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Banking Stability and the Macroeconomy

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Abstract

Turmoil in the banking system triggered some of the most severe crises in decentralized economies. Despite this fact, we have not yet fully understood how banks' activities impact on macroeconomic outcomes. This thesis contributes to a better understanding of the relationship between banking stability and economic welfare. We examine the macroeconomic role of banks conceptually, empirically and analytically. Our results are meant to support policymakers in the optimal design of banking regulation.

In a first part of the thesis, we assess the conceptual and empirical foundations of the macroeconomics of banking. The focus of our survey in Chapter 2 is on the macroeconomic implications of existing research. Our conclusions are twofold. On the one hand, we can reject the hypothesis that financial intermediation by banks is irrelevant for macroeconomic outcomes. On the other hand, existing research on banking does not allow to draw decisive conclusions on the relationship between banking stability and economic welfare.

In our empirical study of bank-credit volatility in Chapter 3, we establish two stylized facts. First, in all countries and almost all historical periods, bank credit is more volatile than aggregate output. Second, we can identify different country-specific volatility regimes over time. In particular, bank credit seems to have been more volatile after the Second World War than before the First World War.

In a second part of the thesis, we investigate the macroeconomic role of banks analytically. We develop a new macroeconomic model with banks in Chapter 4. In its baseline configuration, our general equilibrium model features two production sectors, risk-averse households, and financial intermediation by banks. Banks monitor borrowers in lending and are funded by (outside) equity and deposits. Deposits are guaranteed by the government. In our model, efficient and inefficient equilibria emerge. Imposing minimum capital requirements can eliminate all inefficient equilibria.

Finally, we analyze the nature of equilibria in greater detail and generalize our baseline model in Chapter 5. We conclude that the main results do not critically depend on the assumption of risk-averse preferences and that they are robust to changes in the banks' determination of their capital structure.

Zusammenfassung

Turbulenzen im Bankensystem haben einige der schwerwiegendsten Krisen moderner Marktwirtschaften verursacht. Trotz dieser Tatsache wissen wir nur wenig über den Zusammenhang zwischen der Stabilität des Bankensystems und der gesamtwirtschaftlichen Wohlfahrt. Um diesen Zusammenhang besser zu verstehen, untersuchen wir in der vorliegenden Dissertation die makroökonomische Rolle von Banken konzeptionell, empirisch und analytisch.

In einem ersten Teil werden konzeptionelle und empirische Fragestellungen erörtert. In Kapitel 2 analysieren wir bestehende Forschungsarbeiten aus einer makroökonomischen Perspektive. Dabei können wir die Hypothese der makroökonomischen Irrelevanz von Banken verwerfen. Zudem stellen wir fest, dass die bestehenden ökonomischen Modelle keine definitiven Aussagen über den Zusammenhang zwischen der Stabilität des Bankensystems und der gesamtwirtschaftlichen Wohlfahrt zulassen.

Im Anschluss untersuchen wir in Kapitel 3 verschiedene Zeitreihen zu Bankkrediten. Unsere ökonometrische Analyse lässt zwei Schlussfolgerungen zu. Erstens, in allen untersuchten Ländern und in fast allen historischen Perioden verläuft die Entwicklung von Bankkrediten volatiler als diejenige des Bruttoinlandproduktes. Zweitens können verschiedene historische Volatilitätsregime identifiziert werden. So scheint die Volatilität von Bankkrediten in der Zeit nach dem Zweiten Weltkrieg sowohl im historischen Vergleich als auch in Relation zum Bruttoinlandprodukt besonders hoch zu sein.

In einem zweiten Teil der Dissertation untersuchen wir die volkswirtschaftliche Rolle von Banken analytisch. Dafür entwickeln wir in Kapitel 4 ein allgemeines Gleichgewichtsmodell, welches in seiner Grundform zwei Produktionstechnologien, risikoaverse Haushalte, und Banken beinhaltet. Banken finanzieren sich mit Eigenkapital und Sichteinlagen, welche durch den Staat garantiert werden. In diesem Modell können sowohl effiziente als auch ineffiziente Gleichgewichte auftreten. Wir zeigen, dass Mindestkapitalvorschriften ineffiziente Allokationen verhindern können.

In Kapitel 5 erweitern wir schliesslich unsere Analyse in zwei Richtungen. Zum einen untersuchen wir die unterschiedlichen Gleichgewichte eingehender und analysieren, wie sich diese unter verschiedenen Modellspezifikationen verhalten. Zum anderen zeigen wir, dass die zentralen Resultate des Basismodells robust sind gegenüber alternativen Annahmen zur Kapitalaufnahme von Banken oder den Risikopräferenzen von Haushalten.

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1 Introduction

The Financial Crisis of 2007–08 demonstrated how vulnerable the economic system is to even moderate financial shocks. Problems on the U.S. mortgage market triggered a chain reaction that nearly led to a complete meltdown of the global financial system. Only government intervention at an unprecedented level could prevent a worldwide economic disaster.

Although governments and central banks took decisive action, the economic costs were substantial—both in terms of higher unemployment and increased fiscal expenditures. Empirical studies suggest that banking crises are generally costly, even if not experienced on a global level.[1] Policies that foster financial stability and prevent banking crisis thus promise high returns in terms of welfare. To identify critical policy measures, economists have intensified their research efforts.[2] Nevertheless, there is no agreement yet upon the best measures to prevent further financial crises.

Despite the lack of academic guidance, policy-makers had to react to the increasing political pressure.[3] Many attempts to foster financial stability have focused on tighter bank equity capital requirements (henceforth "capital requirements"). As most research on banking is microeconomic in nature, the impact of such an increase in capital requirements on the macroeconomy is not fully understood yet. The seminal work of Diamond and Dybvig (1983), for instance, had a lasting effect on banking regulation. But the macroeconomic effects of the Financial Crisis of 2007–08 cannot be explained by it.

To devise policies that foster financial stability, we need a new theoretical foundation for the current financial architecture that considers the macroeconomic dimension of banking. A few macroeconomic models have been developed so far that help to understand today's regulatory issues. At the Chair of Macroeconomics: Innovation and Policy, first steps have been undertaken to explore the links between banking and macroeconomic dynamics (Gersbach, 2001; Gersbach and Rochet, 2012a,b). The purpose of this thesis is to take a further step on that research track, which is at the intersection of microeconomic

[1] See, for example, Beck et al. (2006), or Gorton (1988) for an early account.

[2] Soon after the Financial Crisis of 2007–08, economists provided first insights on its causes (see, e.g., Hellwig (2009) or Shin (2009)).

[3] Government-appointed research groups, central banks, and financial market authorities have published recommendations for the redesign of banking regulation (see, for example, Siegenthaler et al. (2010) for Switzerland, or Hellwig et al. (2010) for Germany).

banking theory and macroeconomics.

In particular, we investigate the relationship between banking stability and economic welfare. We define banking stability as the ability of banks to absorb losses incurred on their asset-side activities. Hence, we are primarily concerned with solvency issues, that is, the credit-side of banking. The purpose of our research is to reveal the macroeconomic effects of different bank capital structures. Our results are meant to support policy-makers in the optimal design of banking regulation and of bank capital requirements, in particular. Our analysis is guided by the following five research questions:

1. *What do we already know about the relationship between banking stability and economic welfare?*

2. *How can we integrate banking into a macroeconomic model?*

3. *How does the capital structure of banks affect the allocation of goods and risk in the economy?*

4. *What is the optimal regulation of banks?*

5. *How do changes in macroeconomic fundamentals alter the optimal design of banking regulation?*

These research questions are addressed over the next four chapters, which constitute the main body of the thesis. In Chapters 2 and 3, we review existing research and examine new data on bank credit. In Chapter 4, we present our baseline model, which is generalized and extended in Chapter 5. Chapter 6 concludes. Let us now provide a detailed outline of Chapters 2 to 5.

Banks, Balance Sheets and the Macroeconomy – A Survey (Chapter 2)

In Chapter 2, we review the existing literature on banking and banking regulation from a macroeconomic perspective. In particular, we investigate how banks' activities on both the asset- and the liability-side of their balance sheets are related to macroeconomic outcomes. This chapter directly addresses *Research Question 1: What do we already know about the relationship between banking stability and economic welfare?* Furthermore, it sets the stage for the theoretical analysis of Chapters 4 and 5.

In a first part of our survey, we examine those activities that are defining for banks. Beginning with the asset-side activities, we review analytical models that examine how banks deal with adverse selection and with moral hazard when granting loans. Turning to the liability-side activities, we then discuss how the issuance of bank deposits separates banks from other financial intermediaries. Further, we review the economic functions of bank equity. Bank equity plays a pivotal role in contemporary banking regulation. After reviewing the theoretical literature, we turn to the empirics of banking. We present empirical evidence that underscores the quantitative and the qualitative importance of both bank loans and bank deposits.

In the second part of our survey, we investigate how banks interact with the rest of the economy. We review models that integrate banks and their activities into a macroeconomic setting. In particular, we discuss the different approaches to model the macroeconomic implications of banking. This naturally raises the issue how to regulate banks optimally. Adopting a distinctly macroeconomic perspective, we discuss previous and current regulatory initiatives.

Reviewing both the theoretical and the empirical research on banks and the macroeconomy, we find little support for the *"Irrelevance View of Finance"*. Banks and their activities matter for macroeconomic outcomes. Considering only microeconomic models of banks is not sufficient to design optimal banking regulation: It is necessary to integrate banks in macroeconomic models and to approach banking regulation from a macroeconomic perspective. We take up these issues in Chapters 4 and 5.

An Empirical Analysis of Bank Credit Volatility (Chapter 3)

As in Chapter 2, the empirical analysis conducted in Chapter 3 is intended to prepare the theoretical analysis of Chapters 4 and 5 by addressing *Research Question 1: What do we already know about the relationship between banking stability and economic welfare?* Building on two different datasets, we investigate the volatility of bank credit in a broad sample of countries, over a long time period.

We apply the following techniques for our empirical analysis. First, we calculate the descriptive statistics of the growth rates of our time series to get a first impression of the different volatilities. Second, we apply the band-pass filter developed by Christiano and Fitzgerald (2003) to analyze the cyclical component of our bank credit variable. Third, we derive the rolling standard deviation of the growth rates over the whole time period. Finally, we compute the volatility of GDP and bank credit for specific historical periods, and compare credit volatility to output volatility within each period.

We are able to establish two stylized facts:

- In all countries and for almost all historical periods, bank credit is more volatile than output.

- The relationship between output and bank credit volatility is not stable over time. After the Second World War, bank credit volatility was particularly high—both relative to output volatility and to historical credit volatility.

A macroeconomic model featuring banks should replicate this behavior of bank credit, especially the first point. Indeed, the first stylized fact is also present in the model that we develop in Chapter 4: Bank credit fluctuates more than aggregate output.

Banking in General Equilibrium: Baseline Model (Chapter 4)

Having assessed the conceptual and empirical foundations of the macroeconomics of banking, we tackle the setup of a new macroeconomic model with banks in Chapter 4. We aim to answer *Research Question 2: How can we integrate banking into a macroeconomic model?* We also address *Research Questions 3: How does the capital structure of banks affect the allocation of goods and risk in the economy?* In addition, we provide a tentative answer to *Research Questions 4: What is the optimal regulation of banks?*

To investigate the role of banks' capital structure within a macroeconomic model, the Modigliani-Miller Theorem is a natural starting point. The well-known result of Modigliani and Miller (1958) states that—under a set of stringent assumptions—the capital structure of a firm does not affect its value. In particular, changes in the capital structure only redistribute the total risk of the assets between different claim holders (e.g., equity and debt holders).

A large body of research investigates whether from the investor's or manager's perspective, some capital structures are preferred to others if the underlying assumptions are relaxed. For a macroeconomic model, we have to adopt a welfare perspective. In that case, it is of particular interest if frictions and distortions that are present in the context of banking can alter the result of Modigliani-Miller, that is, if they justify government intervention in the form of higher capital requirements. We consider the validity of a macroeconomic version of the Modigliani-Miller Theorem under the presence of the following financial friction and two distortions:

- There is moral hazard in financing productive projects.
- Bank debt is guaranteed by the government (e.g. deposit insurance, lender-of-last-resort policies).
- If banks default, bailouts are financed by taxes.

Since we want to compare the results with Pareto-efficient allocations that occur in a frictionless economy, we make more stringent assumptions about the two distortions. First, we assume that banks can eliminate moral hazard completely and at zero costs. Second, bailouts are financed with lump-sum taxes.

We set up a two-period general equilibrium model. There is a continuum of risk-averse households, and two technologies are available for real investments, one of which is burdened with moral hazard and features uncertain returns. The presence of moral hazard motivates the intermediation of funds by banks. Banks are funded by debt and equity. Bank debt is guaranteed by the government, and bailouts are financed through taxes.

In our macroeconomic model, two classes of equilibria emerge. If banks' debt-equity ratio is below a certain threshold, the capital structures of banks turn out to be irrelevant. In this class of equilibria, banks invest the socially optimal amount in the risky technology and the first-best allocation obtains. If banks' debt-equity ratio is too high, however, a second class of equilibria emerges, all of which are inefficient. Banks raise too much funds and over-invest in the risky technology. Default and government bailouts happen with positive probability.

Hence, above a critical debt-equity ratio, aggregate investment decisions are not Pareto-efficient. The inefficient equilibria can be avoided by imposing minimum capital requirements. Finally, we show that Pareto efficiency could also be guaranteed by forcing failing banks into bankruptcy when bankruptcy costs are zero.

Banking in General Equilibrium: Extensions and Generalizations (Chapter 5)

Chapter 5 extends the previous analysis and tackles *Research Question 5: How do changes in macroeconomic fundamentals alter the optimal design of banking regulation?* The chapter is divided into three sections.

In the first section, we investigate the nature of equilibria identified in Chapter 4 in detail. We find that in a banking economy, it is possible for highly inefficient equilibria to arise. Furthermore, we find that equilibrium values react intuitively to changes in parameter values. Both increasing risk aversion and higher macroeconomic risk—defined as a lower return in the bad state—reduces investment in the risky technology.

In the second section, we obtain further insights in the determination of banks' capital structure. We model two different ways for banks to issue their liability claims. First, we let banks issue equity and debt sequentially. In this case, all equilibria from Chapter 4 are replicated if we assume a suitable tie-breaking rule. Second, we investigate whether an individual bank has, *ceteris paribus*, any incentive to deviate from an equilibrium capital structure. If banks issue their liability claims simultaneously, efficient and inefficient equilibria still arise. The efficient equilibrium, however, is unique.

In the third section, we generalize our baseline model from Chapter 4 by abandoning our assumption of risk-averse households. Assuming risk-neutral preferences, we establish the existence of a unique equilibrium in the frictionless economy. Further, we show that both inefficient and efficient equilibria arise in the case with financial intermediation by banks. Hence, our results from Chapter 4 do not depend on the assumption of risk aversion.

2 Banks, Balance-Sheets and the Macroeconomy: A Survey

2.1 Introduction

This survey on banks and the macroeoconomy sets the stage for the latter chapters. It is expressly restricted to a macroeconomic perspective on the theoretical concepts and the empirical facts related to the banks' balance sheets. As such, we will not review research on behavioral finance, on alternative forms of banking such as structured finance, or on financial development and growth.[1]

The first part of this survey is structured along the two sides of banks' balance sheets: the asset and the liability side. With regard to the theoretical model presented in Chapter 3, we find this approach particularly helpful. The second part of the survey adopts a holistic perspective on the balance sheets of banks and their relation to the macroeconomy.

Based on the reviewed literature and on empirical facts, we were able to draw two conclusions. First, the hypothesis that financial intermediation is just a veil and not relevant for macroeconomic outcomes—the *Irrelevance View of Finance*—can be rejected. Both theoretical models and empirical data indicate that financial intermediation, particularly by banks, is highly relevant. How banks operate impacts economic outcomes significantly, and it is important to analyze the relationship between banks and the macroeconomy further.

Second, and related to the first result, banking regulation should be addressed from a macroeconomic perspective. One key challenge for the next decade will be to overhaul the existing microeconomic banking regulation, whose primary goal is the stability of the individual bank. Some recent policy efforts have already taken a macroeconomic stance. However, if only single macroprudential rules are added to an otherwise unchanged regulatory framework, such policies might not suffice; a comprehensive re-design of the entire framework is necessary.

This survey is structured as follows. In Section 2.2, basic concepts are introduced. In

[1] For surveys on banking and financial intermediation that follow a different approach, see Bhattacharya and Thakor (1993), Gorton and Winton (2003), Greenbaum and Thakor (2007), Freixas and Rochet (2008), or Brunnermeier et al. (2012).

Sections 2.3 and 2.4, we present theoretical concepts and key empirical facts related to both sides of banks' balance sheets. In Section 2.5, we review the research that embeds banks into macroeconomic models, and present macroeconomic data related to banking. We discuss current banking regulation emphasizing a macroeconomic perspective in Section 2.6. Section 2.7 concludes. The Appendix contains additional figures.

2.2 Financial Markets, Financial Intermediation, and Banks

Let us start with a definition of *financial market*. We shall define financial market in a broad way as the marketplace where financial claims are traded. This definition bases on Pilbeam (2010), who refers to the financial market as *"[...] a generic term describing a marketplace for the buying and selling of financial securities/assets such as equities, bonds, foreign exchange and derivative instruments"* (p. 30).

As we will see, there are various reasons why for some financial claims, there might not exist a financial market. Such situations can give rise to *financial intermediaries*. Financial intermediaries can be defined as institutions that channel financial assets from suppliers to demanders. Again, our definition is rather broad and follows Pilbeam (2010). Another narrower definition, by Greenbaum and Thakor (2007), stresses the parallels to intermediaries in other industries. They define financial intermediaries as *"[...] entities that intermediate between providers and users of financial capital"* (p. 43).

Having clarified the terms financial market and financial intermediary, let us next turn to *banks*. Banks form a subset of the more general group of financial intermediaries. According to Gorton and Winton (2003, p.434f), banks borrow from one and lend to another large group of economic agents, and the financial claims created in this process have different state-contingent payoffs. The last point is particularly important, as we will see. Freixas and Rochet (2008) give the definition that most regulators use: *"[...] a bank is an institution whose current operations consist in granting loans and receiving deposits from the public"* (p. 1).

Receiving deposits from the public is the activity that distinguishes banks from other financial intermediaries.[2] Banks not only supplement incomplete markets with activities on the asset side of their balance sheet—as other financial intermediaries do—but also by issuing *"information-insensitive debt"* (Gorton et al., 2012, p. 1), such as deposits. Bank deposits are special insofar that they can be withdrawn anytime and that their value

[2] Another important feature is the illiquidity of bank loans. Traditionally, they could not be resold on a market as would be the case for other financial securities. Recent technological advances, however, have weakened this argument (cf. securitization or peer-to-peer lending.

does not depend on a given state of nature. They differ from loans granted by banks in two important characteristics: loans are usually long-term debt and they carry significant default risk. Consequently, the state-contingent characteristics of a banks' financial assets differ significantly from those of its liabilities.

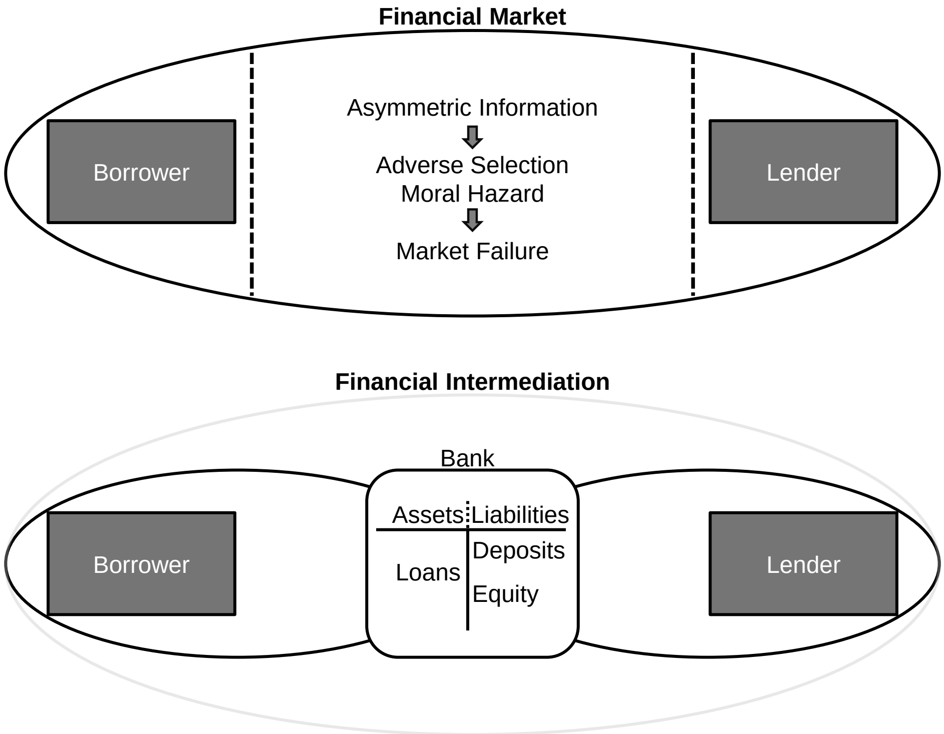

Figure 2.1: Financial market and financial intermediation. *Source:* Own illustration.

Figure 2.1 depicts the concepts we have introduced above and illustrates the relationship between banks, borrowers and lenders. While the functions that banks perform on their liability side separates banks from other financial intermediaries, let us take a closer look at the asset side first.

2.3 The Asset Side

In this and the next section, we focus on the individual bank and its balance sheet. As such, the research presented is primarily microeconomic in nature. Before we can adopt a macroeconomic perspective, we need to establish the microfoundations of the economic unit under investigation, that is, the bank. Both sections that follow are divided into a theoretical and an empirical part. First, we review the theoretical literature that analyzes banks' activities on the asset side of their balance sheet. These activities mainly consist of granting loans to businesses and households. Second, we investigate whether these intermediation services are relevant in practice. To do this, we will look at balance sheets in both the financial and the non-financial sector of the economy.

Before we discuss the asset-side activities of banks, some remarks are in order. First, recall that the offering of credit is not specific to banks. It could be taken over by other financial intermediaries. Banks are set apart from other financial intermediaries by their liabilities. Yet, the economic functions they perform with asset-side activities are a key ingredient to their business. Second, observe that this strand of the literature was less prolific in recent years; the theoretical literature reviewed is thus older than in subsequent sections.

2.3.1 Loans

While defining financial intermediaries and banks, one might asks why there is need for such intermediation, that is, why lenders cannot contract with borrowers directly. As Hellwig (1991) stresses, *"[. . .] in principle, intermediated finance has one disadvantage: the chain of transactions between the firm and the final investor is longer, and ceteris paribus, an increase in the length of the chain of transactions may be taken to entail an increase in transactions costs"* (p. 42). Consequently, financial intermediation could only be justified if the channeling of funds from lenders to borrowers featured a certain transaction cost structure. Such a situation is given if financial intermediation is subject to economies of scales or of scope, an argument that was particularly important in the earlier literature.[3]

More recently, economic research has stressed the fact that the relationship between borrower and lender is characterized by *information asymmetries*. This gives rise to problems known as *adverse selection* and *moral hazard* which ultimately lead to market failure (cf. Figure 2.1). As such, we can broadly distinguish two classes of models: one class focuses on adverse selection and the other one primarily considers moral hazard.

Adverse Selection

Some of the banking models that include an adverse-selection friction can be interpreted as the information-economics update of the old models that were solely based on transaction costs. Information asymmetries giving rise to adverse selection can motivate financial intermediation by economies of scale in information processing, as suggested by Leland and Pyle (1977). Campbell and Kracaw (1980) provide one of the first corresponding models. In their model, economic agents can invest in two types of firms. One type has a higher value than the other one. This information, however, is not publicly observable.

[3] See, for example, Benston and Smith (1976) or Baltensperger (1980).

There are information producers who can reveal the firms' true type at a certain cost. As prices will reveal the true type instantly, only firms—and not investors—can be expected to pay for the information producers' services.[4] There is no moral hazard on behalf of firms; they cannot alter their own value. Hence, information producers only mitigate adverse selection.[5]

In a similar model by Allen (1990), intermediaries can reap more from their production of information. Broecker (1990) provides a model in which banks overcome adverse selection problems by applying credit-worthiness tests. Boyd and Prescott (1986) refrain from modeling banks' activities to overcome adverse selection. They set up a model in which financial intermediaries are simply considered as a mechanism for the truthful revelation of agents' types. As their model implicitly assumes a particular liability structure of the financial intermediaries, we postpone its discussion to the next section.

In models where financial intermediation addresses adverse selection, the firms' investment decisions are not altered by the financial intermediaries' activities.[6] This is a fundamental difference to models emphasizing the role of financial intermediaries in dealing with moral hazard. While, ultimately, financial intermediation is rendered necessary by informational asymmetries, financial intermediaries have an impact on firms' behavior in this case. Let us now turn to these models.

Moral Hazard

In all banking models that motivate financial intermediation by moral hazard of borrowers, banks are assumed to be able to mitigate this moral hazard through various measures. In the economic literature, these measures are often called *monitoring* (see, e.g., Hellwig (1991)).

