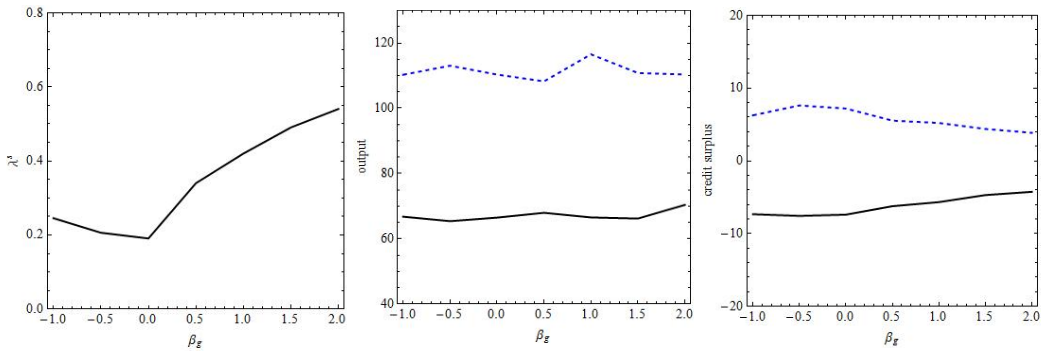

(a) sectoral output (b) credit surplus (c) sectoral credit allocation

Figure 4.10: **Impact of market outlook**

of the market outlook for the impact at $t \in [980,1000]$ for 100 repetitions. Figure 4.10a shows that the output for the high tech sector and the low-tech sector is hardly affected. The reason for the effect on output is visible in figure 4.10b which indicates that for the high-tech sector there will be an increasing amount of credit surplus while at the same time, credit surplus for the low tech sector will be even more negative as soon as the bank takes the outlook into account. However, the degree of this consideration does hardly matter. The ability to produce output is directly linked to access to credit. Figure 4.10c indicates the reason for the evolution of credit surplus. The allocation of credit is more in favour for the high-tech sector as the market outlook becomes effective. The impact of the outlook however, does not have a major impact.

This impact can actually lead to the effect that the high-tech sector will have more access to credit while without taking market outlook into account it would not have at all. The impact on credit supply reveals this very clearly: for market outlook not taken into account at all ($b_\lambda = 0$), both, the low tech sector and the high-tech sector have about zero credit surplus. The importance of market outlook drives a wedge into credit surplus at the expense of the low-tech sector because the bank shifts credit to the high-tech sector. This is a reinforcing effect since more credit means also a higher likelihood of innovating which in return means better a market outlook.

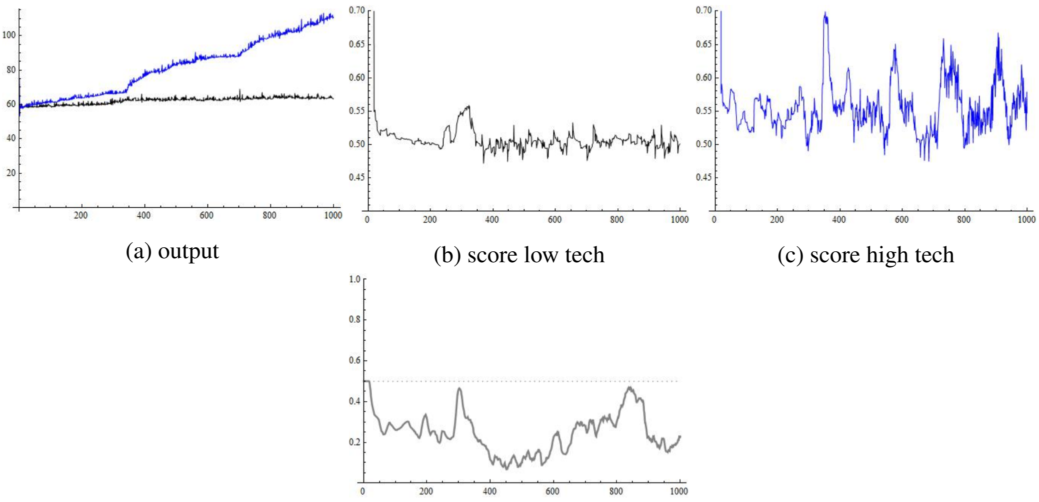
We now ask what impact the kind of expectation formation by the banking sector has. Recall that it may have conservative expectations closely related to the long-term average or that expectations may be formed in a trend-extrapolation fashion. We use $\xi = 400$ and $b_\lambda = 0.35$. The time span is again covered until $T = 1000$. The experiment is conducted for $\beta_g \in [-1, 2]$.