Chan (1983) was among the first who explicitly modeled how financial intermediation can induce entrepreneurs to chose a superior project, that is, how financial intermediaries can influence the behavior of firms. In his model, entrepreneurs chose their project's quality, which is unobserved to outside investors (so-called "hidden action"). Costly monitoring of entrepreneurs can make the quality observable. This, in turn, gives rise to financial intermediaries, as they can economize on monitoring costs.

The feasibility of intermediation is not explicitly modeled in Chan (1983). This is where the analysis of Diamond (1984) sets in. Diamond explicitly tackles the feasibility of financial intermediation, also known as the problem of *monitoring the monitor*.[7]

[4] The seminal paper on the issue of information revealed by prices is Grossman and Stiglitz (1980).

[5] Note, however, that this setup opens up the possibility of moral hazard of information producers. In Campbell and Kracaw (1980), this problem—known as the *"reliability problem"* (cf. Hirshleifer (1971))—can be solved if information producers are able to invest enough of their own funds.

[6] Nevertheless, moral hazard on behalf of the financial intermediary might arise in these models, see above.

[7] Note that contrary to Chan (1983), entrepreneurs cannot affect the outcome of their project, but can deliberately report a lower return. Hence, in the model of Diamond, moral hazard does not materialize as

Diamond's fundamental result is that this problem can be solved by diversification if the returns of entrepreneurs' projects are independently distributed.[8]

Holmstrom and Tirole (1997) model the double moral hazard problem mentioned above explicitly. In their model, entrepreneurs can chose between different projects to implement. If they chose a project with a low probability of success, they obtain a private benefit. This gives rise to the first moral hazard problem, which financial intermediaries can solve by monitoring entrepreneurs. The second moral hazard problem arises due to intermediation, as monitoring is costly and unobservable. Therefore, financial intermediaries have to invest some of their own endowment for monitoring to be incentive-compatible. The financial intermediary can be interpreted either as a provider for certification for investments—similar to current rating agencies—or as a bank whose capital structure consists of inside equity and deposits. We will come back to this point in the next section.

All of the presented papers so far adopt a static perspective on monitoring by banks. Another strand of research intends to shed light on dynamic effects regarding the relationship between banks and their borrowers. Haubrich (1989) was among the first who investigated monitoring as an ongoing process and highlighted the benefits from repeated interaction between borrowers and banks. Sharpe (1990) discussed problems that might arise from an ongoing relationship. He shows how banks are able to extract information rents from borrowers, which in turn impairs the efficient allocation of capital. Hence, in Sharpe's model, the dynamic relationship between banks and borrowers gives rise to moral hazard on behalf of the bank. Finally, Gorton and Kahn (2000) add a moral hazard problem to borrowers' behavior to enrich the model by Sharpe. Gorton and Kahn particularly consider other financial debt contracts in their model. In their analysis, the banks' ability to renegotiate loans is of particular importance.[9]

2.3.2 Key Empirical Facts

We have encountered various theoretical models motivating financial intermediation by banks. These models all provide a microfounded explanation for the asset-side activities of banks, and for bank loans in particular. To assess the empirical importance of banks in the economy, we cannot look at banks only. Their economic role must be deduced from the economic agents they connect with their intermediation services. Hence, before we analyze the banks' balance sheets, we must take a closer look at the balance sheets of corporate borrowers.

"hidden action" but as *"costly state verification"* (cf. Townsend (1979)). See Gale and Hellwig (1985) for the derivation of the optimal contract—a standard debt contract—in this situation.

[8] Krasa and Villamil (1992) extend the model of Diamond (1984) by relaxing the assumption of full diversification.

[9] Cf. the literature on incomplete contracts Hart and Moore (1988, 1994).

Bank Loans Matter

One can highlight either qualitative or quantitative aspects when investigating the relevance of bank financing.

Qualitative Role of Bank Loans

Research that analyzes qualitative aspects of bank loans focuses on the issue whether bank loans differ from other sources of financing. All of the above reviewed literature assigns a special part to banks and their services, such as monitoring, for instance. Fama (1985) and James (1987) were among the first to highlight and investigate the special role of bank loans empirically. Early research identified a positive effect on firms' stock price after the announcement of new bank credit. Further, a large negative effect on stock prices was discovered if bank loans were repaid by issuing public debt.

Lummer and McConnell (1989), Best and Zhang (1993), and Billett et al. (1995) refined the analysis of James (1987) by distinguishing different forms of loan announcements. Their findings, however, did not challenge the fact that bank loans are different from other sources of debt financing. James and Smith (2000) reviewed the existing literature and concluded that the commitment feature (e.g. credit lines) of bank loans is particularly important, not only for small companies but also for larger ones.

Fields et al. (2006) and Billett et al. (2006) question the above findings. However, their empirical studies are challenged by Lee and Sharpe (2009), who use a new monitoring proxy and find an economically small but positive effect of loan announcements on the market value of borrowers. In a similar spirit, Ross (2010) shows that the effect of a loan announcement on the stock price of a firm is larger if the loan is granted by one of the three largest U.S. banks.

While the effect of bank loan announcements is still a controversial issue, there seems to be a consensus that bank loans differ from other forms of debt financing. Hadlock and James (2002) investigate empirically whether firms prefer loans to public debt securities. They show that bank loans enable undervalued firms in particular to obtain financing (cf. our discussion of a *"credit crunch"* in Section 2.5).[10]

Quantitative Role of Bank Loans

To investigate the quantitative relevance of bank loans, we shift our focus to the financing of non-financial firms, notably, to their capital structure. The financing of firms belongs to the theory of corporate finance. Under the stringent assumptions of the Modigliani-Miller Theorem (Modigliani and Miller, 1958), the capital structure is irrelevant; the decision

[10] Research that investigates the effect of a long-term relationship between a borrower and one single bank is closely connected to this strand of literature (see Hoshi et al. (1991) for Japan; Elsas and Krahnen (1998) and Elsas and Krahnen (2003) for Germany); Foglia et al. (1998) and D'Auria et al. (1999) for Italy.

how to finance corporate activity does not matter. In reality, however, these assumptions seem to be too rigid. The presence of agency costs has inspired much research—both theoretical and empirical in nature—on the determinants of firms' capital structure.[11]

To analyze empirically the capital structure of firms, two approaches are possible. One can chose either macro- or micro-data. We give a short overview of the virtues and vices of both approaches.[12] On the one hand, we can use macro-data, such as, readily available national accounts data. These data capture all economic activities and, thus, provide a comprehensive account of sectoral balance sheets. However, although there exist international conventions—the so-called System of National Accounts SNA (2010)—defining how to collect and report national accounts data, many countries deviate from them. Hence, an international comparison can be problematic.

On the other hand, one can use micro-data, which is collected at the level of the individual firm or household. The advantage of such datasets is that they are built bottom-up. The resulting granular character of the data allows to tackle more research questions. However, there are also drawbacks. A first one is a lack of availability; if data exist, they are often proprietary, with gated access only. A second drawback is that the data of different countries cannot be readily compared due to different accounting regimes. In the following two sections, we will examine research that has opted for one of these two empirical approaches.

Although our focus is on (static) balance sheet structures, let us start with an early assessment of Mayer (1990) who investigates the flows of finance, namely, the issue how real investments are financed. Mayer uses national accounts data, which are macro-data. A well-known result of his research is that retentions—that is, internal financing—account for the largest part of companies' funding.

Let us mention some less-known findings of Mayer (1990) that are of particular relevance for our purpose. First, securities markets are of minor relevance, while bank finance dominates in all countries examined (see Figure 2.2). Second, bank finance is much more important for small- and medium-sized companies than for large companies. Later studies by Corbett and Jenkinson (1996, 1997) by and large confirmed Mayer's findings.[13]

We next turn to the empirical study undertaken by Rajan and Zingales (1995). They

[11] For an early account, see e.g. Jensen and Meckling (1976). A seminal paper on the incentive motivation of capital structures is Dewatripont and Tirole (1994). For an overview on the literature on corporate finance in general, see de Matos (2001) or Tirole (2006).

[12] For an extensive discussion, the reader is referred to Mayer (1990), Corbett and Jenkinson (1996), or Hackethal and Schmidt (2004). The latter source provides us with the most extensive discussion of this issue, and also compares data on net and gross flows from financing instruments.

[13] Hackethal and Schmidt (2004) took issue with these results. They claim that the financial systems of countries can be classified either as bank-oriented or as market-oriented. Nevertheless, as their results still imply a rather prominent role of bank financing compared to market financing (except for the U.S.) when considering external funds, we will not discuss their results in greater detail.

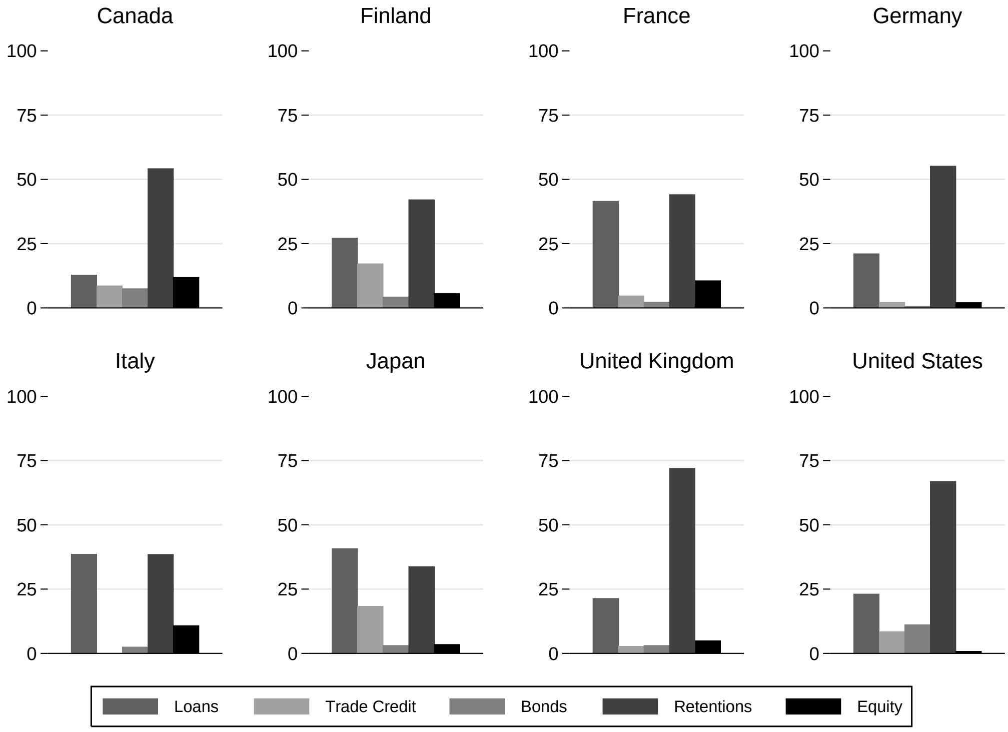

Figure 2.2: Unweighted average gross financing of non-financial enterprises, 1970-1985. *Source:* Mayer (1990), Table 12.3. *Note:* All numbers are percentages of total financing flows. The Category "Securities" contains the original series 'Bonds' and 'Short-term securities'. The original series 'Capital transfers', 'Other', and 'Statistical adjustment' are not depicted. The fact that trade credit is large and positive is due to the unconsolidated nature of the data. Looking at net financing, trade credit is rather low or even negative.

use the accounting data of more than 2500 non-financial corporations of the G7-countries, that is, micro-data. Hence, while Mayer (1990) investigate the composition of financing flows, Rajan and Zingales analyze stocks. Figure 2.3 shows the average liability side of the balance sheet of non-financial corporations in 1991, using data from Rajan and Zingales.

Rajan and Zingales (1995) are interested in the determinants of the capital structure—leverage, in particular. They distinguish between short-term debt, long-term debt and equity. They do, however, not explicitly investigate the importance of bank finance versus market finance. The reason why we present their findings here is because they use firm-level data. We can infer from their data that the general proportions of the different balance sheet positions on the liability side are consistently similar, regardless whether we use national accounts data or firm-level data (see first column in Figure 2.4).

Next, let us look at the latest numbers from national accounts data to assess whether there was a significant change over the past twenty years. Figure 2.4 takes up the sample

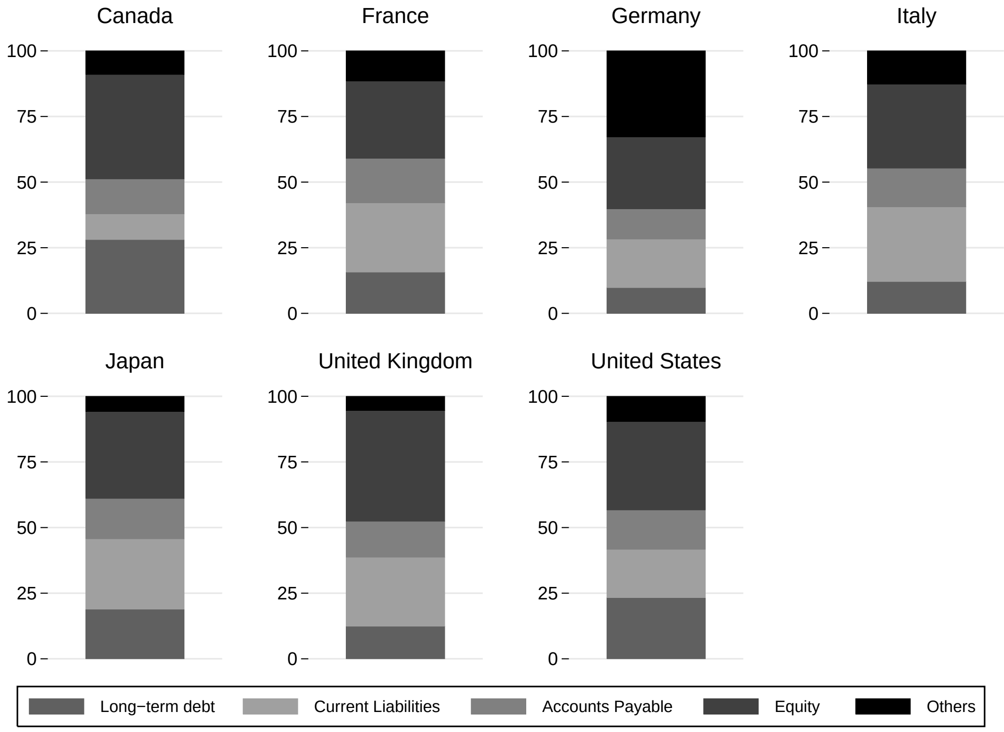

Figure 2.3: Liability side of non-financial firms' balance sheets in the G7 countries, using firm-level data. *Source:* Rajan and Zingales (1995), Table II. *Note:* All numbers are percentages of total liabilities. The category "Current Liabilities" contains the original series 'Current Liabilities—Total' minus 'Account Payable/Creditors'; the category "Others" contains the original series 'Deferred Taxes', 'Minority Interest', 'Reserves—Untaxed' and 'Liabilities—Other'.

used by Rajan and Zingales (1995) and shows the structure of the liability sides of firms since 1995.

We can conclude that the debt-equity structure of non-financial firms has not changed dramatically over the last few years. The broad proportions of non-financial firm's capital structure are still rather similar to those uncovered by Rajan and Zingales (1995). Hence, it seems save to use national account data to investigate the quantitative relevance of loans for corporate finance. In Appendix A, we provide an overview over the capital structure for a large sample of countries, using national accounts data (Figures A.1 and A.2). We see that equity and loans are the two largest positions on the liability side of non-financial firms' balance sheets around the globe. Compared to loans, securities only play a marginal role.

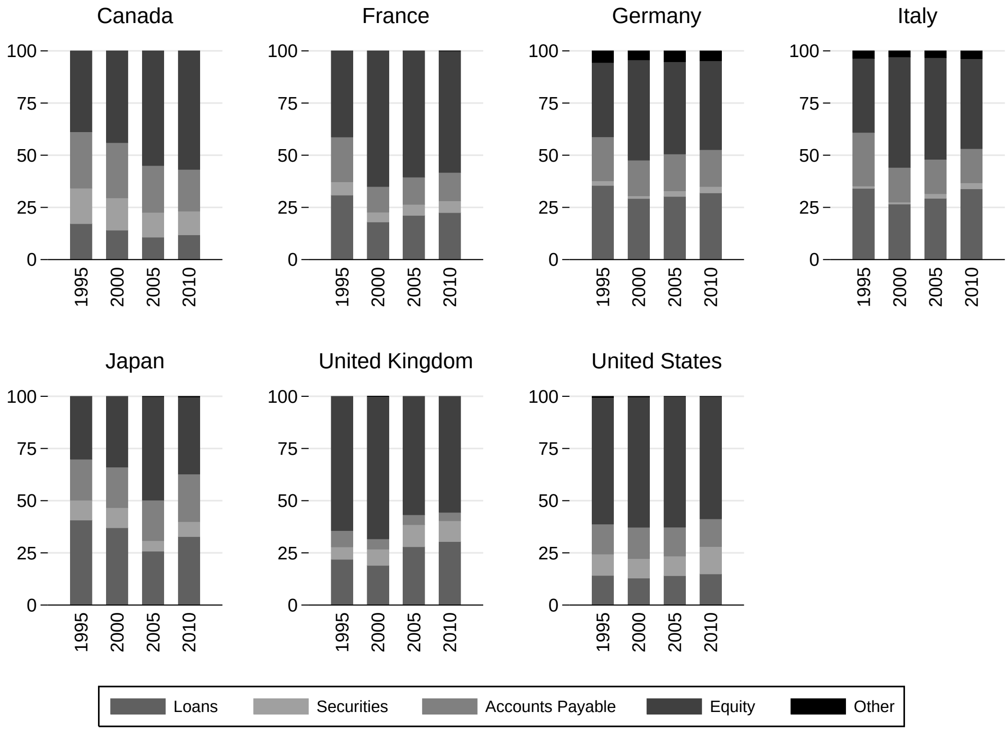

Figure 2.4: Liability side of non-financial firms' balance sheets in the G7 countries, using national accounts data. *Source:* OECD (2010b). *Note:* All numbers are percentages of total liabilities. We use the annual series of non-consolidated stocks for non-financial corporations (OECD code: S11). The category "Others" contains 'Currency and deposits', 'Mutual funds shares', and 'Insurance technical reserves' (OECD codes: SAF2LINC, SAF52LINC, SAF6LINC).

The Asset Structure of Banks

In the last two sections, we have explored the importance of loans, that is, the financial intermediation services that banks perform on the asset side of their balance sheet. Let us now turn to the banks themselves. Figure 2.5 provides an overview over the average balance sheet of banks in the sample of countries analyzed in Mayer (1990).[14] In Appendix A, we provide the same information for a larger sample of countries (Figures A.3 and A.4). We can conclude that in most countries, loans account for about half of all assets and liabilities, respectively.

After this analysis of the asset side of banks' balance sheets, let us now turn to the liability side.

[14] These are the G7 countries, plus Finland. There are no data available for the U.K.

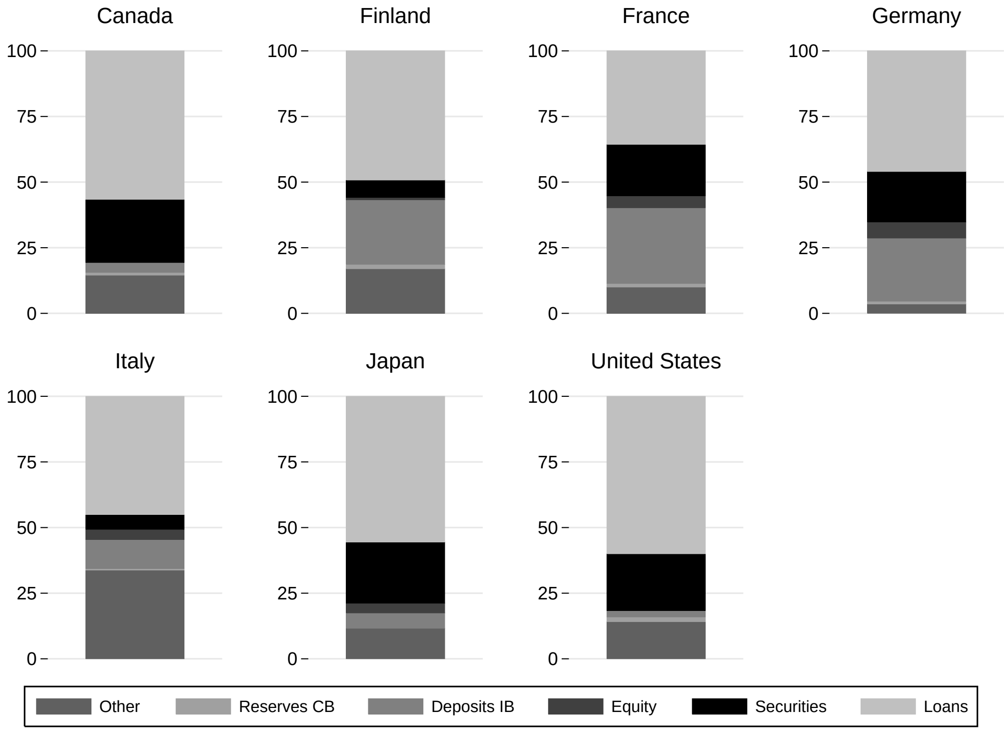

Figure 2.5: The asset side of banks' balance sheets in 2004. *Source:* OECD (2010a). *Note:* All numbers are percentages. "CB" stands for Central Bank and "IB" for Interbank. "Other" is original series 18, "Reserves CB" is 14, "Deposits IB" is 15, "Equity" is 29, "Securities" is 17 minus 29, "Loans" is 16.

2.4 The Liability Side

We have discussed various reasons why borrowers and lenders would not—or could not—contract directly, and have to resort to services provided by financial intermediaries. While rationalizing financial intermediation in general, these reasons do not motivate financial intermediation by banks. Other financial intermediaries could manage transaction costs or problems arising from information asymmetries. For instance, rating agencies could deal with information asymmetries as well. However, banks, as defined in Section 2.2, are a prominent feature of modern economies. Why is this so? To answer this question, we have to shift our focus to the liability side of banks' balance sheets, namely, to deposits.

2.4.1 Deposits

By offering deposit contracts, banks provide the public with unique services such as liquidity and means of payment. Bryant (1980) and Diamond and Dybvig (1983) were among the first to stress the important properties of bank deposits. Both models are real models without any role for money. Hence, we will not follow the standard approach of the economics literature, which interprets the function of banks in these models as *"liquidity insurance"*. Instead, we follow Gorton and Winton (2003, p. 448-453), who call this function *"consumption smoothing"*.

The Bryant-Diamond-Dybvig model has been highly influential both in research and in economic policy. One reason for the prominence of this model was the insight it provides on bank runs (see Section 2.6 below). Note that the so-called sequential service constraint, which states that there is a "first-come, first-served policy" regarding withdrawing depositors, is a crucial assumption for these models (see Wallace (1988, 1990)). One serious drawback of the Bryant-Diamond-Dybvig model is that it does not allow the co-existence of banks and financial markets (see Jacklin (1987) and Haubrich and King (1990) for an early account). As soon as we introduce markets, bank deposits no longer enable consumption smoothing.[15] In a second paper, Diamond (1997) took up this criticism, showing that the initial result can be partly reestablished if not all agents can participate in the market.

In the 1990s, economic research started to study the payment functions provided by bank deposits. Gorton and Winton (2003) identified three different strands in this literature. First, there are models that emphasize the advantages of the clearinghouse function of banks (see, e.g, Freeman (1996) or Green (1999)). Proponents of the so-called new monetarist school have developed analytical models in which bank deposits feature as a medium of exchange. In these models, bank deposits allow the clearing of payments.[16]

Second, Gorton and Pennacchi (1990), and more recently, Gorton (2010) and Dang et al. (2012), emphasize the *"information insensitiveness"* of bank deposits and how this feature allows uninformed agents to trade with such debt contracts without losing money to informed agents. He and Krishnamurthy (2008) even take one further step and omit activities on the asset side of banks' balance sheets. They focus entirely on the money characteristic of bank deposits and an economic equilibria where both cash and deposits can be used as media of exchange.

Third, Holmstrom and Tirole (1998) analyze the usefulness of liquidity for firms rather than households. A paper by Kashyap et al. (2002) is related to this view emphasizing banks' liquidity provision for firms.[17] They claim that there are economies of scope in the provision of liquidity. As long as the use of credit lines by firms and the withdrawals

[15] Hellwig (1994) and von Thadden (1998) show analytically how liquidity provision by banks can be constrained by financial markets, which open up possibilities for arbitrage.

[16] See, e.g., Andolfatto and Nosal (2003), He et al. (2005), or Wright et al. (2009) for models, in which bank deposits that are used for payments arise endogenously.

[17] See also Gatev and Strahan (2006) who investigate other synergies of the liquidity provision of banks.

of depositors are not perfectly correlated, there arises an opportunity to allocate a given amount of liquidity more efficiently within banks. In a similar spirit, Mester et al. (2007) find that deposit accounts held by borrowing firms are a useful tool for bank monitoring, the reason being that banks can read off financial transactions easily from the respective firm accounts.

No matter whether we prefer the notion of liquidity insurance promoted by Bryant (1980) and Diamond and Dybvig (1983) or by Gorton and Winton (2003), one of the key distinguishing characteristic of banks is based on the liability side of their balance sheet. Banks enable the financing of long-term projects in an economy, without households having to give up liquidity or to collect costly information. Note that this benefit comes at a cost; banks carry significant liquidity risk (see, e.g., Greenbaum and Thakor (2007, p. 151-157), which can result in panics. We will come back to this point further on.

To conclude our discussion of bank deposits, observe that the problems related to the fragility of banks have motivated a last strand of research: short-term debt as a commitment device. Models that analyze the disciplining effect of short-term debt and the resulting fragility of banks are provided by Qi (1998), and Diamond and Rajan (2001a,b).[18] Note that the opaqueness of banks is a crucial ingredient of these models, a feature that is analyzed in Dang et al. (2013).

2.4.2 Equity

As we have seen, bank loans and deposits are special. They play an important role in the economy due to their unique characteristics. Bank equity, on the other hand, is mostly considered to be important for banking regulation. Nevertheless, there exists research on bank equity that is detached from regulatory considerations. In the appendix to his paper on bank runs, Diamond (1984) extends the model of Leland and Pyle (1977). He concludes that while banks will raise much debt, they will be financed by little equity, a capital structure that can be found in the data (see Figure 2.5 above). Due to diversification, bank debt will feature low risk nevertheless in the model of Leland and Pyle.

Winton (1995) sets up a model of banks and bank capital in which two measures can alleviate the problem of monitoring the monitor: diversification (as in Diamond (1984)) and bank equity. The latter acts as a buffer for depositors against losses. Since bank equity is taken as fixed, a trade-off arises between the two measures when it comes to choosing

[18] For other models emphasizing the incentive role of short-term debt financing, see Calomiris and Kahn (1991) or Flannery (1994). Calomiris and Kahn (1991) state that their research was meant to shed light on the historical development of deposit contracts and that *"[i]n today's more regulated environment, [. . .] where deposit insurance makes depositor monitoring less important, demandable debt may persist simply as an artifact of regulation"* (p. 510). Nevertheless, their research was criticized fiercely by Admati and Hellwig (2013b) recently.

the optimal size of a bank. Note that in this model, bank equity becomes more important relative to diversification the more the credit risks of loans are correlated, that is, the more systemic risk is present in an economy.

Let us next revert to Holmstrom and Tirole (1997), who provided a model featuring a prominent role for bank equity. In their model, both entrepreneurs and bankers are constrained by their level of (inside) equity, that is, their net worth. This is due to two sources of moral hazard: one at the level of firms and one at the level of banks (see above). Since equity—in the form of initial capital endowment—helps to alleviate two forms of moral hazard, the model of Holmstrom and Tirole allows to analyze how economic outcomes are affected if the distribution of capital in the economy is altered. The fact that bankers need equity as a commitment device because monitoring is privately costly is important. The bankers invest their own endowment in the projects monitored by them, aligning their incentives with those of their creditors and making monitoring credible.[19]

Contrary to Holmstrom and Tirole (1997), in whose model bank equity mitigates moral hazard, Diamond and Rajan (2000) emphasize the role of bank equity for banks' liquidity provision (see our discussion of Diamond and Rajan (2001b) above). Non-verifiable—an hence non-contractible—uncertainty gives rise to inefficient bank runs. In such a situation, bank equity can act as a buffer against fundamental shocks to asset values. However, bank equity lowers the liquidity creation by banks and, in turn, lowers the bankers' ability to channel resources to entrepreneurs. In the model of Diamond and Rajan, an optimal level of bank equity arises endogenously. This has important consequences for externally imposed capital regulation, a point to which we come back in Section 2.6.

Inderst and Mueller (2008) provide a model in which the optimal level of bank equity is determined differently than in Diamond and Rajan. Banks choose a particular level of equity, such that their choice of credit extension coincides with the socially optimal one. In this model, a bank that is financed by equity only or that is restricted by tight capital requirements will take too little risk. There will be no excessive risk-taking, but excessive risk-avoidance. Nevertheless, note that—as the authors mention—banks do not take the socially optimal level of risk if there are government guarantees, e.g. deposit insurance.

Allen et al. (2011) provide a model in which bank monitoring positively affects the firms' expected payoffs. Hence, there are two ways to incentivize banks to monitor: high interest rates for loans or a positive equity level. As loan markets are assumed to be perfectly competitive, the banks' leeway in setting loan rates is restricted. In turn, bank equity is used as a tool to induce banks to monitor. Moreover, note that a positive amount of bank equity reduces the premium claimed by the debt holder, giving the bank access

[19] While the model by Holmstrom and Tirole is static, Chen (2001) provides a dynamic version of the same mechanisms.

to cheaper funding. Hence, bank equity takes effect through both an asset and a liability channel. Based on their model, Allen et al. conclude that the socially optimal level of bank equity is actually lower than the one arising in unfettered markets.

Mehran and Thakor (2011) set up a dynamic model to assess how the level of bank equity affects firm value. They identify different costs and benefits of bank equity. The costs of bank equity are modeled explicitly as an increasing and convex function of the total amount of equity. The benefits of bank equity arise endogenously. There is a direct and an indirect effect. The direct effect is very much in the spirit of Holmstrom and Tirole (1997) and Allen et al. (2011): more equity increases the banks' survival probability, and thus increases the value of monitoring activities. Hence, banks will monitor more. The indirect effect arises from the dynamic nature of the model. Namely, more monitoring leads to a better loan portfolio. Mehran and Thakor test their model by using M&A data. Their results supports the key prediction of the model: total bank value is increasing in bank equity.

2.4.3 Key Empirical Facts

As with the asset side of banks' balance sheets, we cannot focus on banks only, but we also need to investigate the role of banks liabilities for other economic agents. Hence, in this section, we focus on the role of bank deposits for households, the ultimate providers of financial funds.

Bank Deposits Matter

As for bank loans in Section 2.3.2, can distinguish a quantitative and a qualitative dimension when analyzing deposits.

Qualitative Role of Bank Deposits

The central question is whether bank deposits are somehow considered to be "special". One feature of bank deposits is especially important for our model in Chapter 4: bank deposits should be seen as risk-free. Unfortunately, the questionnaire used by the ECB for their household survey does not allow to examine this. In the U.S. Survey of Consumer Finances, however, households were asked to indicate the most important reason for choosing a particular institution for their main checking account. Less than 4% considered safety and absence of risk to be a prime concern (Bricker et al., 2012, p. 33). While various factors can cause this result, it is certainly compatible with the fact that most people believe deposits are safe anyway.

Quantitative Role of Bank Deposits

Let us now consider the quantitative importance of deposits. We have seen that firms use bank finance heavily. The other part of financial intermediation by banks deals with households' savings. How important are banks for households? To assess this, we analyze the asset side of households' balance sheets and their financial assets in particular. Again, we can use either micro-data from household surveys or macro-data from national accounts.[20]

Figure 2.6 gives an overview over the households' financial assets in the sample of countries presented by Mayer (1990) using national accounts data. In Appendix A, the financial asset structure of households can be found for a larger set of countries (Figures A.5 and A.6). We see that bank deposits play a significant role in all countries observed. In general, households hold 25 to 50% of their financial assets in the form of deposits. At the lower end we find the U.S., where deposits account for about 12% of total assets only.[21]

Let us next turn to survey data. We have not analyzed the original micro-data, which are partially confidential in nature, and have reverted to aggregated data provided by Bricker et al. (2012) for the U.S., and the Eurosystem Household Finance and Consumption Network (2013b) for the EU.

Before we turn to the proportions of different financial assets on households' balance sheets, let us have a look at the prevalence of deposits. More than 92% of all households in the United States own at least one deposit (Bricker et al., 2012, p. 24). In the European Union, this figure is even higher and reaches 96% (Eurosystem Household Finance and Consumption Network, 2013b, p. 36). Clearly, deposits have become a financial necessity for most people, as they are a prerequisite for many modern forms of payment.

Figures 2.7 and 2.8 illustrates that people do not just hold deposits for transaction purposes, but also invest a significant part of their savings in deposits. While the share of deposits on total financial assets is generally a bit higher if the data is drawn from survey data, the numbers are still in line with our earlier findings, which were derived from national accounts data. Namely, deposits account for 25 to 50% of all financial assets in most countries, with the exception of households in the United States.

[20] See Honkkila and Kavonius (2012) for a discussion of these two approaches regarding household's balance sheets.

[21] At the upper end, there are the Slovak Republic and Greece with a share of deposits on total financial assets that amounts to almost 75% in 1995 and 2010, respectively (see Figures A.5 and A.6 in Appendix A). While we did not investigate these two outliers any further, one explanation for them might be the major economic turmoils these countries were experiencing at that time (the disintegration of the Soviet Union and the unfolding European sovereign debt crisis).

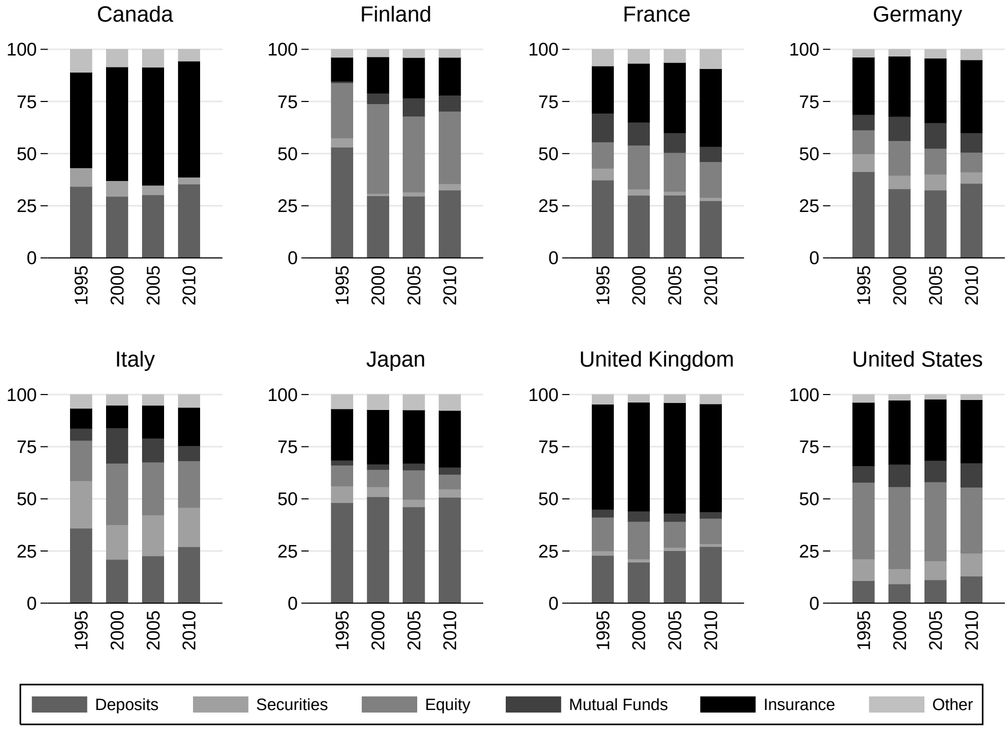

Figure 2.6: Financial assets of households, using national accounts data. *Source:* OECD (2010b). *Note:* All numbers are percentages of total financial assets. We use the annual series of non-consolidated stocks for households and non-profit institutions serving households (OECD code: S14_S15). The category "Other" contains 'Currency', 'Loans', 'Other accounts receivable', and 'Monetary gold and SDRs' (OECD codes: SAF21ASNC, SAF4ASNC, SAF7ASNC, SAF1ASNC).

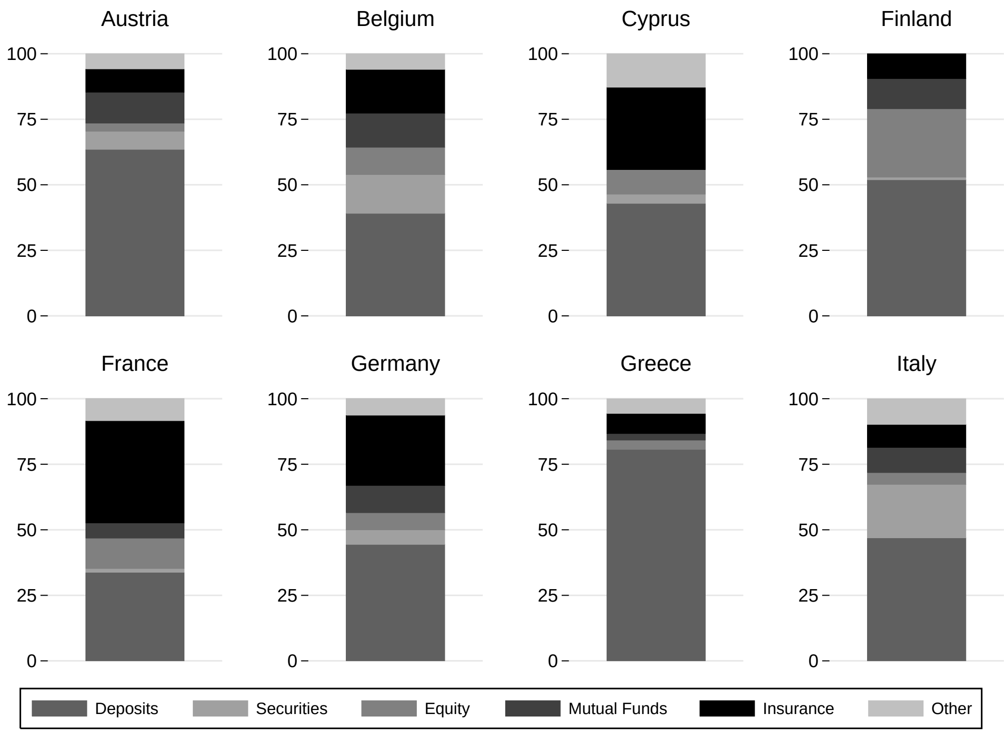

Figure 2.7: Financial assets of households, using survey data. *Source:* Bricker et al. (2012) for the United States. Eurosystem Household Finance and Consumption Network (2013b) for all other countries.
Note: All numbers are percentages of total financial assets. For the U.S., "Deposits" contains 'Transaction accounts' and 'Certificates of deposit', "Securities" contains 'Savings bonds' and 'Bonds', "Equity" contains 'Stocks', "Mutual Funds" contains 'Pooled investment funds', "Insurance" contains 'Retirement accounts' and 'Cash value life insurance', "Other" contains 'Other managed assets' and 'Other'. For the EU, "Securities" contains 'Bonds',"Equity" contains 'Shares', "Insurance" contains 'Voluntary Private Pensions/ Whole Life Insurance', "Other" contains 'Money owed to household' and 'Other Financial Assets' (in case of missing or not reported data, "Other" was determined as the residual). While most EU countries conducted data collection in 2010, some started as early as 2008 and others as late as 2011 (see Eurosystem Household Finance and Consumption Network (2013a, p. 8)).

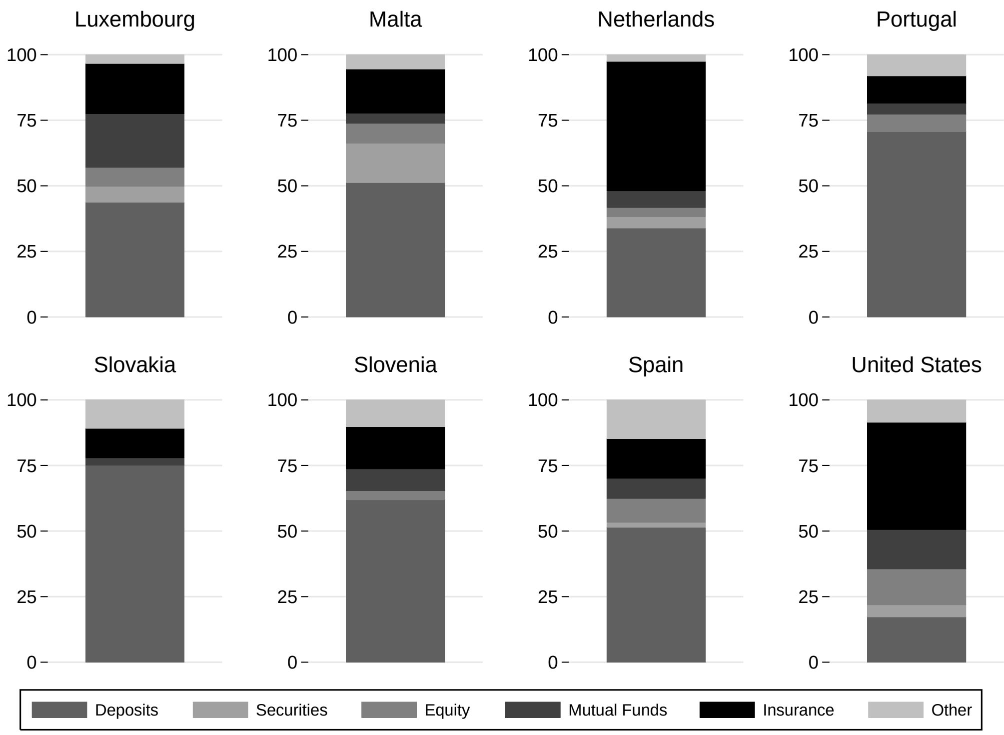

Figure 2.8: Financial assets of households, using survey data. *Source and Note:* See Figure 2.7.

The Capital Structure of Banks

After the asset side of banks' balance sheets has been presented in Figure 2.5, we now turn to the liability side. Again, we present data on the G7 countries plus Finland (the original sample of Mayer (1990)) in the main text and provide supplementary figures showing the situation in a large sample of countries in Appendix A (Figures A.7 and A.8). Observe that the liability side of banks generally differs from the one of non-financial companies. Deposits are an important source of funding and debt-equity ratios are high. They seem particularly high compared to those of non-financial firms (cf. Figures 2.3 and 2.4).

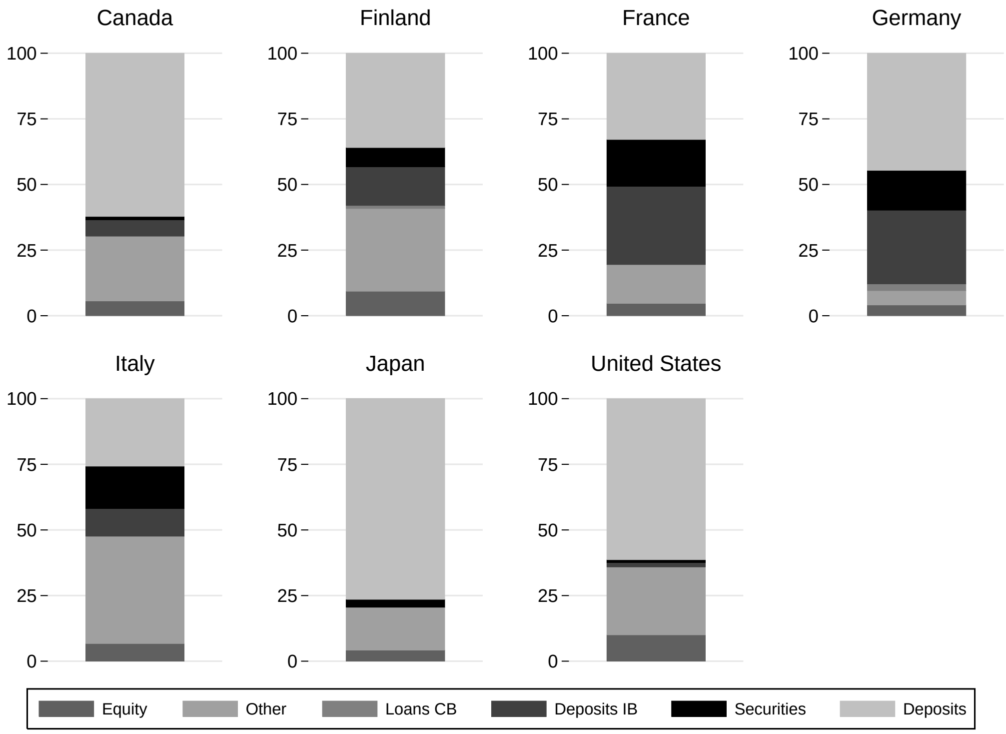

Figure 2.9: The liability side of banks' balance sheets in 2004. *Source:* OECD (2010a). *Note:* All numbers are percentages. "CB" stands for Central Bank and "IB" for Interbank. "Equity" is original series 19, "Other" is 24, "Loans CB" is 20, "Deposits IB" is 21, "Securities" is 23, "Deposits" is 22.

That banks are predominantly funded by debt is a recent development, as we can see in Figure 2.10. More than 150 years ago, the equity levels of banks much resembled those of other firms. One reason for this development was the spread of government guarantees for bank debt, through lender of last resort policies or through the introduction of deposit insurance schemes. We will discuss these issues in greater detail in Section 2.6.[22]

[22] Note that Flannery and Rangan (2008) identify a rapid increase in bank equity ratios during the 1990ties, using market value of bank equity. They attribute this increase to higher asset volatility.

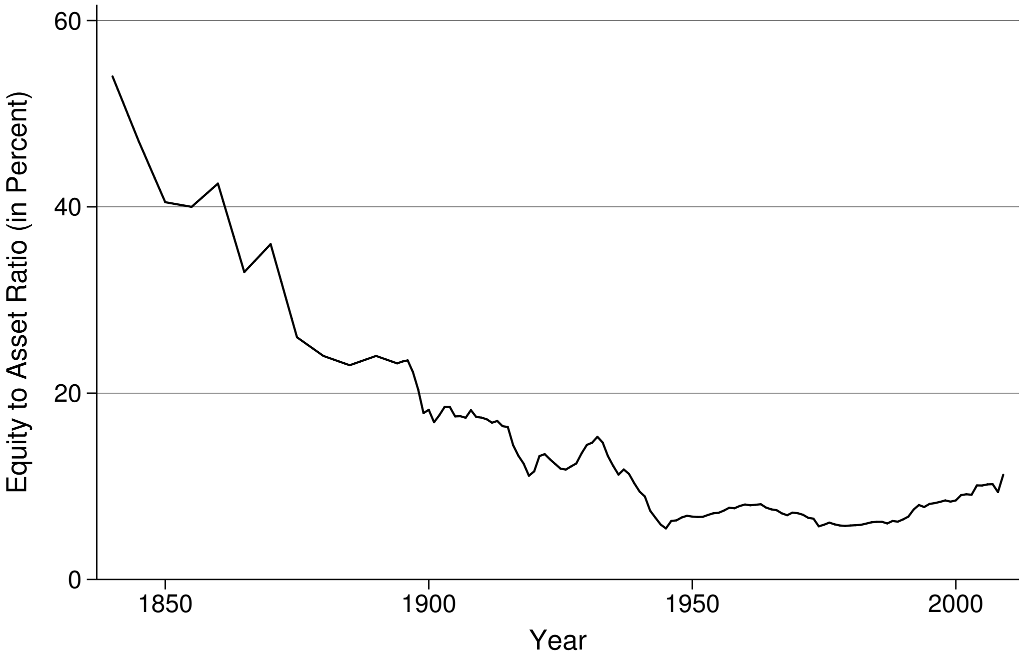

Figure 2.10: Long-term trend of the bank equity ratio. *Source:* Hanson et al. (2011).

2.5 Banks and the Macroeoconomy

In the last two sections, we have presented both the most important theoretical foundations for banks and key empirical facts regarding the qualitative and quantitative importance of bank services. While these theoretical and empirical considerations strongly suggest that banks are an important feature of modern economies, we have not examined the macroeconomic role of banks yet. We will now present research investigating the relationship between banks and the macroeconomy.

Before we start, note that the irrelevance result of Modigliani and Miller (1958) strongly influenced the setup of macroeconomic models. In its most abstract and basic form, banking can be understood as the activity of issuing debt and equity in order to grant loans. Consequently, Fama (1980) argued that activities on both sides of a bank's balance sheet fall under the irrelevance result. Furthermore, the huge success of the monetary explanation of the Great Depression put forward by Friedman and Schwartz (1963) has also overshadowed explanations based on banking factors. For a long time, financial intermediation by banks was treated as a "veil" in macroeconomic models.[23]

[23] The three workhorses of macroeconomics—real-business cycles, neoclassical growth theory and the New-Keynesian model—do not incorporate financial intermediation in their standard text-book versions. As a result, financial intermediation is usually treated only cursory in first–year macroeconomic courses, while monetary policy issues are discussed at length.

Notwithstanding the general view, some economists have conducted a lot of research on the influence of financial factors on macroeconomic outcomes. In particular, some economic historians stressed the importance of banking and currency crises (see, e.g., Kindleberger (1978)). Furthermore, Minsky (1977, 1984, 1986) never endorsed the irrelevance view of finance, and emphasized the importance of the underlying financial system for business cycles. Since then, and in the 1980ties in particular, financial factors have become more and more prominent in macroeconomic research.

In this section, we will not be able to organize our presentation along the individual items of banks' balance sheets (cf. Sections 2.3 and 2.4). This is clear, since as soon as we approach banking from a macroeconomic perspective, we have to view the bank's balance sheet as a holistic concept. In the economy, savings enter the liability side and are channeled via loans, which are held on the asset side, toward productive uses. Instead of using the banks' balance sheets as organizing principle, we will structure the theoretical part of this section along the three main modeling strategies. First, one can include financial frictions in a macroeconomic model. Second, banks can be explicitly modeled in a small-scale general equilibrium model. Third, existing dynamic stochastic general equilibrium (henceforth DSGE) models can be augmented with a financial sector. Most of the current research effort is put into the second and third modeling approach.