(a) sector parameter (b) output (c) credit surplus

Figure 4.11: **Impact of extrapolation of banks**

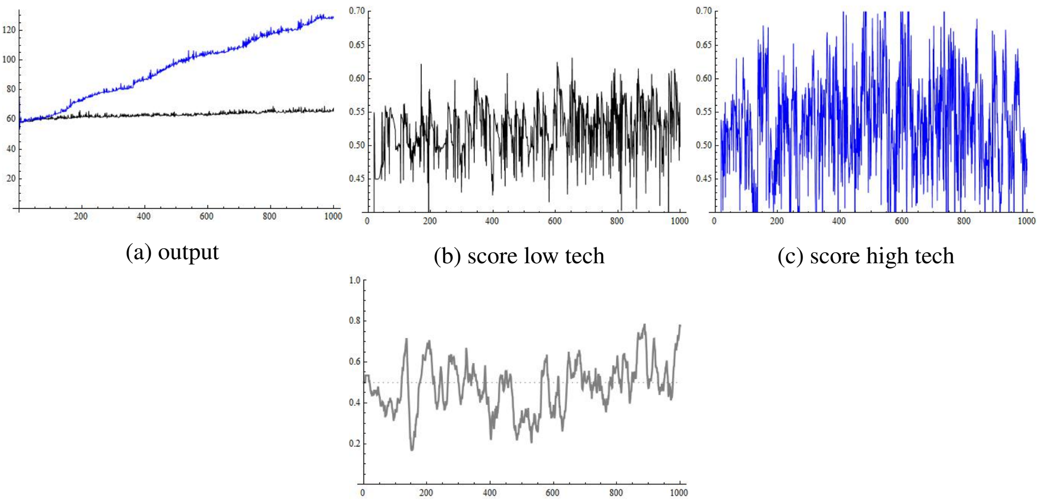
Figure 4.11 shows how the expectational mindset of the bank impacts the economy in the long run. Results reveal that the way expectations are formed does have an impact on the credit decision (figure 4.11a) but the impact on total output. is meager (figures 4.11b). Credit surplus seems to increase for the low tech sector and to decrease for the high tech sector, but the scale is very small (figure 4.11c). Extrapolating the technological progress does lead, however, to *less* credit being supplied to the innovative sector (figure 4.11a). The reason is that increased expectations and increased credit supply for a sector does lead to higher output and better technology. It also is followed by increased competition and industry exits. These exits have a negative impact on further credit supply which is hence shifted away from the innovative sector. Thus, if the bank takes the survival ratios into account it is unlikely that even very optimistic expectations lead to more credit supply for the sector *in the long run*.



(a) output (b) score low tech (c) score high tech

(d) $\lambda^s$

Figure 4.12: **Over time dynamics for mean-reverting expectations** (Blue → high-tech sector)



(a) output (b) score low tech (c) score high tech

(d) $\lambda^s$

Figure 4.13: **Over time dynamics for extrapolative expectations** (Blue → high-tech sector)

The figures 4.12 and 4.13 show the differences in dynamics over time for mean-reverting expectations (figure 4.12) and for extrapolating ones (figure 4.13) as average over 10 simulation runs. The scoring points difference for expectations is visible in figures 4.12b,4.12c and 4.13b,4.13c. If the bank has mean-reverting expectations this has a much longer lasting impact on scoring because the average growth matters more than short term deviations. Also, the scores are usually above the threshold of 0.5. Furthermore, if deviations are extrapolated this works also the other way round after high growth rates due to innovation are not sustained in the following periods. The long lasting scoring impact drives market specific credit supply towards the high-tech sector (4.12d).