2.5.1 Financial Frictions

In the 1980ties, a series of research papers was published that challenged the traditional monetary explanation of the Great Depression. This work was pioneered by Bernanke (1983), and it marked the starting point for research on the role of credit in modern macroeconomics and on alternative monetary transmission channels.[24] In subsequent work, Bernanke and Gertler (1985) elaborated analytically on how a broken credit intermediation process can push economic activity into a downward spiral. This process is now known as the *Financial Accelerator*.

A fundamental principal-agent problem between borrowers and lenders lies behind all these models featuring such a financial accelerator mechanism. A negative shock decreases the net worth of borrowers and, in turn, lowers their lending capabilities.[25] Lorenzoni (2008) developed a model where both lenders and borrowers suffer under financial frictions. Similar to the older models, this setup with incomplete contracts also gives rise to credit cycles.

Recently, this strand of the literature has been extended by research on leverage cycles,

[24] The underlying idea was, however, not completely new as fifty years earlier, Fisher (1933) identified credit as a key driving force of economic cycles. For a critical re-assessment, see Rockoff (1993).

[25] See the models developed in Bernanke and Gertler (1989, 1990), Bernanke et al. (1996, 1999), and Kiyotaki and Moore (1997).

which has been pioneered by Geanakoplos (2010).[26] In these models, collateralized loans are as important as in the models we just presented. However, the margin is determined endogenously. This is a crucial difference, and it makes the credit cycle potentially more accentuated, as margin requirements get tougher in downturns, making it even harder to obtain credit.

While the literature on the financial accelerator provided much insight into the role of credit in business cycles, it did not address banks explicitly.[27] In a way, one can interpret these models as the early macroeconomic adaptations of the microeconomic models presented in Section 2.3. These models are centered around the relationship between borrowers and lenders. They focus on the asset side of banks' balance sheets.[28] Models that allow a more detailed analysis of banks are a logical extension of such research.

2.5.2 Small-Scale Macroeconomic Models

In an early attempt to set up a general equilibrium model with banks, Bernanke and Gertler (1985) integrate a banking sector in an overlapping generation model. In their model, bank capital plays a pivotal role as it determines the amount of funds intermediated by banks and, in turn, the amount of monitoring-intensive projects implemented in the economy.

Setting up such another small-scale macroeconomic model, Gorton and Winton (2000) find that an increase in bank equity will force households to hold less funds in deposits. This reduces welfare, as it limits the households' ability to insure themselves against liquidity shocks. A similar mechanism is at work in the model of van den Heuvel (2008). In both models, the structure of the liability side of banks' balance sheets affects macroeconomic outcomes.

Goodhart et al. (2006) modify the general equilibrium model of Tsomocos (2003). In the model of Goodhart et al., financial fragility arises in an economy without production but with heterogenous banks. They use their model to evaluate the effects of capital requirements on macroeconomic outcomes. In particular, they investigate the situation in which default becomes an option for a bank, that is, the situation in which capital requirements become binding. Goodhart et al. (2012) further extend this model incorporating a shadow banking sector that is linked to the banking sector via repurchase agreements

[26] See also Fostel and Geanakoplos (2008).

[27] Observe that one could, however, reinterpret the entrepreneurs in these models as bankers and the real technologies as lending technologies.

[28] We have seen in Section 2.4, for instance, that liquidity services are often considered to be the defining feature of banking. The resulting liquidity risks, its materialization in bank panics, and the effects on the macroeconomy have inspired much research (see, e.g., Gorton (1988), Calomiris and Gorton (1991), Allen and Gale (1998) or Diamond and Rajan (2005)). These considerations have, however, not found their way into the financial accelerator literature.

(repos). This allows to analyze regulatory policies that are aimed at preventing fire sales in currently unregulated parts of the financial system, e.g., margin requirements for repos.

In the model by Korinek (2011), there are two generations of households and bankers. The bankers are financially constrained, similar as borrowers in Kiyotaki and Moore (1997). Bankers can insure against the risk of becoming financially constrained, using complete financial markets. However, since households are assumed to be risk-averse, such insurance is costly and introduces a trade-off. In an unregulated decentralized equilibrium, too little insurance is taken, and shocks are amplified through fire sales.

Gersbach and Rochet (2012a,b) model moral hazard on behalf of banks within a three-period general equilibrium model. Banks face aggregate shocks and can trade their capital on complete markets. Due to moral hazard, banks are constrained in raising debt by the amount of their (inside) equity. Hence, the capital structure features a prominent role in this model. It turns out that this setup gives rise to credit cycles, meaning that capital is traded excessively, and banks are lending too much in good times and too little in downturns. The same effect is present in the decentralized version of the model by Bianchi and Mendoza (2011), who stress the importance of asset prices in explaining credit cycles.

2.5.3 DSGE Models

Some economists incorporated banking and financial frictions in fully-fledged DSGE models.[29] This approach usually comes at the cost of tractability, which makes calibration and the use of numerical methods necessary. Moreover, nominal rigidities such as price or wage stickiness are a defining criterion of such Neo-Keynesian models.[30]

Aikman and Paustian (2006) examine how optimal monetary policy should be adapted if a financial sector is included in a DSGE model. Their model features a moral hazard problem, which is modeled in the spirit of Holmstrom and Tirole (1997). Hence, the bank lending channel causes second-round effects via the balance sheets of both borrowers and banks. In turn, Aikman and Paustian are able to model a trade-off of monetary policy between the volatility of inflation and output. They conclude that the optimal monetary policy remains inflation-oriented as in a standard DSGE. According to Aikman and Paustian, this common policy should not be extended by including asset prices or credit growth.

Angeloni and Faia (2009) also augment a standard DSGE model with financial intermediation by banks. In contrast to Aikman and Paustian (2006), they put more emphasis on liquidity aspects, as they model banks in the spirit of Diamond and Rajan (2000, 2001b). Hence, they shift emphasis along the liability side of banks' balance sheets from bank

[29] See Christiano et al. (2005) or Smets and Wouters (2007) for the canonical baseline model.
[30] All of the models reviewed below feature price stickiness only.

equity to bank deposits. They conclude that, if bank leverage increases, the optimal mix of bank regulation and monetary policy would consist of a combination of countercyclical capital requirements and raising interest rates.

The model of Christiano et al. (2010) features banks with two asset positions, loans and liquidity reserves. While these banks provide deposits, bank equity does not play a role. Differing from the model by Aikman and Paustian (2006), only the equity level of entrepreneurs gives rise to a standard financial accelerator effect, meaning that a shock features second-round effects via decreased collateral value. This standard financial accelerator effect is augmented in the model of Christiano et al. by a debt deflation effect. Changes in the price level alter the real burden of nominal debt contracts. Furthermore, there is a bank funding channel that operates via the provision of liquidity services to households and firms.

While Christiano et al. (2010) and Angeloni and Faia (2009) all emphasize the role of bank deposits, Meh and Moran (2010) follow the approach of Aikman and Paustian (2006) and implement the double moral hazard setup of Holmstrom and Tirole (1997), which is centered around equity. Meh and Moran examine how the bank capital channel works. They confirm the earlier result that the presence of a bank lending channel exacerbates shocks. Yet, the effect on the credit cycle is determined by the nature of the initial shock. Demand shocks are amplified less than supply shocks. Furthermore, Meh and Moran establish that the higher the initial bank capital, the less pronounced the credit cycles. This, in turn, suggests that shocks that decrease bank capital can indirectly impact output volatility.

Finally, Bianchi (2011) quantifies the macroeconomic effects that are due to a financial accelerator within a DSGE model with financial intermediation. He calibrates his model with Argentinian data and finds that the effects of endogenous credit cycles are severe. A financial crisis is more than ten times more likely in the decentralized economy than in the constrained efficient social planer outcome. Bianchi proposes different policy measures such as taxes on debt, for example, to avoid the inefficient credit cycles that are present in the decentralized economy.

2.5.4 Key Empirical Facts

Let us next turn to some key empirical facts regarding banks and the macroeconomy. First, we will present the three main positions on banks' balance sheets—equity, deposits, and loans—in relation to key macroeconomic figures. Second, we will review empirical research on credit cycles, which are suggested to be intimately related to the structure of banks' balance sheets.

Banks' Balance Sheets and the Macroeconomy

We have already depicted the secular trend of bank equity relative to GDP in Figure 2.10. In Figure 2.11, we show the ratio of deposits to GDP and its historical development for the G7 countries. Again, we provide the same information for a broader sample of countries in Appendix A (Figure A.9). It seems that this ratio and its tendency depend on country-specific factors. For example, we can identify a decline of deposits over GDP in the U.S., starting after the Great Depression, while in Canada we can see an increase.

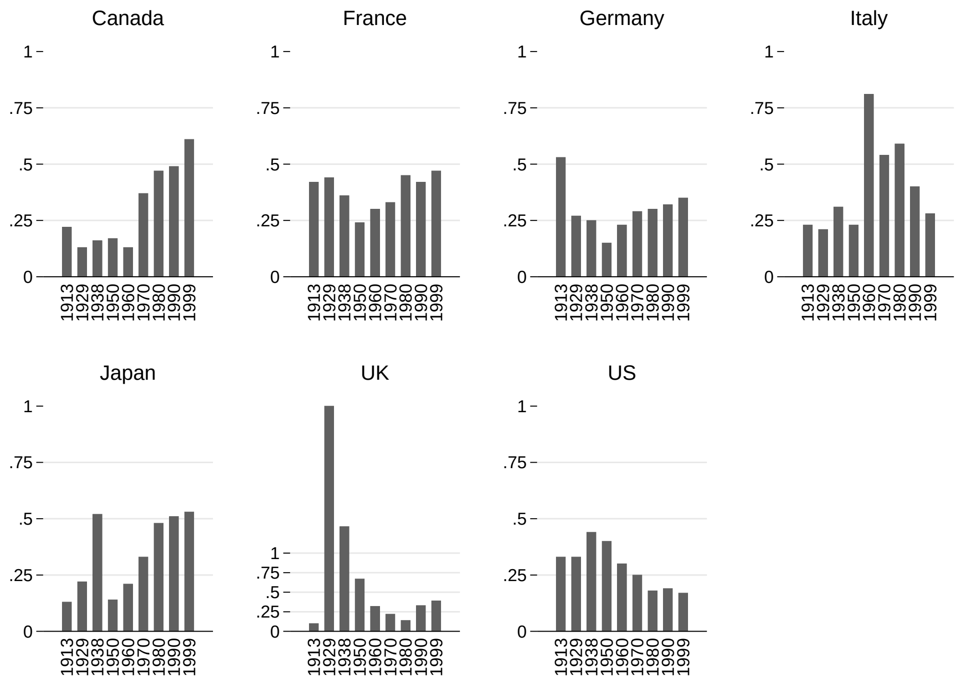

Figure 2.11: Ratio of deposits to GDP from 1913 to 1999. *Source:* Rajan and Zingales (2003).

We also depicted loans over GDP in Figure 2.12. The marked increase over the last fifty years is striking. For an extended empirical analysis of bank loans and their relationship to key macroeconomic variables, the reader is referred to Schularick and Taylor (2012) and Chapter 2 of this thesis.

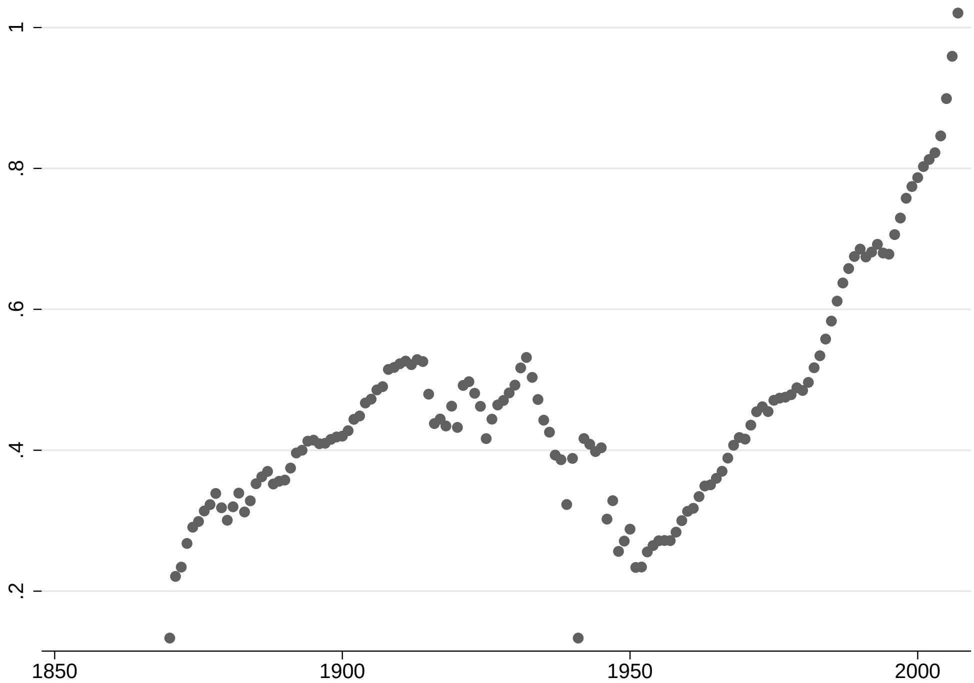

Figure 2.12: Aggregate ratio of bank loans to GDP. *Source:* Schularick and Taylor (2012).

Credit Crunches and Credit Cycles

Theoretical research on the financial accelerator suggests that we can observe distinct credit cycles in the economy. The central research question is: Does credit feature any cyclical pattern that can be put into relation to other macroeconomic fluctuations? There is overwhelming empirical evidence that this is the case.

Before the onset of the Great Recession, the relationship between credit and economic output was primarily a topic in development economics. This is not surprising since various Asian, South American and Central American crises were widely discussed. Kaminsky and Reinhart (1999), for example, find a self-enforcing cycle between banking and currency crisis, with a key role of bank credit fueling economic booms. Mendoza and Terrones (2008) investigate the effect of credit booms on key macro- and microeconomic figures. They also find a clear procyclical pattern of credit and output. Furthermore, their analysis indicates that fluctuations seem to be less severe and persisting in developed economies than in emerging economies. This could be seen as an indicator that moral hazard problems are stronger in underdeveloped financial systems, and tend to enforce some sort of a financial accelerator.

As mentioned, the focus of the empirical literature has shifted away from emerging towards developed economies in recent years. Borio et al. (2001) provide some results regarding the procyclicality of credit and, in particular, of bank provisions.[31] Claessens et al. (2009) investigate the relationship between business and financial cycles for a sample of OECD countries. They find that recessions are more severe if they coincide with a sharp decrease in lending, that is, a so-called *"credit crunch"*. In a second study, Claessens et al. (2012), mostly confirm their earlier findings, using a larger sample of countries.

Finally, Jordà et al. (2011) substantiate the results of Claessens et al. (2009, 2012), using long-term data ranging as far back as the late 19th century. Recessions that have been preceded by credit booms have generally turned out to be much more severe than "non-financial" recessions.[32] Using the same data, Schularick and Taylor (2012) take a further step and investigate the usefulness of credit variables to predict crises. They conclude that while in earlier times, money indicators have featured much predictive power, credit aggregates seem to fare better recently.

The empirical research discussed up to now investigated credit cycles in general. By this, we mean that financial frictions in general can be responsible for the fluctuations in credit and output. Recalling the balance sheet structure of banks, we next review empirical studies that consider bank equity in particular as well as its effect on credit supply. In a way, we narrow our view to the effect of bank equity on lending, and do no longer consider credit conditions in general.

The theoretical models of Aikman and Paustian (2006) and Meh and Moran (2010) suggest that shocks to bank equity capital—potentially through losses on bank assets—severely lowers bank lending. This effect, often called *Credit Crunch* has been investigated extensively in the empirical literature. Bernanke and Lown (1991) analyze whether capital-constrained banks have caused the strong decrease in lending during the 1990 recession. They find that while the effect of a shortage of bank credit is statistically significant, it cannot account for the drop in lending due to its economic size. Investigating other funding sources (e.g. commercial paper), Bernanke and Lown conclude that credit demand-side factors have been more important than a supply-side credit crunch.

Hancock and Wilcox (1998) investigate the credit crunch during the same period as Bernanke and Lown (1991). They find that small banks especially react to a decrease in their own equity by reducing their loans. Interestingly, banks that are not equity-constrained partially react to the "individual" capital crunch emanating from small banks by expanding their supply of credit. Using Italian data, Gambacorta and Mistrulli (2004) find that equity-constrained banks react strongly to adverse macroeconomic shocks by contracting their credit supply. They conclude that bank capital is indeed an important factor for total lending, and as such has macroeconomic consequences.

[31] Procyclicality of bank provisions for loan losses means that they are lowest in booms and highest in downturns.

[32] For an earlier assessment using shorter time series data, see Borio and Drehmann (2009).

Investigating whether a shock to bank equity—due to unexpectedly high losses,for example—can lead to a decrease of bank lending has yielded mixed research results. While it is likely that there is such an effect, its size seems to be small. This result has far-reaching policy implications and one must bear it in mind when regulating banks.

2.6 Regulating the Capital Structure of Banks – A Macroeconomic Perspective

Recall that this survey is intentionally restricted to the banks' balance sheets and the banks' macroeconomic role. Hence, our view on banking regulation is necessarily limited in two important aspects. First, we only consider bank regulation that directly affects the banks' balance sheets. Second, we adopt a distinct macroeconomic perspective on the different regulatory policies and neglect microeconomic issues.[33] Note also that we do not further elaborate on that strand in the literature that emphasizes the over-regulation of banks and advocates *"free banking"* (e.g. Selgin (1994), or Dowd (1999)).

This section is organized along the historical development of banking regulation. This is due to the *ad hoc* nature of banking regulation. In most cases, banking regulation was not the result of academic research, but the immediate reaction of policy-makers to a crisis. In the words of Goodhart (2010): *"Financial regulation has always been a-theoretical, a pragmatic response by practical officials, and concerned politicians, to immediate problems [. . .]"* (p. 165). Hence, we choose a chronological structure. Liquidity risk gave rise to the regulation of deposits, which again then called for a regulation of equity.[34]

2.6.1 Lender of Last Resort and Deposit Insurance

We have already mentioned that the particular features of bank deposits lead banks to carry significant liquidity risk. Liquidity risk is the fact that depositors' withdrawals could exceed a bank's liquidity reserve. In this case, the bank has to liquidate long-term loans at possibly adverse conditions, thus making a loss. As such, the initial liquidity problem can become a matter of bank solvency. This bank run phenomenon is well-documented.[35]

[33] For a comprehensive introduction to banking regulation, see Greenbaum and Thakor (2007) or Freixas and Rochet (2008). The former identify five different objectives of bank regulation: *competition*, *safety*, *consumer protection*, *credit allocation*, and *monetary control*. The latter classify banking regulation along six dimensions: *deposit insurance*, *capital requirements*, *regulatory supervision*, *restrictions on deposit interest*, *industrial organization*, and *bank portfolios*. For key empirical facts about international bank regulation, see Barth et al. (2013).

[34] For an approach to banking regulation that does not emphasize the historical development, but regulatory theory, see Freixas and Santomero (2002).

[35] See, for an overview, Gorton and Winton (2003, p 494-518).

As described analytically by Bryant (1980) and Diamond and Dybvig (1983), a bank run can give rise to suboptimal equilibria. It is important to note that the different equilibria in the Bryant-Diamond-Dybvig model are *sunspot equilibria*. There is no rationale within their model why one particular equilibrium should arise. There is a large literature that took this issue seriously and provided models in which the arrival of new information—e.g. falling asset prices—can trigger bank panics.[36]

If one starts from the reasoning underlying the models of Bryant, and of Diamond and Dybvig, different policies might help to prevent bank runs—and inefficient equilibria, in turn. Historically well-known is the step-in of a lender of last resort.[37] Rochet and Vives (2004, 2008) provide a new analytical model that includes interbank markets to examine the lender of last resort role. Suspension of convertibility can also be implemented, although this actually violates the deposit contract.[38] Finally, governments can insure deposits; a measure taken first in the U.S. as a reaction to the events of the Great Depression (Federal Deposit Insurance Corporation, 2012). Deposit insurance is a rather attractive policy instrument, as it implies no immediate and direct costs and immediately reduces the threat of bank runs.[39]

The main body of research on deposit insurance is microeconomic in nature. Nevertheless, there is a distinct macroeconomic dimension to deposit insurance and lender of last resort policies. From a macroeconomic perspective, both instruments are especially useful as circuit breakers. Deposit insurance can be motivated from a macroeconomic standpoint either by research on the financial accelerator presented above (see Section 2.5.1) or by research on bank panics (e.g., Gorton (1988) and Calomiris and Gorton (1991)).

While deposit insurance can prevent bank runs and bank crises, it creates moral hazard for the bank managers.[40] Merton (1977) explained that deposit insurance is conceptually equal to a put option issued by the insuring body, that is, the government.[41] A bank hold-

[36] See, e.g., Gorton (1985), Jacklin and Bhattacharya (1988), Allen and Gale (1998), or Goldstein and Pauzner (2005). For supporting empirical evidence, see Rolnick and Weber (1984), Gorton (1988), or Economopoulos (1990).

[37] For an early account, see Thornton (1802) or Bagehot (1873). See Freixas et al. (2000) for an overview of the literature. Freixas et al. (2008) further investigate the particular role of central banks in providing liquidity.

[38] See Wallace (1990) for a model with partial suspension of convertibility.

[39] It is thus no surprise that deposit insurance was implemented in many countries (cf. the international database provided by Demirgüç Kunt et al. (2005)).

[40] Furthermore, recall that there is one line of research that interprets the fragility inherent to banks as a desirable feature necessary to provide liquidity (Diamond and Rajan, 2001a,b, 2012; Calomiris and Kahn, 1991). This line of reasoning has been taken into account in reform proposals such as the Squam Lake Report (French et al., 2010, p. 44). Yet, it also has strong opponents (Admati and Hellwig, 2013a,b). Farhi and Tirole (2012) and Brunnermeier and Oehmke (2013) provide a different rationale why banks fund themselves with a lot of short-term debt. Note that skeptics of current banking regulation acknowledge that in combination with a deposit insurance scheme and a central bank acting as a lender of last resort, government regulation can be justified (cf. Benston and Kaufman (1996)).

[41] See also Kareken and Wallace (1978) or Acharya and Dreyfus (1989). For a different interpretation of

ing such a put option can maximize its value by maximizing the volatility of its returns, that is, by taking more risk. Chan et al. (1992) analyze the problems of fair pricing of deposit insurance if banks can adjust the risk of their asset portfolio.

The value of deposit insurance for a bank is not only affected by the volatility of the bank's assets, but also by the bank's amount of equity. The higher the debt-equity ratio is, the higher the value of the deposit insurance *ceteris paribus* (cf. Buser et al. (1981)). Hence, bank managers have an incentive to increase their debt-equity ratio to maximize their return from government guarantees. There is empirical evidence that this has actually been the case.[42] Capital requirements are a logical regulatory answer to such a development, especially as they can be seen as an integral component of deposit insurance (see Giammarino et al. (1993) or Freixas and Gabillon (1999)).

2.6.2 Capital Requirements

While deposit insurance was introduced in the U.S. as early as in the 1930s (Federal Deposit Insurance Corporation, 2012), explicit bank capital requirements are a relatively recent phenomenon. In the 1980s, an expert group of the G-10 (plus Switzerland and Luxembourg) elaborated the so-called Basel Capital Accord, generally referred to as *Basel I* (see Basel Committee on Banking Supervision (1988)). Basel I was the first international initiative to achieve banking regulation. It was the reaction to the aforementioned secular trend towards declining bank equity levels. Basel I included not only minimum capital requirements for banks but also the concept of risk weights.

The necessity of such risk weights is the logical consequence of the "deposit put option". It was analyzed by Kim and Santomero (1988) and Rochet (1992), among others. Without risk weights, banks have an incentive to hold very risky assets. These risk weight also have become one of the major point of criticism of Basel I. An extensive literature followed its adoption. While some economists have highlighted the problems arising from (sub-)optimal risk-weighting (e.g. Jones and King (1995), Thakor (1996), or Jackson et al. (1999)), others have assessed the portfolio shift of banks (e.g. Berger and Udell (1994), or Furfine (2001)).

Another widely discussed issue arising from the introduction of minimum capital requirements was the migration of banking activities to other, less regulated sectors.[43] After the Financial Crisis of 2007–08, this discussion centered around advances in structured finance such as the securitization, structuring and tranching of loans.[44]

deposit insurance as a trilateral performance bond, see Kane (1995).

[42] See Figure 2.10 in Section 2.3.2 or Greenbaum and Thakor (2007, p. 427-430).

[43] For an early paper indicating the relevance of off-balance sheet items, see Boyd and Gertler (1993, 1994). For a later account, see Jones (2000).

[44] For an overview of the activities of various financial institutions in the so-called *shadow banking* sector,

These concerns regarding Basel I were taken up by policy-makers and regulators. In 2004, the revised Basel Capital Accord, known as *Basel II*, was published by the Basel Committee on Banking Supervision (2004). Basel II rests upon three pillars and is quite comprehensive compared to Basel I.