If the bank has extrapolative expectations its judgment is much more volatile and short-lived. Because growth expectations are both, highly positive and severely negative, the overall impact on $\lambda^s$ is volatile and the parameter is slightly increasing, under huge fluctuations (figure 4.13d). Therefore, the impact of the survival ratio is of higher weight and $\lambda^s$ tends to shift credit to the low-tech sector over time more distinctly for $\beta_g > 0$. If the bank follows mean-reverting expectations scoring differences last longer and technology improvements have a longer lasting impact on $\lambda^s$. Therefore, the high-tech sector benefits more from that as a larger share of credit is allocated to this sector (figures 4.12a and 4.13a).

Only mean-reverting expectations have the potential to offset the impact of bankruptcy ratios. If expectations change too quickly as in trend extrapolating scenarios there is no lasting expectation that can cope with increasing bankruptcy ratios. The positive expectations of the high tech sector are just not lasting long enough to exert a positive impact over the bankruptcies triggered by competition and therefore fast changing expectations have not a distinct effect.

The robustness check in the appendix reveals that even the allocation parameter is very sensitive to varying parameters. In fact, there is no significant impact on any variable. This supports the meager impact of the expectation formation not only on the allocation of credit, but especially on the aggregate variables. As long as credit surplus for a sector does not change signs for increasing parameter values, there is no distinct effect. Figure 4.10b shows that for all values of the expectation rule parameter $\beta_g$ credit surplus does not change the sign in neither sector. Whether credit surplus is at a critical stage where the expectation has the potential to leading to a change in signs depends on the parameter $\lambda$ – the bank rule.

Although the impact of expectations is quite visible in $\lambda^s$, the composition of the creditworthiness judgment is such that the impact of expectations does not overshadow financial rating. In practice, financial rating accounts for fifty to eighty-five percent of the rating outcome (Everling et al., 2009, p. 234). Therefore, there is a visible but not significant impact of the expectations for economic outcomes, such as output or market power in this model. Also in reality the impact of expectations on the long term economic pattern can be expected to be limited as far as credit rating is concerned.

## 4.6 Concluding Remarks

In this paper we addressed the question which role bank routines play in the pace of innovation in an economy. We focused on rating rules that impact two different sectors via credit supply by constraining firms in investment and R&D. In particular, technological progress enhances productivity and output in a sector but also competition so that an increasing number of firms may exit the industry. If the increase in productivity of the surviving firms is too low to compensate for the loss of production by exiting firms, sectoral output decrease in average productivity of a sector.

We build on an evolutionary model where firms in each sector compete by their productivity. They choose how much they invest and how much to spend on R&D on top of investment. R&D spending depends positively on the profit history. Both sectors feed back to each other, as well as do single firms, via credit supply. The supplier provides credit according to a rating rule and therefore firms might be constrained. We examine the impact of rating behaviour by addressing two aspects. First, the importance a bank adjoins to either profitability or sector-specific information. Second, we assess to what extent expectation formation of the bank affects the credit supply.

Within the credit supply decision there are also contrary effects. The bank assesses the prospects of any firm relative to its rivals. An individual firm may have good prospects but if the prospects of the sector, for instance the survival ratio, are low due to increased competition the firm might be constrained in credit nevertheless.