The first pillar addresses risk-weighted capital requirements, the second deals with the review of these requirements by regulators, and the third proposes complementary measures such as market discipline. Decamps et al. (2004) and Rochet (2004) have analyzed the interaction of the three different pillars within a single model.[45] Like its predecessor, Basel II criticized heavily by academics and practitioners for its various deficiencies; some of the problems were identified even long before the current crisis (see, e.g., Danielsson et al. (2001); Kashyap and Stein (2004)).

Both Basel I and Basel II address capital requirements from a predominantly microeconomic perspective. Capital requirements are meant to mitigate the banks' moral hazard problem, and to foster the stability of the individual institution. Although capital requirements primarily have been motivated by microeconomic research, one can adopt a macroeconomic perspective on this regulatory tool. Capital requirements can be seen as a way to protect the banking system from a system-wide crisis. Higher equity levels across banks can be interpreted as buffers against adverse shocks. There is, however, a lack of theoretical research analyzing this reasoning.

Interestingly, most of the criticism on the Basel Capital Accords stems from the conflicting priorities of different viewpoints, that is, whether one adopts a microeconomic or a macroeconomic perspective. This is best shown in the three fundamental problems of contemporary capital regulation identified by Hellwig (2009, p. 193-197):

(i) The purpose of capital regulation has not been identified and stated yet. Bank equity can be seen as an incentive device to curb risk-taking (see Section 2.4.2) or as a buffer against negative shocks. While the former is an *ex ante* argument for capital requirements, the latter is an *ex post* argument for it. Depending on one's notion of the purpose of bank equity, capital regulation needs to be designed differently.

(ii) Second, capital requirements are mainly focused on the individual bank. Systemic risks are dismissed. The reason for this focus lies in the predominantly microeconomic nature of early banking models. Before the outbreak of the Financial Crisis of 2007–08, the general consensus was that if every single institution is stable, the system as a whole is stable.[46]

see Pozsar et al. (2010). For a discussion of recent trends in securitization, see Gorton and Metrick (2013).

[45] See Calomiris (1999) for a theoretical model in which market discipline—the third pillar—has a containing effect on banks' moral hazard.

[46] The model of Wagner (2010) sheds some light on the links between individual stability and systemic

(iii) Third, the regulatory framework is based on a static view of bank capital. Most models of banks are not only microeconomic in nature but also limited to a static framework.[47]

These problems can yield the roadmap for regulatory reform. Indeed, their identification served as a basis for the recent reform proposals to which we now turn.

2.6.3 Current Debates

While the two previously presented regulatory instruments were addressed from a microeconomic approach, this is not the case for the kind of banking regulation that is currently discussed. The Great Recession has triggered a marked shift from a microeconomic approach of banking regulation towards a macroeconomic one. This change can be recognized in reform proposals elaborated by academic economists (e.g. Brunnermeier et al. (2009), French et al. (2010), or Admati and Hellwig (2013b)), and, to some extent, in the two recent regulatory efforts Basel III and the Dodd-Frank Act.

Basel III and the Dodd-Frank Act

Basel III is not a new regulatory framework, but an updated version of Basel II. While Basel III is still structured along the three pillars introduced in Basel II, liquidity issues are now given more weight.[48] The key novelties are (Basel Committee on Banking Supervision, 2011):

- Higher capital requirements (common equity and Tier 1 Capital must not be below 4.5% and below 6.0% of risk-weighted assets, respectively) (p. 12),
- More emphasis on common equity (p. 12),
- Introduction of a capital conservation (p.54) and countercyclical buffer (p. 57),
- Introduction of a leverage ratio (p. 60).

Basel III is meant to serve as a set of guidelines for policy-makers, it has no legally binding character. It needs to be transposed into each country's national law. Contrary to Basel III, the Dodd-Frank Act is a legislative text. It is the regulatory answer of the United States Congress to the Financial Crisis of 2007–08.

The Dodd-Frank Act has the purpose *"[t]o promote the financial stability of the United States by improving accountability and transparency in the financial system, to end 'too big to fail', to protect the American taxpayer by ending bailouts, to protect consumers*

stability.

[47] For an early theoretical model that incorporates the dynamics of capital regulation, see Blum (1999).

[48] See the additional document provided by the Basel Committee on Banking Supervision (2013).

from abusive financial services practices, [...]" (Frank, 2010, p. 1376). The Act is not only meant to solve the problems of financial institutions and products. It also overhauls the United States' regulatory landscape. It strengthens the role of the Federal Reserve System and introduces new regulatory agencies such as the Financial Stability Oversight Council (FSOC), which is in charge of the monitoring of systemic risk, or the Consumer Financial Protection Bureau (CFPB), which assists the uninformed customers of financial institutions.[49]

Basel III and the Dodd-Frank Act have been heavily criticized, mainly for not adopting a macroeconomic perspective. Let us focus on the Dodd-Frank Act first. Acharya (2012) casually mentions that the Dodd-Frank Act *"[...] certainly has its heart in the right place."* (p.5). Regardless of this rather favorable—if not scientific—first assessment, Acharya identifies some important issues raised by this new regulation.

First, he states that the implicit government guarantees will remain in place and that they will still be mispriced.[50] Wilmarth (2011) expresses a similar concern: the Dodd-Frank Act does not solve the TBTF problem, even though this objective is stated in the preamble of the Act. Second, Acharya (2012) claims that the Dodd-Frank Act is too engaged in regulating institutions and too little engaged in regulating functions.[51] This argument is related to Acharya's argument that the shadow banking sector remains largely untouched by the Dodd-Frank Act.

Like the Dodd-Frank Act, Basel III was criticized heavily. Acharya (2012), for instance, starts his assessment of Basel III with the sentence: *"From a conceptual standpoint, the Basel capital requirements are a flawed macroprudential tool"* (p. 13). He then points out that Basel III still focuses on risk at the level of the individual institution instead of tackling systemic risk. According to Acharya, Basel III lacks a consequent macroeconomic perspective. Moreover, the *"boundary problem"* has not been addressed either; banking activities are expected to be moved into the shadow banking sector. Finally, Acharya blames the procyclicality of the proposed rules. Acharya's criticism is supported by many economists and banking experts. Let us bundle the different criticism of the current regulatory efforts into two groups to examine it: macroprudential regulation and significantly higher capital requirements.

Macroprudential Regulation

Most of the criticism of Basel III and the Dodd-Frank Act centers around the lack of

[49] For more information on the FSOC and the CFPB, see http://www.treasury.gov/initiatives/fsoc/Pages/home.aspx (retrieved October 28, 2013) and http://www.consumerfinance.gov/ (retrieved September 19, 2013).

[50] This view is supported by an empirical study by Malysheva and Walter (2010) who identify an increase of the liabilities guaranteed by the U.S. government.

[51] Goodhart (2008) describes this as the *boundary problem* of financial regulation. See also Goodhart and Lastra (2010) and Appendix A in Brunnermeier et al. (2009).

a macroeconomic perspective. Basel III, in particular, was blamed for focusing too exclusively on the individual bank and for neglecting systemic effects. This is why most academic economists have elaborated alternative policy proposals that focus on macroeconomic issues. Such proposals are often subsumed under the term macroprudential regulation.

"Macroprudential" has become a buzz word in recent debates about banking regulation. This can be interpreted as a pendulum swinging back, since—as we have mentioned repeatedly—most of the earlier banking regulation adopted a microeconomic perspective. That the macroeconomic dimension has been neglected for so long is surprising, even more so as the external effects of banking panics have long been considered as the ultimate cause for all banking regulation (cf. Gorton and Winton (2003)).

It is necessary to distinguish *macroprudential regulation* from a *macroeconomic perspective* on banking regulation. The latter is much more general. As we have seen, even microprudential regulatory instruments can be interpreted from a macroeconomic perspective. Such a perspective does not deal with the individual bank in the first place but emphasizes the macroeconomic effects of banking regulation. In contrast, macroprudential regulation is a more narrow concept and refers to new regulatory tools specifically designed from a macroeconomic perspective.[52]

The call for macroprudential regulation and the issue of procyclical capital requirements are closely related. As early as in the 1990ties, Blum and Hellwig (1995) warned against rigid capital requirements which might exacerbate business cycles. They were among the first to emphasize the macroeconomic consequences of banking regulation. Since then, different models that explain the cyclical behavior of capital regulation have been developed.

Repullo and Suarez (2013) demonstrate in an analytical model that Basel II was more procyclical than Basel I. Further, Repullo and Saurina Salas (2011) show that even the countercyclical capital buffers of Basel III might feature procyclicality. Angelini et al. (2011) find that the dampening effects of the countercyclical capital buffers are small. In contrast, Jiménez et al. (2012) find empirical evidence that the particular countercyclical capital regulation introduced in Spain in 2000 had a dampening effect on economic booms and busts.[53] In many recently published policy papers, countercyclical elements play a crucial role (cf. Turner (2010) or Brunnermeier et al. (2009)).[54]

Nevertheless, macroprudential regulation does not only address the procyclicality of

[52] There is no consensus on the definition of macroprudential regulation yet. See Galati and Moessner (2012) for an overview of the various approaches to such a definition.

[53] For a short discussion of the Spanish countercyclical capital regulation, see Brunnermeier et al. (2009, p. 37).

[54] Note that even without banking regulation, the banks' financial intermediation is considered as procyclical *per se* by many economists (cf. Section 2.5).

capital requirements. There is a variety of tools proposed for macroprudential banking regulation. The International Monetary Fund (2011) offers a comprehensive set of such tools, and classifies them along two dimensions: risk and initial purpose.[55] Interestingly, *"living wills"* of banks (cf. Goodhart (2010)) and the implementation of orderly resolution mechanisms (cf. Avgouleas et al. (2013)) were not considered to be macroprudential policy tools in this study of the IMF. A different classification of these available tools is provided by Hanson et al. (2011). They identify six sets of macroprudential tools: countercyclical capital regulation, maturity regulation, shadow banking regulation, design of corrective action, higher-quality capital, and contingent capital. The last two classes of tools in this list guide us to the next section.

Significantly Higher Capital Requirements

In the aftermath of the Great Recession, an intense debate started on the necessity to raise capital requirements significantly. Interestingly, this debate is decoupled from earlier microeconomic research on banking regulation, as a distinct macroeconomic perspective is adopted throughout the discussion. The best-known proponents of significantly higher capital requirements are without doubt Anat Admati and Martin Hellwig. These two economist have first called for tighter capital regulation in a working paper primarily addressed to other academics (Admati et al., 2011). Two years later, they have published a book in order to reach a greater public and, ultimately, the policy-makers (Admati and Hellwig, 2013b). They are still active in disseminating their ideas, as a supplement to their book illustrates (Admati and Hellwig, 2013a).

They key argument of both the working paper and the book is that bank equity is not costly from a social point of view, that is, from a macroeconomic perspective. The irrelevance result of Modigliani and Miller (1958) serves as a basis for this argument. While their passionate proposal has attracted quite some attention in the media, some economists are taking issue with their arguments.

First, there exists academic research on the cost of bank capital which was published before Admati et al. (2011). Van den Heuvel (2008), for example, finds rather significant welfare effects of capital requirements. In his analytical model, these costs arise because capital-regulated banks are constrained in their potential to create the liquidity that is demanded by households. Further, Angelini et al. (2011) find that both liquidity requirements and capital requirements as proposed by Basel III lower economic growth. Finally, VanHoose (2007) states that current capital requirements can be legitimated only partly

[55] The former is subdivided into risk through time (e.g. countercyclical capital regulation) and risk across institutions (e.g. taxing trades that are not centrally cleared). The latter dimension divides the different policy tools into those that have been developed specifically to tackle systemic risk (e.g. systemic capital surcharges) and those that have been redesigned to mitigate systemic risk (e.g. deposit insurance premium depending on systemic risk).

by economic research. This research challenges the usefulness of capital requirements in general.

Second, since Admati and Hellwig's attack against the argument of costly bank equity, further research has been published that recognizes (social) costs of higher bank capital requirements. In a working paper, DeAngelo and Stulz (2013) identify effects of bank capital regulation similar to the ones of Van den Heuvel (2008). They claim that the Modigliani-Miller Theorem is inapplicable to banks due to the social value of liquidity provided by bank deposits. Similarly, Baker and Wurgler (2013) empirically establish the presence of a *low risk anomaly* for banks. They show that while bank equity risk is increasing in leverage, the return of bank equity is not increasing at the same pace. Actually, banks with lower risk feature higher returns on a risk-adjusted and on a raw basis. In other words, while bank equity becomes less risky if banks hold more equity, this does not necessarily imply that equity returns are lower, that is, that the cost of equity decreases.

Contrary to the research cited above, some economists find strong positive effects of significantly increased bank capital. This is in line with Admati and Hellwig. Miles et al. (2013) establish that at current capital levels—and at the levels proposed by Basel III—the costs of increased bank capital requirements are much lower than the benefits. Further, the model by Meh and Moran (2010) suggests that higher bank capital potentially reduces output volatility.

Finally, there also exists research indicating a non-linear relationship between capital requirements and welfare. De Nicolò et al. (2012), for instance, find that increasing capital requirements first increase output and welfare, but, at a certain point, start to impact both negatively. A similarly cautious opinion is given by Gale (2010). Hence, there is a rather large body of research indicating that a significant increase of capital requirements does not necessarily increase welfare.

2.7 Conclusion

We have reviewed both theoretical and empirical economic research on banks and their role in the macroeconomy. Throughout the text, we adopted a macroeconomic perspective on banks' balance sheets. Informational asymmetries, which motivate financial intermediation in the first place, run like a common thread through this survey. The first two sections dealt with modeling asymmetric information with credit from first principles and with the mechanisms—such as banks—that might mitigate these problems. The last two sections were centered around the macroeconomic consequences of these problems.

Based on the research reviewed in this survey, it is safe to say that financial intermediation by banks is not irrelevant for macroeconomic outcomes. Consequently, contemporary banking regulation, which is by and large microprudential in nature, should be reconsidered. It will not suffice to superimpose some new macroprudential rules such as countercyclical capital buffers on the existing regulatory framework. On the contrary, the regulatory framework should be overhauled completely. policy-makers and regulators alike should dismiss a regulatory approach built around the individual institution and adopt a consistently macroeconomic perspective.

3 An Empirical Analysis of Bank Credit Volatility

3.1 Introduction

Whether over-borrowing has played an important role in the severity and the duration of the *Great Recession* is an issue that was discussed extensively by policy-makers and academic economists. The debate has been accompanied by both theoretical and empirical research. Interestingly, until now, empirical studies have focused on credit growth and its relationship to output growth. Research investigating the cyclical behavior of bank credit over the long-run and over a large sample of countries is scarce. While the fact that the *Irrelevance View of Finance* is still rather popular in macroeconomics might partly explain this fact, another important reason for this lack of research has been the unavailability of data.

Coinciding with the awakening interest in the relationship of financial intermediation and macroeconomics, however, new data on bank credit became available. First, Schularick and Taylor (2012) have assembled a comprehensive dataset on money, credit and output. Second, the Bank for International Settlement (BIS) has published data on credit for a large set of countries. While Schularick and Taylor's dataset on credit dates as far back as 1870, the advantage of the BIS data is its availability for more countries and its quarterly frequency.

In this chapter, we investigate the cyclical properties of bank credit and relate these to output volatility. We will track the development of bank credit volatility over a long time period and for various countries. Drawing on the aforementioned data sources and applying various econometric techniques allows new insights regarding the role of credit in modern economies.

We are able to derive the following stylized facts:

1. Bank credit volatility is higher than output volatility across countries and over time.

2. Different country-specific volatility regimes can be identified over time. On average, credit volatility in relation to output volatility was higher after the Second

World War than before the First World War.

Regardless of the volatility measures and econometric techniques we have chosen, bank credit is more volatile than economic output. In the analysis of the volatility of bank credit over time, some historical periods stand out as featuring particularly high volatility. One can also investigate the volatility of bank credit in relation to output volatility. For this, we calculate the ratio of output to the volatilities of bank credit. It turns out that this economic relationship is not stable over time. There are historical periods in which bank credit is more volatile compared to both contemporaneous output volatility and bank credit volatility of other periods.

The remainder of this chapter is organized as follows. Before we start with the empirical analysis, we provide a short overview of the related literature in Section 3.2. In Section 3.3, we describe the data used and mention potential issues regarding data quality. We proceed by providing some descriptive analysis of volatility in Section 3.4. This allows to set up two working hypotheses. In Section 3.5, we investigate the first hypothesis that bank credit is more volatile than output. The second hypothesis that there exist different volatility regimes, is analyzed in Section 3.6. Section 3.7 reviews our results in the light of other findings in the literature, and cross-checks the stylized facts using alternative U.S. data. Section 3.8 concludes. The Appendix contains descriptive statistics of all data used and additional figures.

3.2 Related Literature

The importance of credit for explaining key macroeconomic variables has been emphasized by many economists (see, e.g., Fisher (1933), Kindleberger (1978), or Minsky (1986)). Early analytical models that include financial frictions indicate how important credit is to explain output fluctuations (see, e.g., Bernanke et al. (1996), Kiyotaki and Moore (1997), Bernanke et al. (1999), or Lorenzoni (2008) for a recent account). In theses models, a so-called financial accelerator can be identified, which deepens recessions and spurs booms.

Some economists integrated financial intermediaries into standard dynamic stochastic general equilibrium models (henceforth, DSGE models). In all of these models, a financial accelerator effect is at work, which amplifies business cycles. In the models by Aikman and Paustian (2006) and Meh and Moran (2010), exogenous shocks are intensified by balance sheet effects. This ultimately results in a credit crunch or in a credit boom. In Christiano et al. (2010), changes in the price level—a classic debt deflation effect—exacerbate the procyclicality of bank lending.

Bank lending and its macroeconomic consequences have not only been investigated within DSGE models. Some economists have developed alternative macroeconomic models specifically for this purpose. In the models by Gersbach and Rochet (2012a,b) and Korinek (2011), financial frictions give rise to pecuniary externalities. Due to these externalities, the reduction of bank lending in a downturn turns out to be excessive and thus welfare decreasing. In both models, there is a distinct credit cycle, and credit fluctuates more than output. This is also the case in Bianchi and Mendoza (2011). In this model, asset prices are the driving force behind excessive bank lending, and credit features higher volatility than output in the decentralized variant of their model.

Credit has not only played a role in theoretical models, but it has also been analyzed extensively in empirical studies. Most of these are primarily concerned with the level of credit. First, there is empirical research investigating whether shocks to bank equity can lead to a so-called *"credit crunch"*, that is, a significant reduction in bank lending.[1] Second, economists have investigated whether changes in credit growth are indicative of subsequent economic booms and recessions.[2] Our research differs from these approaches, as we do not investigate changes in the level of bank credit but in credit volatility.

From a methodological standpoint, research on output volatility is related to our empirical approach. First, there is one strand of literature in development economics that investigates the role of financial development on output volatility.[3] Second, econometric research on growth volatility in developed countries has been highly popular in the first decade of the 21st century. This research has investigated and tried to explain the unprecedented decrease in GDP volatility in the 1980ties. Today, the period from 1984 to the *Great Recession* is usually called the *Great Moderation*. Main contributions to this debate were provided by McConnell and Perez Quiros (2000), Blanchard and Simon (2001), and Stock and Watson (2003) using U.S. data, and by Summers (2005) and Cecchetti et al. (2006) for a broad sample of countries. We will apply some of the econometric tools that were used in this research.

The study that is probably most closely related to ours is the one by Aikman et al. (2010). Aikman et al. set up a small-scale analytical model featuring excessive credit cycles. In the second part of their paper, they provide empirical evidence for distinct credit cycles by looking at credit and output growth volatility in the U.S. and the U.K. Our empirical analysis differs both in scope and in depth. We build two different datasets, drawing data from various sources, and we investigate credit cycles for a broader sample of countries. Furthermore, we cross-check our results by setting up a third dataset with quarterly U.S. data only.

[1] See, for example, Bernanke and Lown (1991), Hancock and Wilcox (1998), or Gambacorta and Mistrulli (2004).
[2] See, for example, Claessens et al. (2012) or Jordà et al. (2011).
[3] See, for example, Easterly et al. (2000), Raddatz (2006), or Bekaert et al. (2006).

3.3 Data Description

To analyze the volatility of credit and output, we have set up two different datasets. First, we obtained long-run annual data on bank credit from Schularick and Taylor (2012). Second, we collected quarterly data for the second half of the 20th century provided by the BIS. This second dataset serves the purpose of cross-checking our results obtained from historical annual data. While we discuss the results from the analysis of our quarterly dataset, we have moved most of the supporting material to the appendix.

To compare our results with those of Meh and Moran (2010), we have also built a quarterly dataset with U.S. data only. We will provide a detailed data description of these data in Section 3.7. Hence, in the following, we will discuss the different data sources of the data used in the main analysis of this chapter only.

3.3.1 Annual Data

To analyze long-run trends in credit, we make use of the dataset assembled by Schularick and Taylor (2012). Their dataset contains annual data for 14 countries from 1870 to 2008. For a detailed description how these data were collected, the reader is referred to the original paper and its online appendix.[4] Due to the historical nature of these data, results should be treated with the usual care (cf. Schularick and Taylor (2012, p. 1033)).

The series on bank credit, which was assembled by Schularick and Taylor (2012) using various national statistics, is of crucial importance for the purpose of our analysis. This bank credit variable *"[...] is defined as the end-of-year amount of outstanding domestic currency lending by domestic banks to domestic households and nonfinancial corporations (excluding lending within the financial system)"* (Schularick and Taylor, 2012, p. 1033). The term "domestic banks" is broadly defined as monetary financial institutions; excluded are brokerage houses, finance companies, insurance firms, and other financial institutions.

There are different long-run GDP series available. First, one can use real GDP per capita from Angus Madison (Madison (2008), cf. Bolt and van Zanden (2013)). Second, Barro (2009) has compiled long-run series on real GDP per capita.[5] Third, one can take nominal GDP data from Mitchell (2003, 2007). Our results are not materially affected by the choice of the GDP variable. Hence, we use exclusively GDP data by Barro (2009) in our analysis.

[4] Both data and online appendix can be downloaded from http://www.aeaweb.org/articles.php?doi=10.1257/aer.102.2.1029 (retrieved September 17, 2013).

[5] Barro (2009) used data from Angus Madison extensively, such that these two series do not differ significantly.

We use the same consumer price index (CPI) to deflate nominal data as Schularick and Taylor (2012) for their analysis.[6] Observe that there is no GDP deflator readily available for the whole period. To verify the robustness of our results obtained with CPI-deflated series, we use GDP deflator series provided by the World Bank (2012) for the years 1960 to 2008. To compare per capita GDP with total bank credit, we use population data provided by Madison (2008). Descriptive statistics of these variables can be found in Appendix B.1.

3.3.2 Quarterly Data

We have obtained quarterly series on domestic bank credit from the Bank for International Settlements (2013). This dataset has been compiled from various national statistics on banking and national accounts. The bank credit variable is comparable to the bank loan variable from Schularick and Taylor (2012), as both refer to domestic bank lending to non-financial corporations and households. For a comprehensive discussion of the statistical techniques applied to obtain the final series, the reader is referred to Dembiermont et al. (2013, p. 68-75).

Quarterly Series on real GDP and CPI data used to deflate the credit series were obtained from the International Financial Statistics published by the International Monetary Fund (2013). For some countries, GDP data was only available in a seasonally adjusted form, while for other countries, only seasonally unadjusted series were available. For this reason, we use four-quarter growth rates in our entire analysis. Descriptive statistics of all variables are provided in Appendix B.1.

3.4 Bank Credit and Real GDP at a Glance

Let us start our analysis with a look at the annual growth rates of real GDP and bank credit over the whole time span. Figures 3.1 and 3.2 provide an overview how growth rates of real GDP and bank credit have evolved over more than a century. For expositional purposes, we have restricted our overview to the G7 countries and Switzerland. In Appendix B.2, the growth rates of real GDP and bank credit for further countries are shown in Figure B.1 and B.2. Furthermore, the growth rates of real GDP and real bank credit for the quarterly data can also be found in the appendix (see Figures B.3 to B.7).

This descriptive analysis of the two main time series—GDP and bank credit—gives a good first impression for the dynamics of bank credit in the macroeconomy. It allows the formulation of two hypotheses:

[6] Schularick and Taylor (2012) have taken much of their historical CPI data from Taylor (2002).

1. Bank credit is more volatile than GDP across countries.

2. Bank credit volatility varies over time.

Furthermore, it is worth noting that bank credit volatility in the two recent decades seems to be rather hight compared with both economic output and with other historical periods. Although this period was sometimes called the *Great Moderation*, this term appears to be inappropriate for describing the development of bank credit. In the case of the Scandinavian countries, it might be even more accurate to speak of the *"Great Volatility"* (see Figure B.1 and B.2 in Appendix B.1).