Both aspects of the bank decision have a decisive role in a rating process that takes the sectoral risk from competition into account. As a sectoral average productivity increases more firms in that sector go bankrupt at the same time. Both, the weight and the way the bank forms expectations can influence the impact of the rating procedure. The weight parameter simply determines the impact that risk can exert on the rating decision. If the bank focuses on cash-flow (financial information) the high-tech sector evolves much differently than the low tech sector. It benefits much from its inherent advantages of a higher ability of finding new technology. The low tech sector suffers from that success as the high-tech sector will absorb almost all the credit supply.

The expectation formation of the bank is able to counterbalance the impact of the risk assessment. If the bank has mean-reverting expectations it keeps up expecting a good evolution of the high-tech sector for an extended period. This leads to a persistent shift of credit to the high-tech sector. If the bank has extrapolative expectations it follows upswings and downswings in the average productivity. Therefore there is no persistent force that can outbalance the impact of the higher risk in the high-tech sector. Hence, credit is shifted gradually to the low tech sector and differences between sectors are less pronounced.

Nevertheless, the structures of the regime matter more for the evolution of the economy while the expectation formation is hardly decisive. The robustness check reveals that the decision parameter is quite robust in its impact while the expectation formation is not significant at all. Therefore, there is a clear hierarchy in the determinants of the evolution of the economy.

# Appendix C

## C.1 Parameters and Variables

| **Control Parameters - basic values** | | |
|---|---|---|
| average credit supply in unit of capital | $l_t^s$ | 0.05 |
| bank's weighing parameter for credit offer | $\lambda$ | 0.375 |

The intervals that the parameters for the test are chosen from are:

| | |
|---|---|
| $\delta$ | $\in [0.027, 0.033]$ |
| $c$ | $\in [0.144, 0.176]$ |
| $a_I^{im}$ | $\in [0.018, 0.022]$ |
| $a_I^{in}$ | $\in [0.0063, 0.0077]$ |
| $b_I^{RD}$ | $\in [0.0018, 0.0022]$ |
| $a_J^{im}$ | $\in [0.0216, 0.0264]$ |
| $a_J^{in}$ | $\in [0.00756, 0.00924]$ |
| $b_J^{RD}$ | $\in [0.00216, 0.00264]$ |
| $\varphi$ | $\in [2.7, 3.3]$ |
| $\lambda^F$ | $\in [1.8, 2.2]$ |
| $a_\lambda$ | $\in [0.45, 0.55]$ |
| $b_\lambda$ | $\in [1.8, 2.2]$ |
| $D_I$ | $\in [35, 45]$ |
| $D_J$ | $\in [35, 45]$ |
| $\lambda_{ini}^s$ | $\in [0.45, 0.55]$ |

Table C.1: Parameter space for the robustness check

| Parameters | | |
|---|---|---|
| Demand low-tech sector | $D_I$ | 40 |
| Demand high-tech sector | $D_J$ | 40 |
| Effectivity of imitation effort low-tech sector | $a_I^{im}$ | 0.02 |
| Effectivity of innovation effort low-tech sector | $a_I^{im}$ | 0.007 |
| Effectivity of effort high-tech sector | $a_J^{im,in}$ | $1.2 \cdot a_I^{im,in}$ |
| Effectivity of effort low-tech sector | $b_I^{RD}$ | 0.002 |
| Effectivity of effort high-tech sector | $b_J^{RD}$ | $1.2 \cdot b_I^{RD}$ |
| Adaptation speed for sector-specific credit due to survival ratios | $a_\lambda$ | 0.5 |
| Adaptation speed for sector-specific credit due to technol. change | $b_\lambda$ | 0.25 |
| initial no. of firms | | 10 |
| initial capital | $K_{it}^0$ | 100 |
| initial technology | $A_{it}^0$ | 0.15 |
| interest rate | $i$ | 0.05 |
| initial R&D spending desire | $\Phi_{it}^0$ | 0.004 |
| firms' R&D adjustment policy parameter | $\lambda^F$ | 2 |
| depreciation rate | $\delta$ | 0.03 |
| production costs | $c$ | 0.16 |
| lower capital barrier for bankruptcy | $crit$ | 1 |
| time horizon for profit history | $T$ | 3 |
| time horizon for productivity history | $H$ | 20 |
| markup parameter for investment desire | $\varphi$ | 3 |
| parameter for scoring points | $\xi$ | 400 |