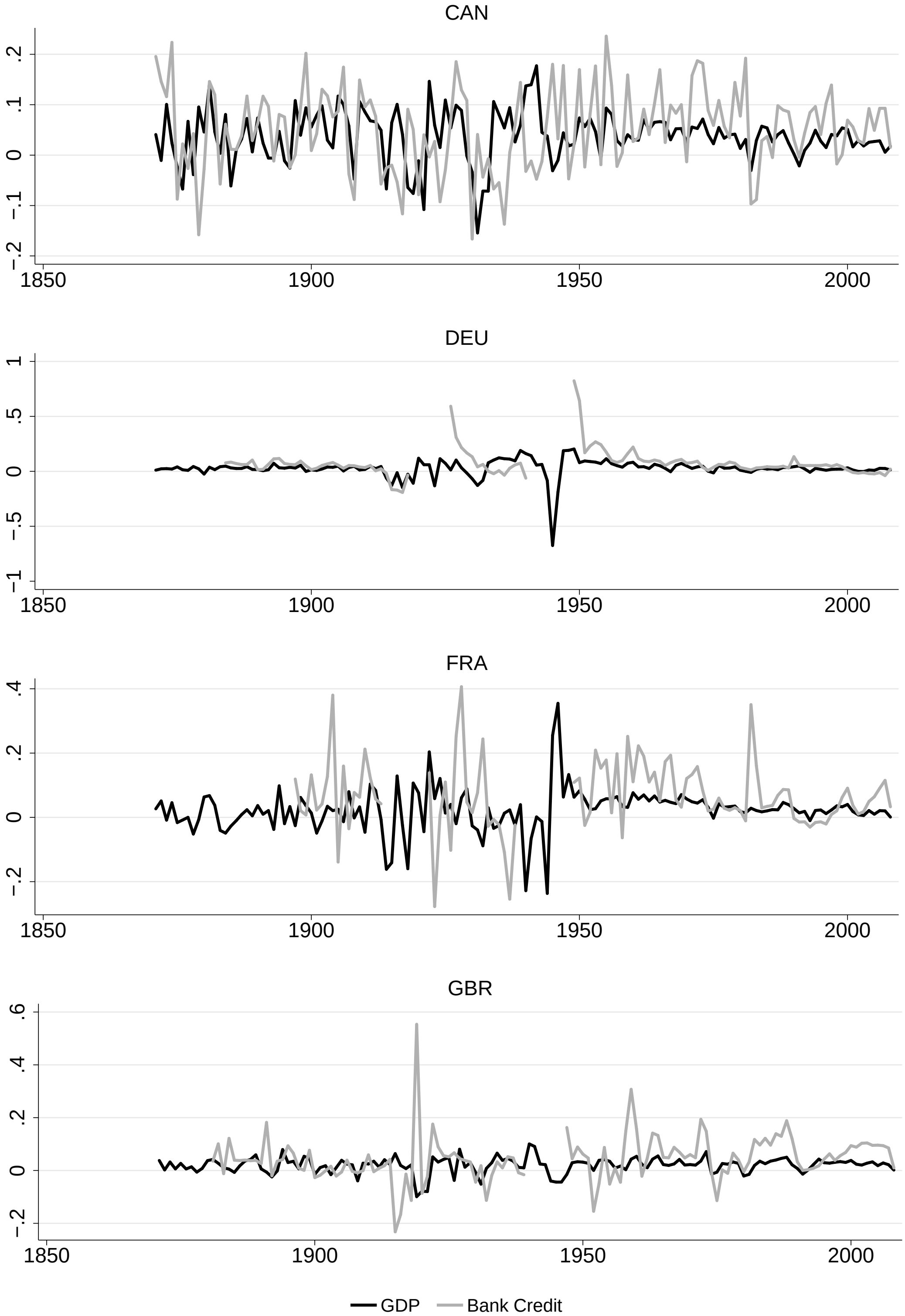

Figure 3.1: Annual growth rates of real GDP and real bank credit. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009).

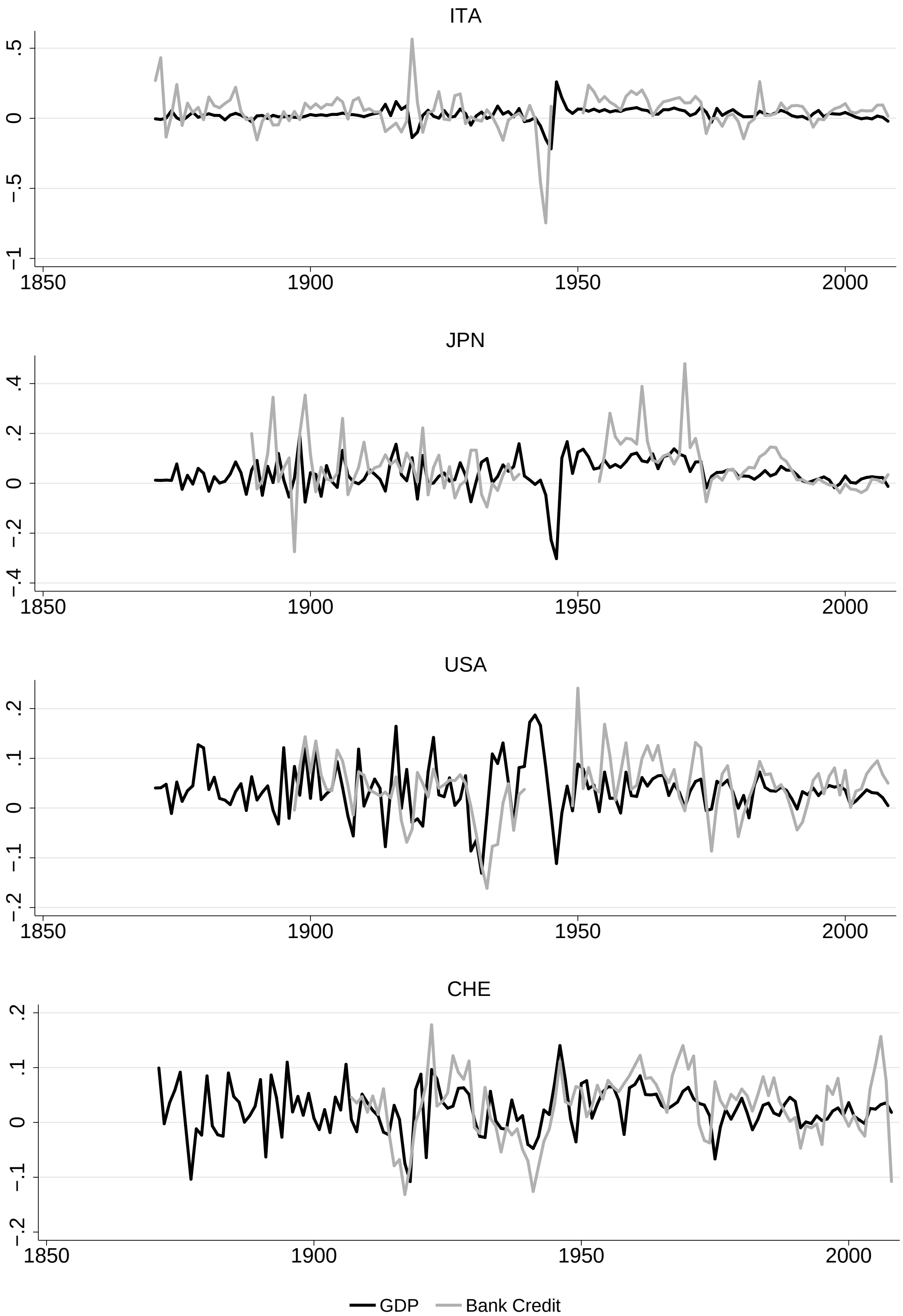

Figure 3.2: Annual growth rates of real GDP and real bank credit. *Source:* See Figure 3.1 (p. 53).

3.5 Stylized Fact No. 1 – Bank Credit is more Volatile than GDP

In this section, we will apply some econometric tools suitable for analyzing the volatility of non-stationary time series to challenge our preliminary result that bank credit volatility is generally higher than GDP volatility.

3.5.1 Volatility of Growth Rates

To start our analysis, we first show the standard deviation of both real GDP growth and real bank credit growth for our annual dataset in Figure 3.3. In Appendix B.3, the standard deviation of GDP growth and real bank credit growth is depicted for the quarterly data (Figure B.8). While the differences between countries are sizable, bank credit is more volatile than GDP in every single country.

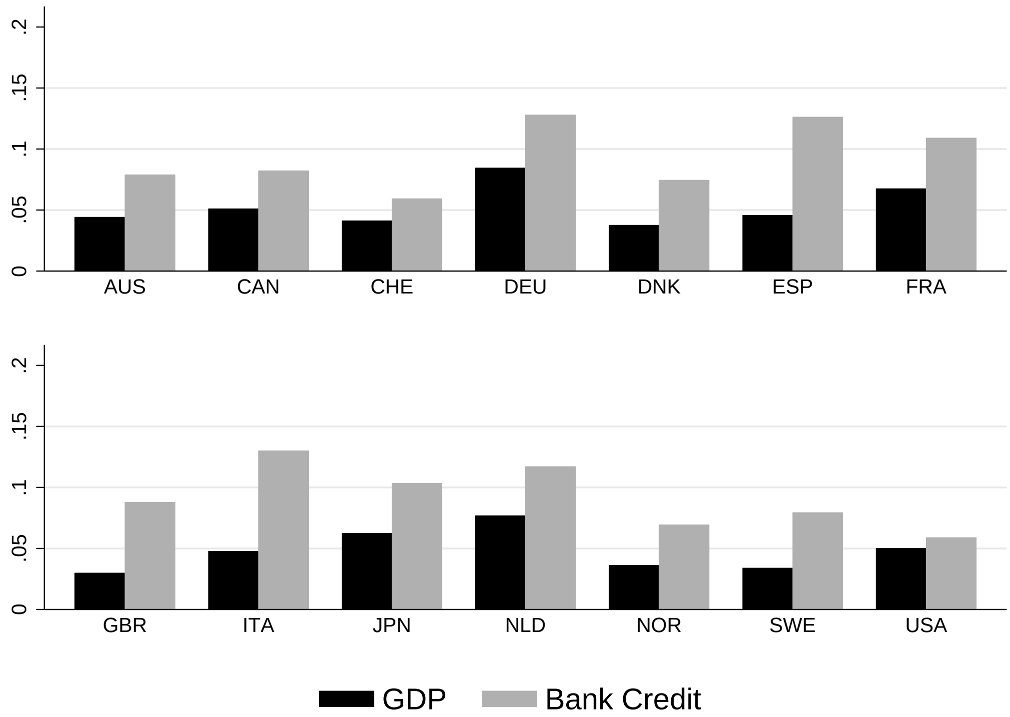

Figure 3.3: Standard deviations of annual growth rates of real GDP and real bank credit. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009).

3.5.2 Business Cycles and Credit Cycles

As the standard deviation is a single summary statistic for data covering more than 100 years, we will next resort to other econometric tools to investigate the volatility of bank credit. In particular, we will compare the business cycle with the credit cycle. For this, one needs to apply a suitable time series filter to decompose the time series into a trend component and a cyclical component.[7] To investigate cycles at low frequencies, as we do here, the band-pass filter developed by Christiano and Fitzgerald (2003) is suggested to be superior.[8]

Aikman et al. (2010, pp.12-21) identify a medium-term cycle in credit growth of about 11 years.[9] While their analysis suggests that the variation of credit growth is also influenced by a shorter business cycle frequency, they conclude that the medium-term cycle dominates the overall credit cycle. For the analysis of this section, we follow Aikman et al. (2010) and model the credit cycle at a frequency of 8 to 20 years, which is lower than the frequency of the business cycle.

In Figures 3.4 to 3.7, we show the results for the G7 countries and Switzerland when we apply the band-pass filter developed by Christiano and Fitzgerald (2003) to obtain the cyclical component of real GDP and real bank credit. Observe that the difference in volatility is much more pronounced after the Second World War. This can be seen particularly in Figures B.9 to B.12 in Appendix B.3.[10]

[7] For the same approach—although using the filter developed by Hodrick and Prescott (1997)—applied to quarterly GDP growth in the context of the debate on the Great Moderation, see Taylor (2000).

[8] For low frequencies, this filter is supposed to result in better finite sample approximations than other filters such as the one developed by (Baxter and King, 1999). In the words of Christiano and Fitzgerald (2003, p. 454), their filter *"[...] dominates the BK and Trigonometric Regression filters. The differences are most pronounced for filter approximations designed to extract frequencies lower than the business cycle."*

[9] Cf. the discussion of medium-term cycles in Comin and Gertler (2006).

[10] We have also derived both the business cycle and the credit cycle for our quarterly data. Calculating the cyclical components using the same band-pass filter, we are able to confirm our results obtained using annual data (see Figures B.13 to B.17 in Appendix B.3).

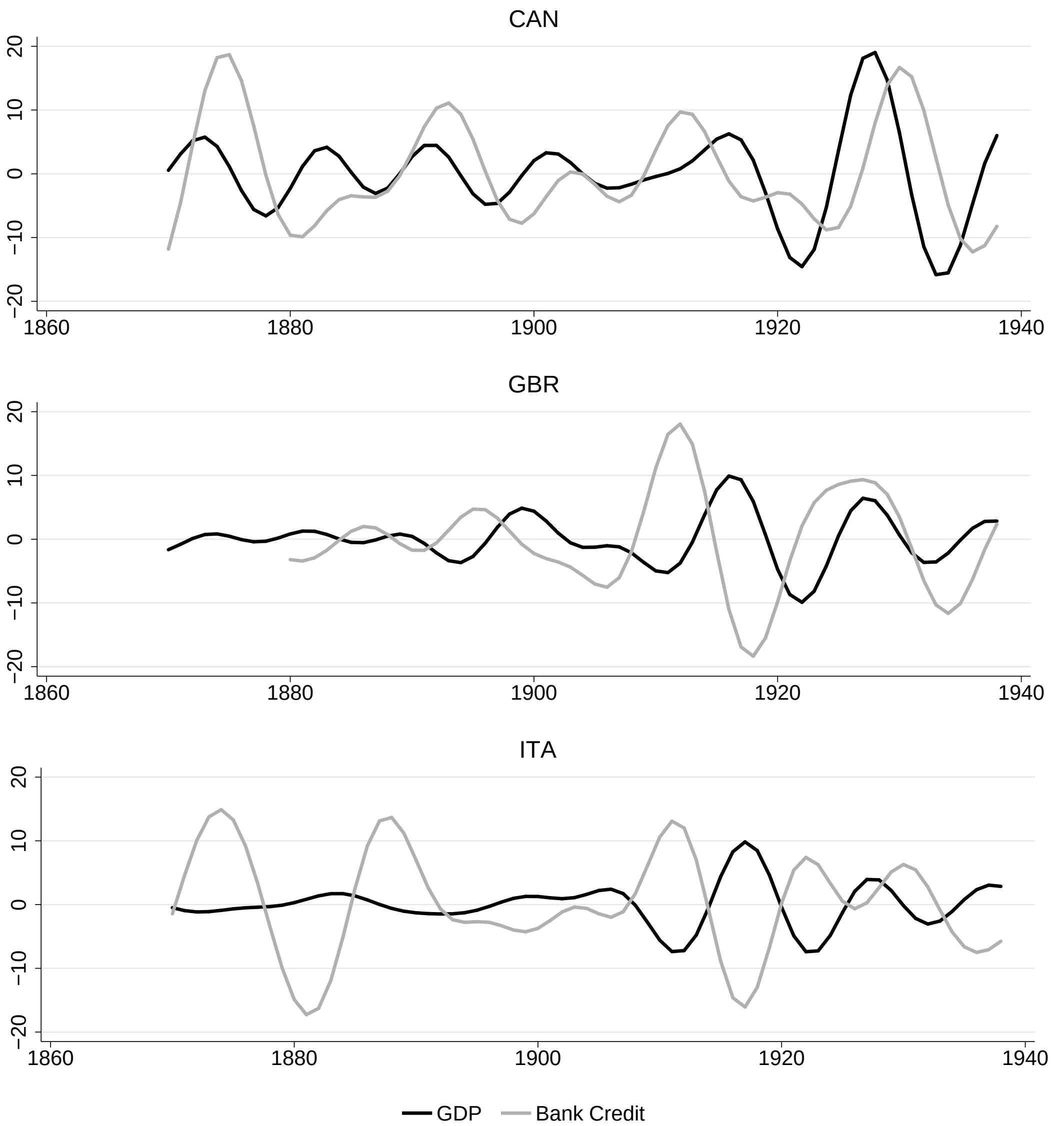

Figure 3.4: Deviation from trend of real GDP and real bank credit before the Second World War. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009). *Note:* The trend component was generated using the band pass filter developed by Christiano and Fitzgerald (2003). We have filtered out stochastic cycles at periods smaller than eight and larger than twenty years. Germany and France are missing due to gaps in the respective time series.

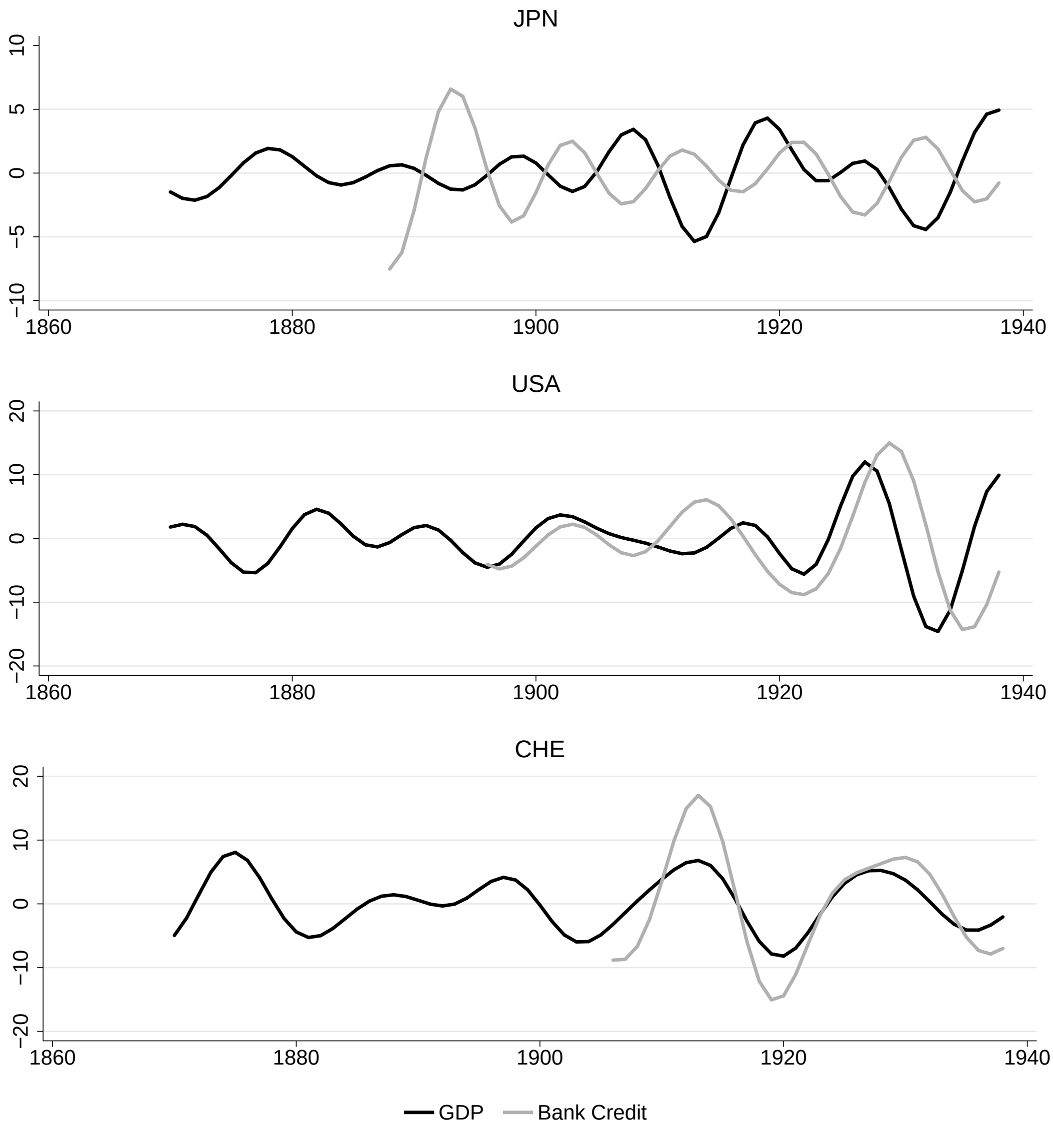

Figure 3.5: Deviation from trend of real GDP and real bank credit before the Second World War. *Source* and *Note:* See Figure 3.4 (p. 57).

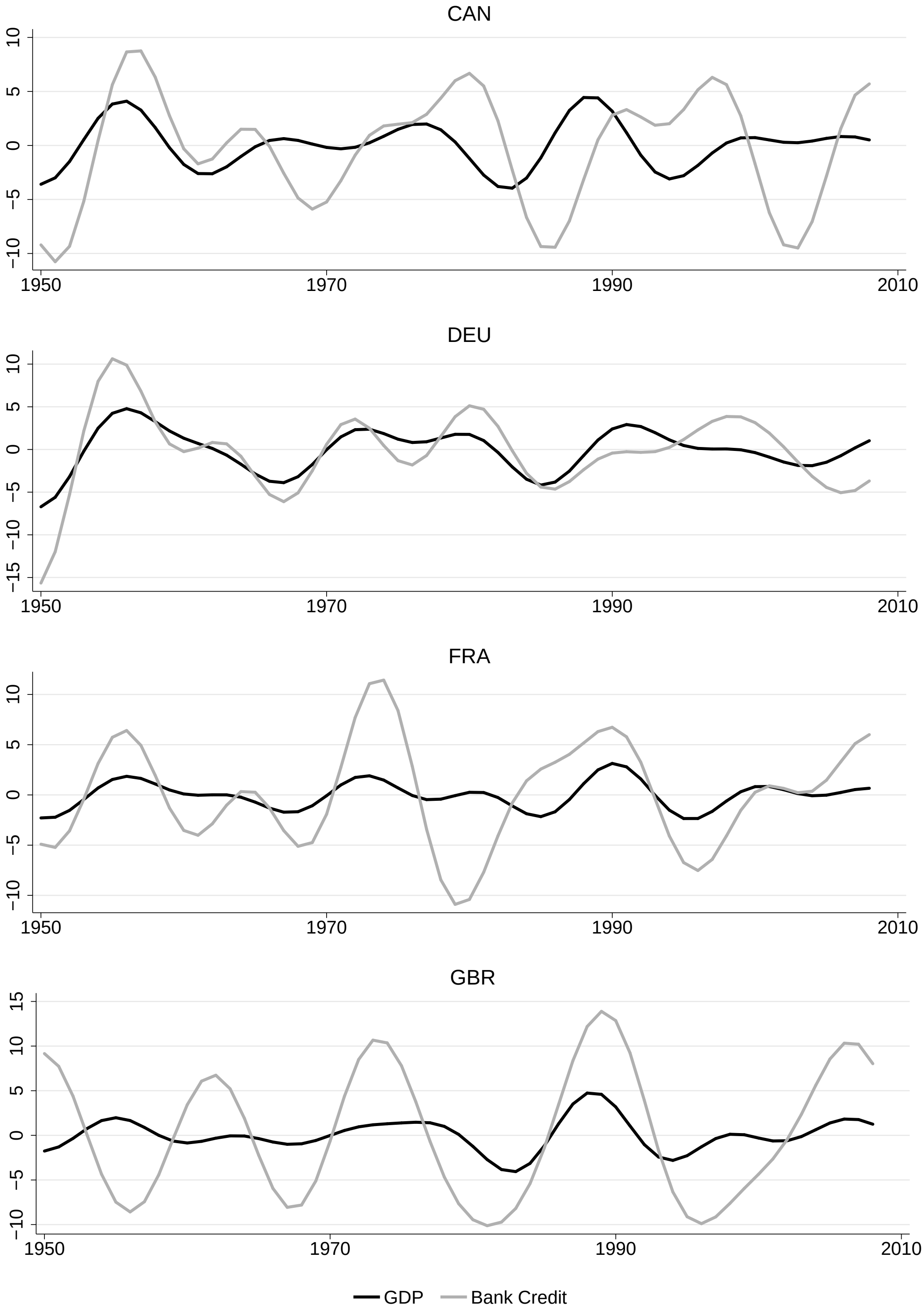

Figure 3.6: Deviation from trend of real GDP and real bank credit after the Second World War. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009). *Note:* The trend component was generated using the band pass filter developed by Christiano and Fitzgerald (2003). We have filtered out stochastic cycles at periods smaller than eight and larger than twenty years.