## C.2 Robustness Check

The following tables depict the result of the Wilcoxon Signed Rank test for 100 random samples of above parameter space. If the Null Hypothesis cannot be rejected, $''ns''$ is depicted. If it can be rejected, then the direction of difference between sample medians is shown. Where $*$ is depicted, there is no debt to be repaid because credit supply is zero and thus there is no test for that particular case.

**Low Tech Sector**

| credit supply | output. | credit surpl. |
|---|---|---|
| **$\lambda = 0$ vs. $\lambda = 0.5$** | | |
| $b_\lambda = 0$ | *ns* | *ns* |
| $b_\lambda = 0.25$ | $<$ | $<$ |
| $b_\lambda = 0.5$ | $<$ | $<$ |
| **$\lambda = 0.5$ vs. $\lambda = 1$** | | |
| $b_\lambda = 0$ | $<$ | $<$ |
| $b_\lambda = 0.25$ | *ns* | $<$ |
| $b_\lambda = 0.5$ | *ns* | $<$ |
| **$\lambda = 0$ vs. $\lambda = 1$** | | |
| $b_\lambda = 0$ | $<$ | $<$ |
| $b_\lambda = 0.25$ | $<$ | $<$ |
| $b_\lambda = 0.5$ | $<$ | $<$ |

**High Tech Sector**

| credit supply | output | credit surpl. |
|---|---|---|
| **$\lambda = 0$ vs. $\lambda = 0.5$** | | |
| $b_\lambda = 0$ | *ns* | *ns* |
| $b_\lambda = 0.25$ | $<$ | $<$ |
| $b_\lambda = 0.5$ | *ns* | *ns* |
| **$\lambda = 0.5$ vs. $\lambda = 1$** | | |
| $b_\lambda = 0$ | $<$ | $<$ |
| $b_\lambda = 0.25$ | *ns* | $<$ |
| $b_\lambda = 0.5$ | *ns* | *ns* |
| **$\lambda = 0$ vs. $\lambda = 1$** | | |
| $b_\lambda = 0$ | $<$ | $<$ |
| $b_\lambda = 0.25$ | $<$ | $<$ |
| $b_\lambda = 0.5$ | $<$ | *ns* |

Table C.2: Results of the Wilcoxon-Signed-Rank Test for the bank policy

**Low Tech Sector**

| credit supply | output | credit surpl. | $\lambda^s$(both sectors) |
|---|---|---|---|
| $\beta_g = -1$ **vs.** $\beta_g = 0$ | | | |
| $b_\lambda = 0$ | *ns* | *ns* | *ns* |
| $b_\lambda = 0.25$ | *ns* | *ns* | *ns* |
| $b_\lambda = 0.5$ | *ns* | *ns* | *ns* |
| $\beta_g = 0$ **vs.** $\beta_g = 2$ | | | |
| $b_\lambda = 0$ | *ns* | *ns* | *ns* |
| $b_\lambda = 0.25$ | *ns* | *ns* | *ns* |
| $b_\lambda = 0.5$ | *ns* | *ns* | *ns* |
| $\beta_g = -1$ **vs.** $\beta_g = 2$ | | | |
| $b_\lambda = 0$ | *ns* | *ns* | *ns* |
| $b_\lambda = 0.25$ | *ns* | *ns* | *ns* |
| $b_\lambda = 0.5$ | *ns* | *ns* | *ns* |