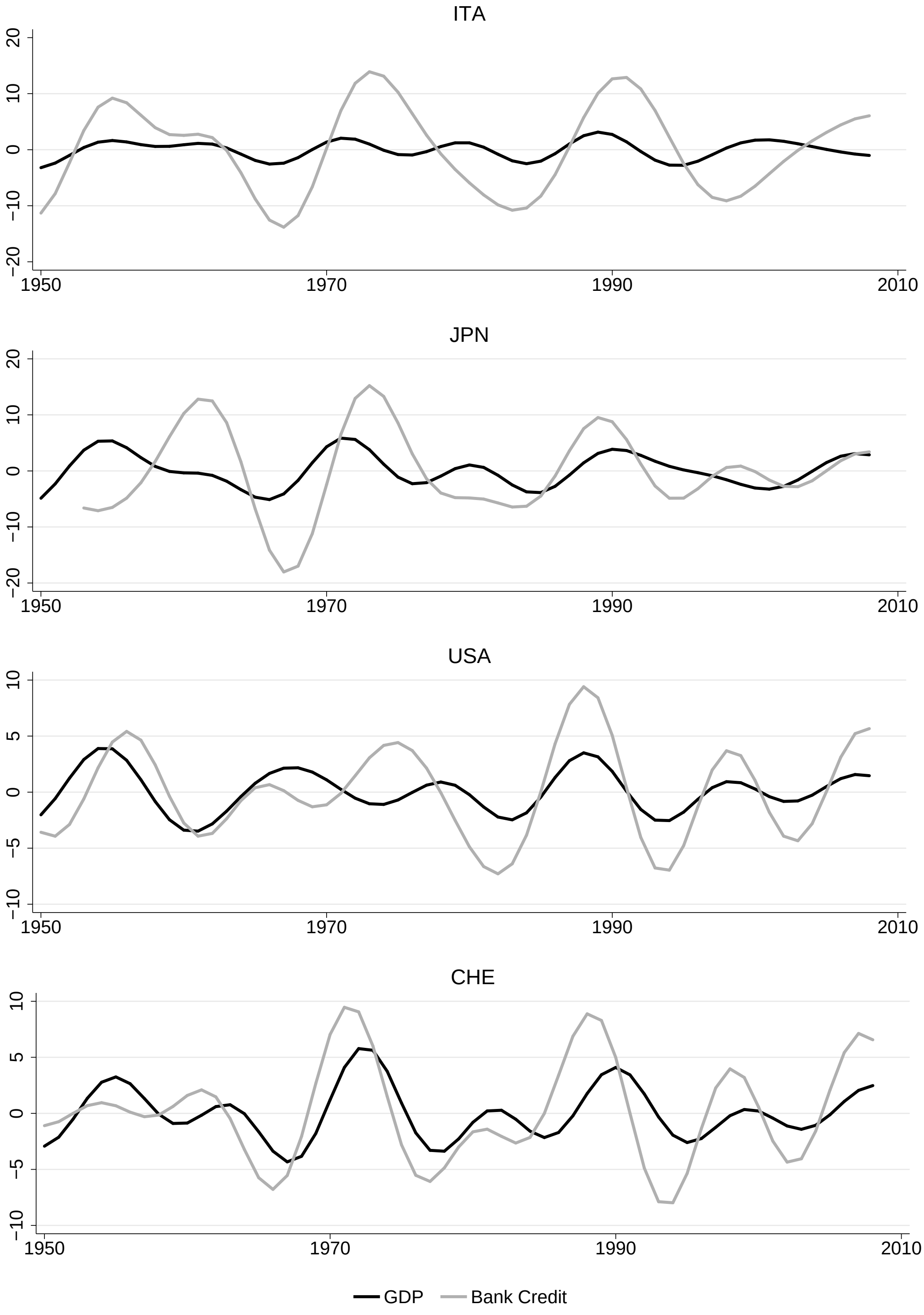

Figure 3.7: Deviation from trend of real GDP and real bank credit after the Second World War. *Source* and *Note:* See Figure 3.6 (p. 59).

In this section, we have investigated whether bank credit volatility is higher than real GDP volatility. Using different datasets and different ways to define volatility, we have not been able to reject our first working hypothesis. All results indicate that bank credit is indeed more volatile than output.

3.6 Stylized Fact No. 2 – Different Volatility Regimes

We have inferred in Section 3.4 that volatility might feature a particular pattern over time. To further investigate this possibility, we will now analyze the time properties of GDP and bank credit volatility. First, we will calculate the rolling standard deviation of the growth rates over the whole time period.[11] Second, we will look at the volatility of GDP and bank credit in specific periods.

3.6.1 Rolling Standard Deviation

In Figure 3.8 and 3.9, we illustrate the development of real GDP and credit volatility over time for the G7 countries and Switzerland (for further countries, see Figures B.18 and B.19 in Appendix B.4). The solid vertical lines are drawn at the years 1913, 1950, and 1973 in order to divide the sample into four different periods. While the first two periods have been chosen for evident historical reasons, the after-war period break might need some further explanation. Contrary to Aikman et al. (2010), who chose 1979 as a threshold, we opted for 1973, due to the fact that the Bretton-Woods System was officially suspended that year. Finally, a dotted line was drawn at the year 1984. This date was identified by several authors as marking a regime shift in GDP volatility.[12] In Figures B.20 to B.24 in Appendix B.4, we have also depicted the rolling standard deviation of real GDP and bank credit for the quarterly data.

[11] For the same approach applied to quarterly GDP growth in the context of the debate on the Great Moderation, see Blanchard and Simon (2001).
[12] See Kim and Nelson (1999), McConnell and Perez Quiros (2000), Stock and Watson (2003), or Summers (2005).

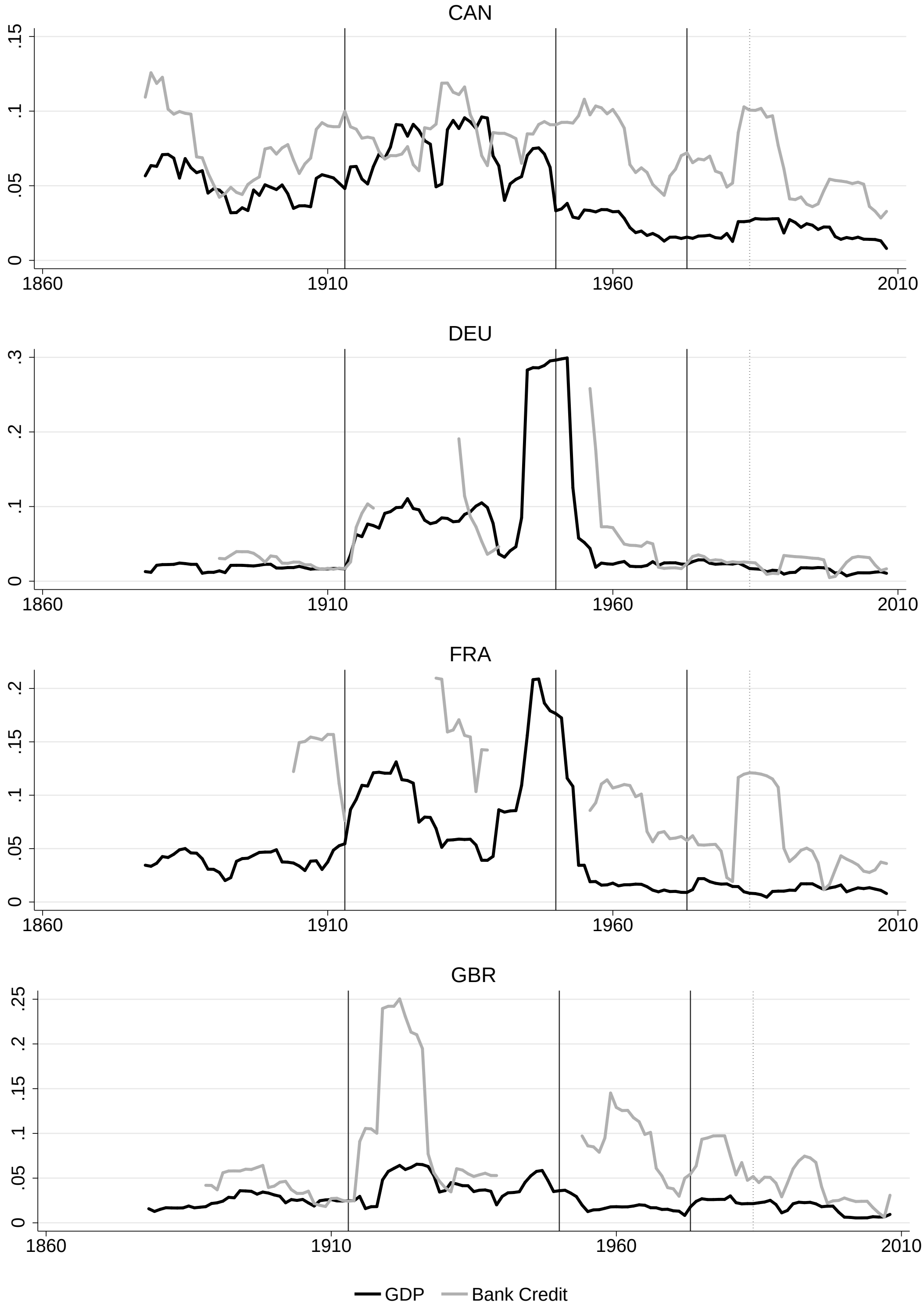

Figure 3.8: Rolling standard deviation of real GDP and real bank credit over an eight year window. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009). *Note:* The reported value in every chart at year t is the standard deviation of the respective time series over the period $t - 7$ to t. If there is one or more missing values in this period, there is no value for t. Vertical lines drawn at 1913, 1950, 1973, and 1984.

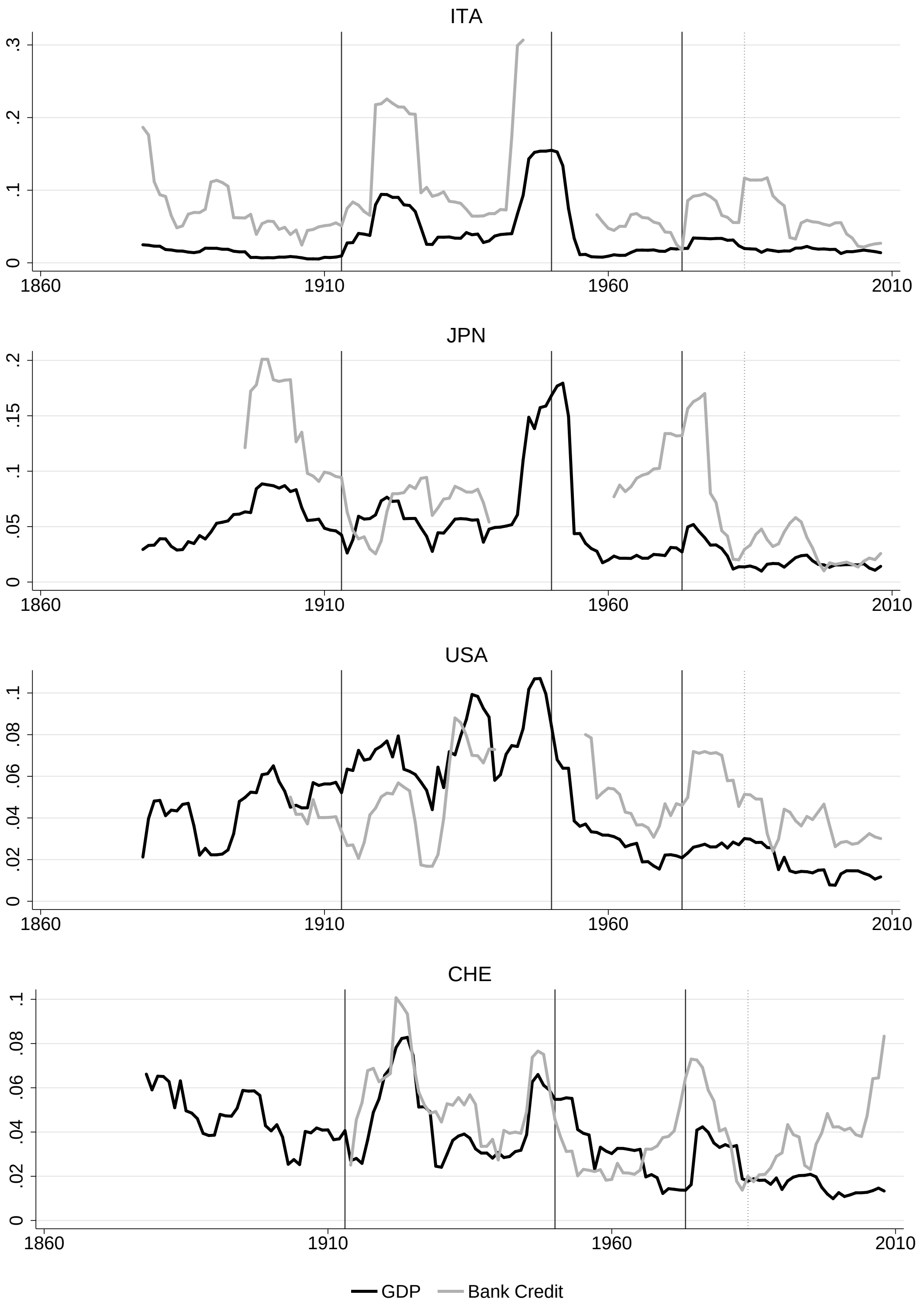

Figure 3.9: Rolling standard deviation of real GDP and real bank credit over an eight year window. *Source* and *Note:* See Figure 3.8.

The advantage of rolling standard deviations is that it allows for identifying turning points in volatility regimes. We can identify such turning points around the years 1913 and 1950 for almost all countries. At the beginning of the First World War, volatility of both output and credit starts increasing, and after the end of the Second World War, volatility falls again. Furthermore, for more than half of the countries, there was a spike in volatility around the collapse of the Bretton-Woods System. Finally, we are able to replicate the results of the *Great Moderation* debate; in the U.S., output and credit volatility fell after 1984.[13]

3.6.2 Relationship of Credit Volatility and Output Volatility

We next have a look at the standard deviation within each of the previously identified periods. We report the standard deviations of GDP and bank credit for the annual data in Figure 3.10. For the standard deviations in our quarterly dataset, see Figure B.25 in Appendix B.4.

Let us highlight some interesting results. First—and as was to be expected—the period from 1913 to 1950 is exceptional, with very high volatility of both macroeconomic variables under investigation. Second, the period before the First World War was the one featuring the lowest volatility in bank credit for almost half of the countries in the sample. This is remarkable insofar as advances in banking and financial innovation, as well as regulatory initiatives, might have given rise to a contrary intuition.

[13] This result is more pronounced for output volatility than for credit volatility.

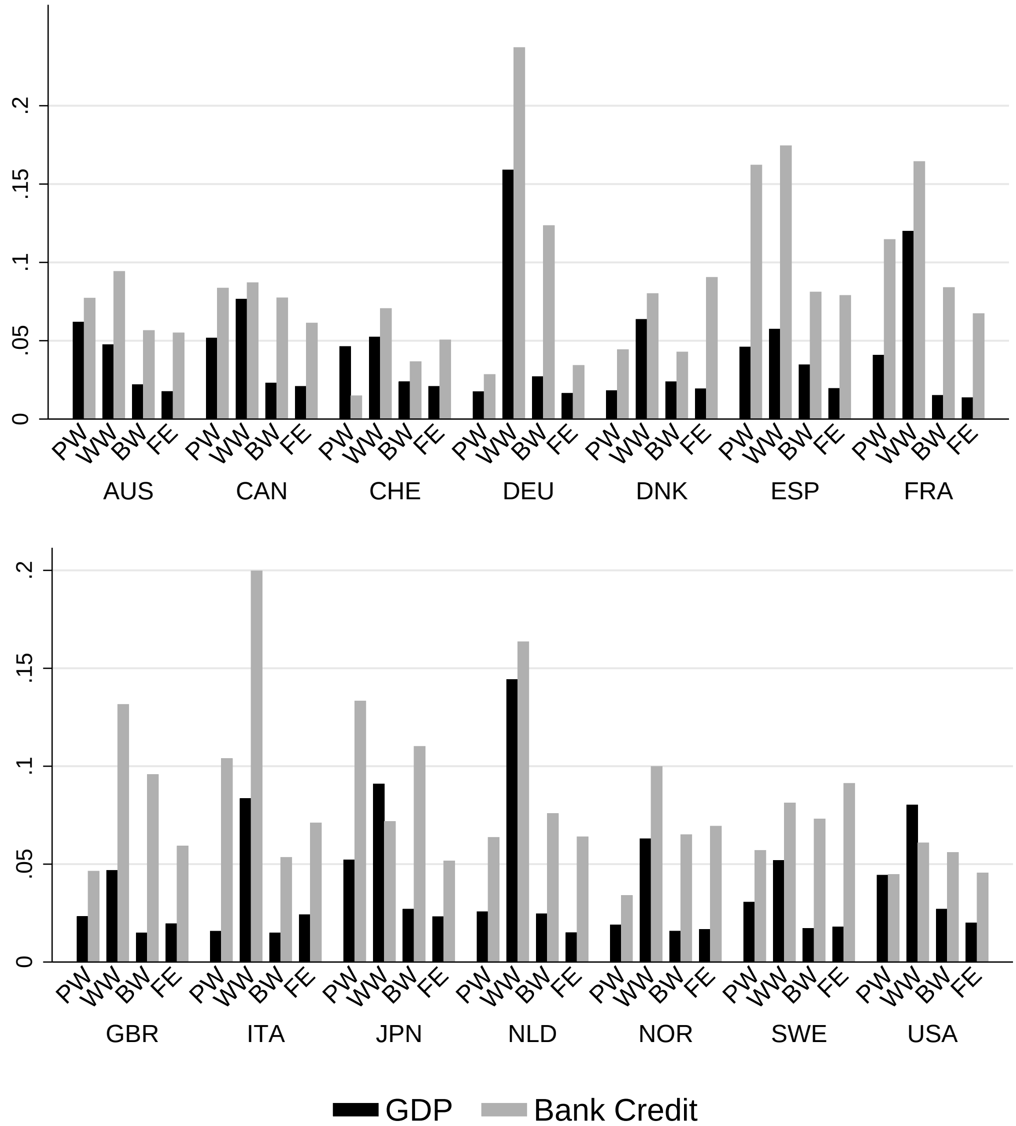

Figure 3.10: Standard deviations of growth rates of real GDP and real bank credit. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009). *Note*: PW: "Pre-War", data before 1913; WW: "World Wars", data for 1913-1950; BW: "Bretton Woods", data for 1950-1973; FE: "Floating Exchange Rates", data after 1973.

Finally, we investigate whether the change in volatility in bank credit is determined by a common trend in the economy. Namely, we want to know whether bank credit is more volatile when economic activity in general fluctuates more. For this, we compare credit volatility to output volatility within each period. We have computed the ratio of the standard deviations of real GDP and bank credit, and reported the results in Table 3.1.

Table 3.1: Standard Deviation of Real Bank Credit Growth Diveded by the Standard Deviation of Real GDP Growth

	PW	WW	BW	FE
AUS	1.25	1.98	2.57	3.12
CAN	1.62	1.14	3.36	2.93
CHE	0.32	1.35	1.53	2.42
DEU	1.63	1.49	4.56	2.08
DNK	2.44	1.26	1.80	4.67
ESP	3.52	3.04	2.34	4.03
FRA	2.81	1.37	5.53	4.92
GBR	2.00	2.81	6.43	3.02
ITA	6.58	2.39	3.61	2.94
JPN	2.55	0.79	4.07	2.23
NLD	2.48	1.13	3.07	4.25
NOR	1.79	1.59	4.12	4.18
SWE	1.86	1.57	4.26	5.10
USA	1.01	0.76	2.07	2.28
Total	2.28	1.62	3.52	3.44

Note: PW: ”Pre-War“ (before 1913). WW: ”World Wars“ (1913-1950). BW: ”Bretton Woods“ (1950-1973). FE: ”Floating Exchange Rates“ (after 1973). *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009).

While the statistic provided in Table 3.1 is only descriptive and we cannot say anything about significance, the differences in the volatility ratios are striking. On average, credit fluctuates much more relative to real output during the period after the Second World War than in the period before the First World War. In the U.S., the volatility of real GDP and bank credit was about the same before the First World War. After the Second World War, real GDP volatility was significantly lower but bank credit volatility remained high (cf. Figure 3.10). In the Scandinavian countries, the behavior of the ratio of the standard deviations of real GDP and bank credit is similar to the one in the U.S. In these countries, however, the result is driven by an increase in bank credit volatility (cf. Figure 3.10). These two examples—the U.S. and the Scandinavian countries—indicate that the results from Table 3.1 have to be interpreted with care. While it seems safe to say that the relationship between the volatilities of real GDP and bank credit is not a stable one, the reasons for this might differ from country to country.

In this section, we have investigated our second hypothesis that bank credit volatility changes over time. Our empirical analysis, using rolling standard deviation of growth rates, strongly supports this hypothesis. Moreover, subdividing the sample into historical periods, we were able to identify different volatility regimes for bank credit. The analysis in this section also allows us to refine our first hypothesis. Namely, we can infer from Figures 3.8 to 3.10 that not only in most countries, but also for almost all historical instances, volatility of bank credit is higher than volatility of output.

3.7 Alternative Credit Variable

In the last two sections, we have been able to substantiate our hypotheses regarding the volatility of bank credit. While our results suggest that bank lending is more volatile than GDP, Meh and Moran (2010) have stated that the former is more than four times as volatile than the latter. This is in contrast to our results that indicate that bank lending is much less volatile. To review this inconsistency, and to assess the robustness of our results in general, we have assembled the dataset used by Meh and Moran.

We have obtained data from the U.S. Department of Commerce: Bureau of Economic Analysis (2013) on the quarterly real GDP, the implicit GDP price deflator, and the consumer price index for all urban consumers (CPI).[14] For bank credit, we have taken the commercial and industrial loans (henceforth, CI loans) at all commercial banks series provided by the Board of Governors of the Federal Reserve System (2013).[15] Finally, we have used U.S. population data provided by the U.S. Department of Commerce: Census Bureau (2013) in order to obtain per capita values.[16]

Given these data sources, we expect that the additional volatility in Meh and Moran (2010) arose from their choice of the credit variable. While in our previous analyses, we have used a broad measure for bank credit, Meh and Moran are limiting their view to one class of credit only, namely, CI loans; real estate loans and consumer credit are not included in their measure. We will come back to this point below. In Appendix B.1, descriptive statistics of all variables can be found. In the following analysis, we will refer to the credit variable chosen by Meh and Moran as “bank credit MM”.

[14] Real GDP is measured in chained 2005 Dollars, the base year for the GDP deflator and the CPI is 2005 and 1982-84, respectively.

[15] Meh and Moran (2010) state in their paper that they have obtained the latter series from the Bank for International Settlement (BIS). However, we could not find this data on the BIS website. Since it was not possible to contact Meh and Moran, we had to replicate their study without being able to clarify this point.

[16] All data can be accessed via the FRED® database operated by the Federal Reserve Bank of St. Louis (FRED, 2013). The respective data codes are GDPC1, GDPDEF, CPIAUCSL, BUSLOANS, and POP.

Before we examine the two key stylized facts, let us have a look at the four quarter growth rates of real GDP and CI loans for the U.S. only. in Figure 3.11.

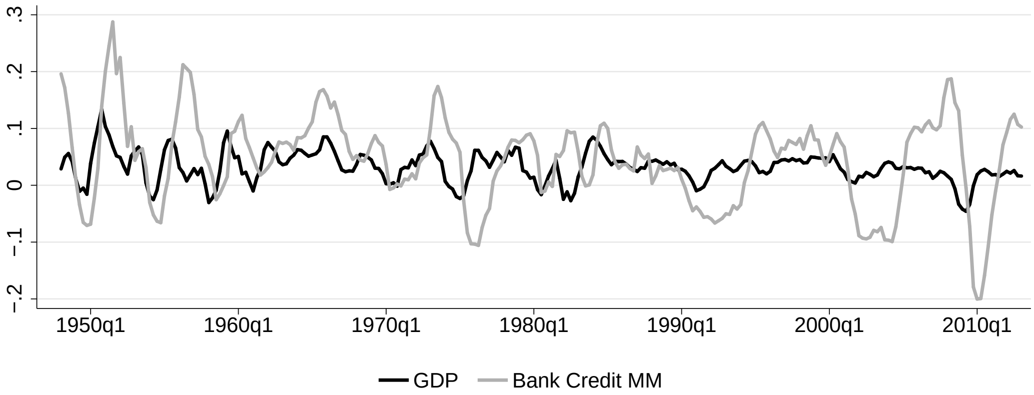

Figure 3.11: Four-quarter growth rates of real GDP and real bank credit MM. *Source:* Own calculations. GDP data from U.S. Department of Commerce: Bureau of Economic Analysis (2013), Bank credit data from Board of Governors of the Federal Reserve System (2013).

3.7.1 Cross-Checking Stylized Fact No. 1

Calculating the standard deviations in our U.S. dataset, we obtain a value of 0.027 for real GDP growth and 0.078 for real CI loan growth. Note that contrary to Meh and Moran (2010), we do not use per capita values for better comparability with our earlier results.[17]

Observe that the credit variable used by Meh and Moran (2010) is more volatile than the credit variables used before. If we restrict our dataset to the same period as Meh and Moran, we are able to replicate their result that bank lending is four times as volatile as output. As we have presumed while describing the data, this result is due to the high volatility of the credit variable chosen; CI loans are much more volatile than real estate loans and consumer credit.[18] Hence, a bank credit variable that is defined more broadly, as the one we have used in our previous analysis, will be less volatile than the one used by Meh and Moran.

Finally, we have also applied the same band-pass filter as before. Figure 3.12 shows the deviation from trend for both real GDP and real bank credit MM.

[17] We have also calculated all volatility measures with per capita values. Since the volatility of population growth is rather low, the results are almost identical (SD of real GDP growth per capita is 0.025 and SD of real bank credit MM growth per capita is 0.072).

[18] See www.federalreserve.gov/datadownload/Choose.aspx?rel=H.8 (retrieved October 10, 2013).