**High Tech Sector**

| credit supply | output | credit surpl. |
|---|---|---|
| $\beta_g = -1$ **vs.** $\beta_g = 0$ | | |
| $b_\lambda = 0$ | *ns* | *ns* |
| $b_\lambda = 0.25$ | *ns* | *ns* |
| $b_\lambda = 0.5$ | *ns* | *ns* |
| $\beta_g = 0$ **vs.** $\beta_g = 2$ | | |
| $b_\lambda = 0$ | *ns* | *ns* |
| $b_\lambda = 0.25$ | *ns* | *ns* |
| $b_\lambda = 0.5$ | *ns* | *ns* |
| $\beta_g = -1$ **vs.** $\beta_g = 2$ | | |
| $b_\lambda = 0$ | *ns* | *ns* |
| $b_\lambda = 0.25$ | *ns* | *ns* |
| $b_\lambda = 0.5$ | *ns* | *ns* |

Table C.3: Results of the Wilcoxon-Signed-Rank Test for the expectation formation

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# Short Curriculum Vitae

**Doctoral Student at Bielefeld University**

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**Master Student at University of Bamberg**

2008-2010

**Bachelor Student at University of Bamberg**

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**Customer Advisor at Sparkasse Hochsauerland**

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**Bank Apprentice at Sparkasse Hochsauerland**

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**Military Service**

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**High School Graduate at Geschwister-Scholl Gymnasium Winterberg**

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# Summary

This dissertation deals with the impact of speculative behaviour on output patterns of the real economy. The impact may be twofold. Speculative behaviour occurs due to positive developments at the real economy and optimistic outlooks. Also, speculative behaviour may occur at other markets, like the stock market. We address both, a spill-over effect and the build up of speculation due to economic activity. Therefore, we implement realistic behaviour in an evolutionary framework and use emerging heterogeneity for the impact assessment. Inspired by the dotcom-bubble we focus on technological advancement as possible factor of growing optimism.

In the first part of this thesis we introduce feedback from stock prices into a model of economic growth determined by financing constraints. We focus on three known feedback channels: stock market information for the assessment of creditworthiness, stock market value as determinant in determining bankruptcy of a firm and performance based compensation of the firm management.

The second part introduces financing constraints into an evolutionary framework and tackles determinants of credit supply for their impact on the occurrence of innovation. Those determinants are market based and also behavioural in nature.

The third part provides a more detailed bank behaviour and two industrial sectors competing for credit. Therefore, the third part is a refinement of the second one.

Keywords: Stock Prices, Speculation, Financial Fragility, Innovation, Credit Constraints

# Résumé

Cette thèse parle de l'impact des comportements spéculatifs sur l'économie réelle. Les comportements spéculatifs peuvent avoir deux origins: les développements positifs de l'économie réelle et les perspectives économiques, les marchés financieres comme par exemple les marchés actions. Nous analyserons les deux origines. Par conséquent, nous allons mettre en œvre des comportements réalistes dans un contexte évolutif en utilisant l'hétérogénité grandissante, pour évaluer l'impact des comportements spéculatifs. En se basant sur la bulle dotcom, nous allons nous concenter sur l'avancement technologique comme possible facteur de l'optimisme grandissant.

Dans la première partie de cette thèse nous allons présenter les résultats obtenus via un modèle déterminé par des contraintes de financement, et utilisant les prix des actions. Nous allons nous concentrer sur 3 types de répercussions assez connues: l'information donnée par le marché de l'action en vue de déterminer la solvabilité, la valeur de marché du titre en vue de déterminer la probabilité de banqueroute, et la partie de la rémunération du management qui est adossée sur la performance.

La seconde partie de la thèse parlera les contraintes de financement dans un cadre évolutif et soulignera les déterminants de l'offre de crédit qui impactent la fréquence des innovations. Ces déterminants sont basés sur les données de marché et concernent des aspects comportementaux.

La troisième partie fournit en détail le comportement des banques et de deux secteurs industriels qui se battent pour le crédit. La troisième partie est donc un approfondissement de la seconde.

Mots clefs: Prix des Actions, Spéculation, Fragilité Financière, Innovation, Restrictions du Crédit