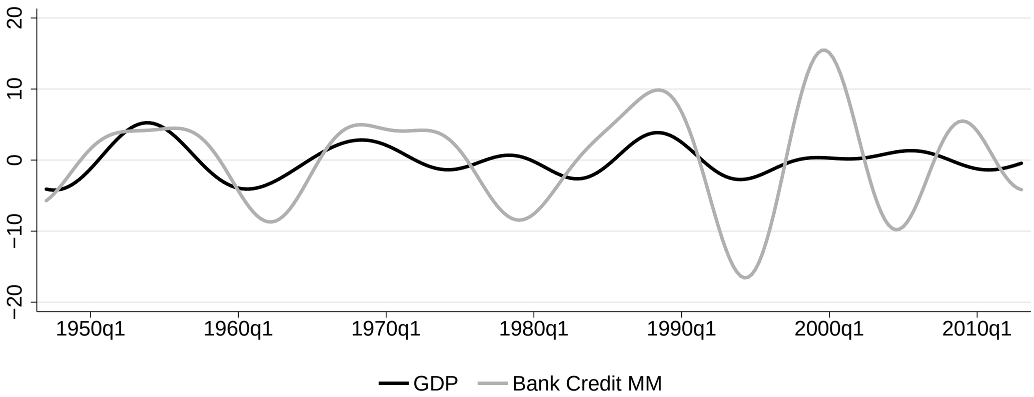

Figure 3.12: Deviation from trend of real GDP and real bank credit MM. *Source:* Own calculations. GDP data from U.S. Department of Commerce: Bureau of Economic Analysis (2013), Bank credit data from Board of Governors of the Federal Reserve System (2013). *Note:* The trend component was generated using the band pass filter developed by Christiano and Fitzgerald (2003). We filtered out stochastic cycles at periods smaller than eight and larger than twenty years.

3.7.2 Cross-Checking Stylized Fact No. 2

Before we conclude, let us quickly reexamine our second stylized fact using CI loans. Figure 3.13 illustrates how volatility of real GDP and CI loans evolved in the U.S., and Figure 3.14 depicts the standard deviation for the different periods. Note how the volatility of this credit variable differs from the one used in the previous section. Again, the reason for this can be tracked down to Meh and Moran's choice of a narrow credit variable (see discussion above).

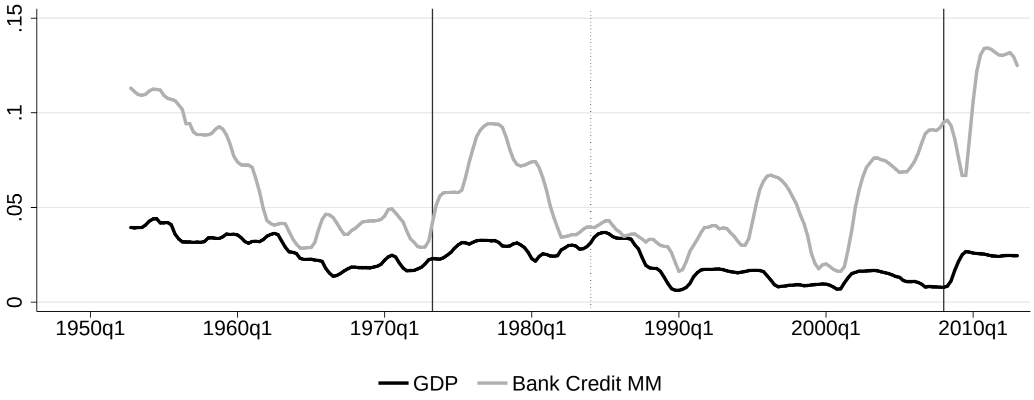

Figure 3.13: Rolling standard deviation of real GDP and real bank credit MM over a twenty quarter window. *Source:* Own calculations. Bank credit data from Board of Governors of the Federal Reserve System (2013), GDP data from U.S. Department of Commerce: Bureau of Economic Analysis (2013). *Note:* The reported value in every chart at year t is the standard deviation of the respective time series over the period $t-19$ to t. Vertical lines drawn at 1973, 1984, and 2008.

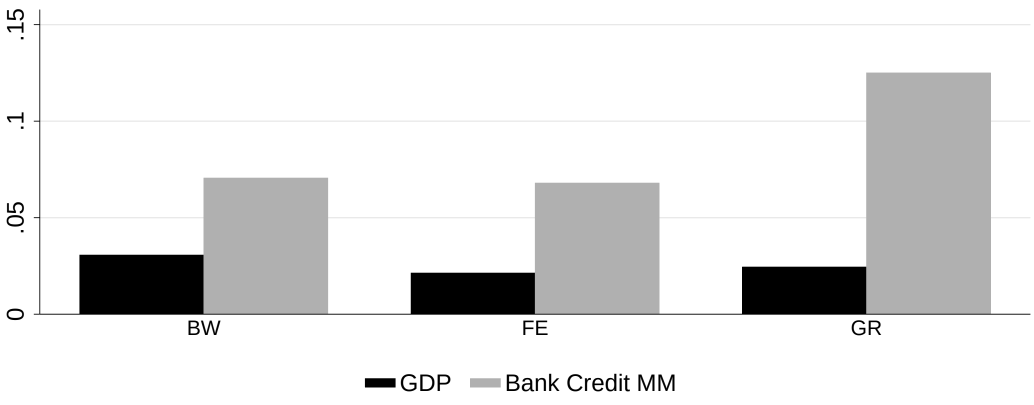

Figure 3.14: Standard deviations of growth rates of real GDP and real bank credit MM. *Source:* Own calculations. Bank credit data from Board of Governors of the Federal Reserve System (2013), GDP data from U.S. Department of Commerce: Bureau of Economic Analysis (2013). *Note:* BW: “Bretton-Woods”, data for 1950-1973; FE: “Floating Exchange Rates”, data for 1973-2008, GR: “Great Recession”, data after 2008.

3.8 Conclusion

We have analyzed and compared the volatility of bank credit and economic output. Drawing data from different sources and applying various econometric techniques, we were able to establish two stylized facts. First, bank lending is generally more volatile than output. Second, the volatility of bank credit is not constant over time. It seems that historical periods feature different volatility regimes. In particular, the relationship between the volatility of GDP and bank credit is not stable.

On average, credit volatility in relation to output volatility is higher in period after the Second World War than in the period before the First World War. We have seen that the reason for this fact depends on country specific factors. Even for the most recent period, when countries have become increasingly connected financially, we cannot identify a global pattern in bank credit volatility and output volatility.

Further empirical research is needed to shed light on these issues. On the one hand, the question why there is not more global convergence in credit volatility deserves more attention. On the other hand, the identification of the country-specific factors influencing bank credit volatility appears to be a promising path for future research. Finally, it would be interesting to investigate the effects of bank credit volatility on economic welfare.

4 Banking in General Equilibrium: Baseline Model*

4.1 Introduction

Motivation

The socially optimal capital structure of banks has become the focus of an extended debate among policy-makers and academics. New regulatory standards epitomized in Basel III aim at increasing bank capital requirements by moderate amounts. Some countries have considered a further strengthening of these requirements.[1] There is, however, no consensus among academics regarding the net effects of higher capital requirements on welfare. On the one hand, several studies point to higher and potentially significant welfare costs when capital requirements are substantially heightened (e.g. Van den Heuvel (2008), Angelini et al. (2011) or Bolton and Samama (2012)). On the other hand, a variety of papers stress that welfare costs of substantially heightened capital requirements are small or vanishing (see e.g. Brealey (2006)).[2] Recently, Admati et al. (2011) have set out and scrutinized the underlying logic for this line of reasoning.

It has long been recognized that the examination of bank capital regulation has to start with the Modigliani-Miller Theorem.[3] Modigliani and Miller (1958) state that changes in the capital structure of a firm—and in particular changes of the ratio of debt and equity funding—only redistribute the total risk of the firm's asset returns among those who fund the firm. However, investment opportunities, total risk of the firm's (the bank's) asset returns and overall funding costs are not affected.[4] A large strand of literature has identified how deviations from the underlying assumptions of the Modigliani-Miller Theorem

* This chapter is based on Gersbach, Haller and Müller (2013).

[1] See, for example, Siegenthaler et al. (2010) for Switzerland, where stricter capital requirements came into force on 1 March 2012.

[2] Furthermore, several studies acknowledge some costs of higher capital requirements over Basel II but conclude that the benefits exceed the costs (e.g. Basel Committee on Banking Supervision (2010), Hanson et al. (2011) or Miles et al. (2013)).

[3] See Schaefer (1990), King (1990), Berger et al. (1995) and Admati et al. (2011). Miller (1995) discussed whether the irrelevance result holds for banks and why enhanced capital requirements could protect depositors at comparatively low costs.

[4] See also the later succinct account in Miller (1977).

in the form of distortions and market frictions can imply that particular capital structures are preferred over others from the perspective of an investor or from a social point of view (see Admati et al. (2011) for a comprehensive account). If a social perspective requires a lower debt-equity ratio than a private perspective, then raising capital requirements above the level prevailing in unfettered markets is justified.

In the context of banking, we consider one friction and two potential distortions that have been at the center of the discussion on the foundations of capital requirements:

- Moral hazard of entrepreneurs,
- Deposit guarantees by governments,
- Bailout by governments in case of default, financed by taxes.

Alleviating moral hazard of entrepreneurs is standard in rationalizing the need for financial intermediaries. The guarantee of deposits and the associated bailout of banks in case of default are usually justified by high social costs of bank defaults, in particular when many banks fail simultaneously. They are also justified by protection of risk-averse depositors or the special role of deposits as a means of payment and the corresponding need to have a large amount of safe assets in the economy.

We are interested in types of bank capital structures that can occur in economies when there appears to be a rationale for making deposits safe. This may be because of social costs of bank failures or the protection of deposits of risk-averse households.[5]

Model

We adopt a general equilibrium perspective to investigate the validity of a macroeconomic version of the Modigliani-Miller Theorem. By this we understand that different equilibrium capital structures have no impact on the allocation of commodities and on welfare. We address this issue in the simplest model with the following characteristics:

- There is a homogeneous group of risk-averse households.
- Two technologies are available for real investments. In one technology, households can invest without frictions (henceforth called frictionless technology or FT). Funding of investments in the other technology is plagued by moral hazard and returns are risky (henceforth called risky technology or MT).
- Banks alleviate moral hazard in lending to MT. Banks fund themselves by means of debt and outside equity (henceforth called equity).

[5] In the final section we comment on how our findings may be applied to economies in which deposits function as a medium of exchange and should be safe for this reason.

- The government guarantees bank debt. If banks default they are bailed out and rescue funds are obtained via taxation.

On purpose, we make two assumptions that allow for the possibility for this economy to achieve Pareto efficient allocations that would occur in an Arrow-Debreu version of the economy:

- Banks can eliminate moral hazard in MT at no cost. There is no moral hazard on the part of bank managers monitoring entrepreneurs.
- Taxation to fund bailouts is lump-sum and thus non-distortionary.

Given these favorable manifestations of the underlying frictions and distortions, it is *a priori* unclear whether bank capital structures matter at the macroeconomic level. For instance, if the government guarantees deposits and bails out banks in case of default, then depositors are rescued; but they may be taxed by the same amount that they receive in rescue funds. Hence, when taxes are lump-sum, such bailouts may not affect the total risk investors are facing and thus may not affect welfare.

Main Results

We first establish existence, uniqueness and Pareto efficiency in the Arrow-Debreu version of the economy. In this version, frictions and banks are absent and households can invest frictionlessly in both technologies via complete contingent commodity markets or complete security markets.

When frictions and distortions—in the favorable manifestation outlined above—as well as banks are present, two classes of equilibria occur. In the first class, the first-best allocation obtains, and the capital structure of banks is irrelevant to investment, total risk and consumption allocation. Specifically, banks attract and channel the socially optimal amount of resources to the risky technology exposed to moral hazard. Banks are funded by a portfolio of debt and (outside) equity, with a sufficient amount of equity such that debt can be repaid in all states, and no bailout is necessary. Up to a critical debt-equity ratio, above which banks default with positive probability, every capital structure is a first-best equilibrium outcome. The resulting allocation replicates the Arrow-Debreu solution.

In the second class of equilibria, debt-equity ratios are high. Banks attract more funds than in the efficient equilibria, over-invest in the risky technology and are financed considerably by debt. Banks generate high returns on equity in the good state and default in the bad state. In the case of default, banks receive funds from the government to pay out their debt holders. Those government expenditures are financed by lump-sum taxes levied on households and thus on the debt holders themselves. *Ex post*, the bailout is neutral for households as they essentially finance their deposit claims with their own taxes. *Ex ante*, however, households are willing to hold large amounts of deposits. This is due to the fact that repayments of deposits are guaranteed and households have no influence on the risky investments of banks, the implied riskiness of bank equity, and on the ensuing tax burden when those banks default.

We conclude that the macroeconomic version of the Modigliani-Miller Theorem fails to hold in an unregulated banking system.[6] Debt-equity ratios above a critical level cause changes in aggregate investment decisions and an increase in total risk of the assets held in the banking sector.

To avoid the inefficiencies associated with high debt-equity ratios, the regulator can impose bank equity capital requirements (henceforth "capital requirements"). Such requirements essentially prevent the occurrence of inefficient equilibria—so that only efficient equilibria emerge. With suitable capital requirements in place, the macroeconomic version of the Modigliani-Miller Theorem holds: all equilibria yield the same resource allocation and total risk for the economy. Finally, if bankruptcy costs were absent, the same welfare implications would prevail when the regulator could commit to forcing failing banks into bankruptcy. More specifically, equilibria with and without bank defaults can occur. However, all of them are efficient.

Broader Policy Implications

The concern here and in the contemporary policy debates is not risk taking by banks *per se*. Extending credit to firms with the risky technology and monitoring those firms is the key role of banks in our model. As long as these loans are primarily financed by bank equity, banks will not default and the equilibrium outcome is efficient.

But as soon as banks' debt-equity ratio exceeds a certain threshold, banks can find themselves in a situation where they can no longer keep their promises to depositors and default. Depositors are indemnified by deposit insurance. Banks obtain more total funds, which they channel into some sectors, thereby diverting funds from other sectors. An inefficient outcome results.

Our findings show that bank regulators do not necessarily have to face a trade-off between avoiding the adverse consequences of major bank failures and an efficient allocation of investment goods. In our model, capital requirements help prevent default of banks without tightening credit to businesses.

Conceptual Background

While we focus on the foundation of capital requirements in the main body of the chapter, conceptually, our model deals with the compatibility of household portfolio decisions

[6] In Chapter 5, we show that both classes of equilibria occur under different bank funding procedures: simultaneous issuance of debt and equity, sequential issuance of debt and equity, and possibility to raise equity further.

(cum tax risks) with risky investment decisions of banks from a general equilibrium perspective without and with capital requirements. In equilibrium and without regulation, a portfolio of debt and equity is the optimal choice of households given optimal investment decisions of banks at such debt-equity ratios and ensuing tax risks from bailouts. With suitable capital regulation, there is no tax risk, and the portfolio of debt and equity at the household level is compatible with optimal investment of banks at equilibrium debt-equity ratios.

Organization of this Chapter
This Chapter is organized as follows. In the next section, we present the setup of our model in detail. The frictionless equilibrium as a benchmark case is established in Section 4.3. In Section 4.4, the implication of frictions and distortions on equilibria and welfare is analyzed. We also provide several examples. In Section 4.5, we examine how regulation can eliminate inefficient equilibria. Section 4.6 concludes. The Appendix contains further examples, a detailed characterization of both the households' optimal portfolio choice and the banks' return on equity maximization, proofs, and an analysis of equilibria arising under sequential and simultaneous issuance of debt and equity by banks.

4.2 Model Setup

We consider a two-period economy ($t = 1, 2$). At $t = 1$, there is a single physical good – called investment good – that can neither be stored nor consumed. Total endowment with this good in the economy is W ($W > 0$). Different technologies can transform the investment good into a consumption good in period $t = 2$. There are two different types of agents: households and entrepreneurs. All agents live for two periods.

4.2.1 Technologies

The model includes two different technologies that convert the investment good at $t = 1$ into a consumption good at $t = 2$. One is called the frictionless technology (FT) and is supposed to represent established businesses. There is no uncertainty about the returns in this sector. The other sector runs a risky technology that is plagued by moral or other hazards (MT). The returns from that technology are uncertain and subject to a sector-specific shock. The technology stands for innovative and risky new business ventures.

The amount K_F ($K_F \in [0, W]$) invested in FT at $t = 1$ yields $f(K_F)$ of the consumption good in period $t = 2$. This technology features decreasing returns to scale with $f'(K_F) > 0$ and $f''(K_F) < 0$. We assume that $f(\,\cdot\,)$ satisfies the Inada conditions

$\lim_{K_F \to 0} f'(K_F) = \infty$ and $\lim_{K_F \to W} f'(K_F) = 0$. The return of investing in FT is given by

$$R_F := f'(K_F).$$

Given $W = 1$, then two explicit examples of such a production function are $f(K_F) = \sqrt{2K_F - K_F^2}$ and $f(K_F) = 2\sqrt{K_F} - K_F$ for $K_F \in [0, 1]$.

The amount invested in MT is denoted by K_M. Its return $\widetilde{R}$ is a binomially distributed random variable. There are two states of the world: good and bad. In the good state, occurring with probability σ, every unit invested in period one will turn into $\overline{R}$ units in period two. With probability $1 - \sigma$, we will end up in the bad state and the return will be $\underline{R}$ ($0 \leq \underline{R} < \overline{R}$). The expected return of investing one unit of the investment good in MT is given by

$$R_M := \mathbb{E}[\widetilde{R}] = \sigma\overline{R} + (1 - \sigma)\underline{R}.$$

4.2.2 Households

There is a continuum of households $h \in [0, 1]$ that derive utility from consumption in period $t = 2$. Preferences are represented by a utility function with constant relative risk aversion, $u(c) = \frac{c^{1-\theta}}{1-\theta}$ where $\theta > 0$ and $\theta \neq 1$. All households have the same preferences and own the same amount of the investment good in the first period. Furthermore, they are all equally endowed with property rights to the FT and MT technology. Property rights cannot be traded.[7] Under these assumptions, we can proceed as if there was a single representative household with utility function u and endowment bundle W.

4.2.3 Entrepreneurs

The technologies are operated by representative entrepreneurs that only play a passive role in our model. The representative entrepreneurs stand for a continuum of entrepreneurs and thus are assumed to behave competitively.[8] The entrepreneur operating FT is denoted by e_F and can be directly financed by households. The entrepreneur operating MT is denoted by e_M. She needs to be monitored and, hence, will be funded by banks. Related to the technology they run, one can interpret entrepreneur e_F as a manager of an established company while entrepreneur e_M can be taken as an innovator or a start-up founder.

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[7] As asset markets are complete in all variants of the model, this assumption merely simplifies the analysis.
[8] In the case of FT, one typically assumes that each entrepreneur operates a project of size 1 with a specific productivity. The distribution of entrepreneurs' productivities generates the function $f(K_F)$.

4.3 Frictionless Economy – Arrow-Debreu Equilibrium

Before we introduce banks, we characterize the Arrow-Debreu equilibrium of the economy and assume that no frictions are present. Both entrepreneurs can be financed directly by households, and all agents can trade in markets with complete asset structures or contingent commodity markets. We follow first the latter approach and define the following variables:

- $(1, p_g, p_b)$ is the price vector, where the price of the investment good has been normalized to 1. The price at $t = 1$ for obtaining one unit of the consumption good in the good state and nothing in the bad state is denoted by p_g. The price at $t = 1$ for obtaining one unit of the consumption good in the bad state and nothing in the good state is denoted by p_b.

- (c_g, c_b) denotes demand of households in states g and b.

- (y_F, y_M) denotes demand of entrepreneurs for investment goods for operating technology FT and MT.

- (Π_F, Π_M) denotes (aggregate) profits of firms in sector FT and MT.

We will next derive consumption and factor demand and state the market clearing conditions. Then, we establish existence and uniqueness of market equilibria.

4.3.1 Production

Consumption goods are produced in the production sector. Entrepreneurs operating the technologies maximize profits, taking prices of input and output goods as given. Entrepreneur e_F running FT solves

$$\max \left\{ \Pi_F(y_F) = (p_g + p_b) f(y_F) - y_F \right\}.$$

This yields the following factor demand function[9]

$$y_F(p_g, p_b) = f'^{-1} \left(\frac{1}{p_g + p_b} \right). \tag{4.1}$$

[9] Note that this demand function is well defined as $f(\,\cdot\,)$ is concave and the Inada conditions hold.

Operating MT, entrepreneur e_M solves

$$\max\left\{\Pi_M(y_M) = y_M(p_g\overline{R} + p_b\underline{R} - 1)\right\}.$$

We observe that in any equilibrium,

$$p_g\overline{R} + p_b\underline{R} = 1. \tag{4.2}$$

Otherwise entrepreneur e_M would either demand an infinite amount of the investment good or none. Prices p_g and p_b adjust in equilibrium such that demand $y_F + y_M$ equals supply W. Therefore, infinite demand cannot occur in equilibrium. Furthermore, $y_M = 0$ would imply that $y_F = W$. But the first-order condition from profit maximization $(p_g + p_b)f'(W) - 1 = 0$ and the Inada condition $f'(W) = 0$ cannot hold simultaneously. As a result, $y_M = 0$ can be ruled out in equilibrium as well. Hence, $0 < y_M < W$, which requires (4.2). Equilibrium condition (4.2) implies that $\Pi_M = 0$.

4.3.2 Consumption

As households own all technologies and the total endowment, they are the only agents consuming. Risk-averse households face the following utility maximization problem:

$$\max\left\{u_h(c_g, c_b) = \sigma\frac{c_g^{1-\theta}}{1-\theta} + (1-\sigma)\frac{c_b^{1-\theta}}{1-\theta}\right\}$$
$$\text{s.t. } W + \Pi_F + \Pi_M \geq p_g c_g + p_b c_b. \tag{4.3}$$

The corresponding demand functions for risk-averse households are given by

$$c_g(p_g, p_b) = \left[p_g + \left(\frac{p_g}{p_b}\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b\right]^{-1}(W + \Pi_F + \Pi_M), \tag{4.4}$$

$$c_b(p_g, p_b) = \left[\left(\frac{p_b}{p_g}\frac{\sigma}{1-\sigma}\right)^{\frac{1}{\theta}} p_g + p_b\right]^{-1}(W + \Pi_F + \Pi_M). \tag{4.5}$$

We note that for $p_g = p_b$ and $\sigma = \frac{1}{2}$, $c_g(p_g, p_b) = c_b(p_g, p_b) = \frac{W+\Pi_F+\Pi_M}{p_g+p_b}$. We also note that equilibrium prices p_g^* and p_b^* have to be positive as otherwise $c_g(p_g^*, p_b^*)$ or $c_b(p_g^*, p_b^*)$ would not exist.

4.3.3 Market Clearing

We have derived factor and consumption demand functions. For markets to clear at prices $p_b > 0$, $p_g > 0$, the values of all excess demand functions must be equal to zero:

$$y_F(p_g, p_b) + y_M(p_g, p_b) - W = 0, \tag{4.6}$$

$$z_g := c_g(p_g, p_b) - f(y_F(p_g, p_b)) - y_M\overline{R} = 0, \tag{4.7}$$

$$z_b := c_b(p_g, p_b) - f(y_F(p_g, p_b)) - y_M\underline{R} = 0. \tag{4.8}$$

Next we show existence and uniqueness of market equilibrium.

4.3.4 Equilibrium

We first aim at an existence result. Assume first $\overline{R} > \underline{R} > 0$. Because of the Inada conditions, $y_F \in (0, W)$ and because of the equilibrium condition (4.6),

$$y_M = W - y_F. \tag{4.9}$$

It remains to clear the market in the good state and in the bad state. We consider the aggregate excess demand function $z(p)$ where $p = (p_g, p_b)$ and $z = (z_g, z_b)$. Using the equilibrium condition (4.2), we can restrict ourselves to price pairs in the simplex

$$\Delta = \{(p_g, p_b) \in \mathbb{R}^2_+ | \, p_g\overline{R} + p_b\underline{R} = 1\}.$$

z is well defined and continuous in the relative interior of Δ and satisfies a boundary condition. Therefore, we can apply the argument of the proof of Proposition 17.C.1 in Mas-Colell et al. (1995) to z and Δ and obtain existence of $p^* \in \mathsf{Relative\ Interior}(\Delta)$ with $z(p^*) = 0$.

Suppose next $\overline{R} > \underline{R} = 0$. Then the equilibrium condition (4.2) implies $p_g = 1/\overline{R}$, while it imposes no restriction on p_b. Now the formulas (4.1), (4.5) and (4.8) imply $\lim_{p_b \to 0} z_b(1/\overline{R}, p_b) > 0$ and $z_b(1/\overline{R}, p_b) < 0$ for p_b sufficiently large. For the second claim, consider

$$\left[\left(\frac{p_b}{p_g}\frac{\sigma}{1-\sigma}\right)^{\frac{1}{\theta}} p_g + p_b\right] \cdot z_b(1/\overline{R}, p_b) = f(y_F) \cdot \left[p_g - \left(\frac{p_b}{p_g}\frac{\sigma}{1-\sigma}\right)^{\frac{1}{\theta}} p_g\right] + W - y_F.$$

Hence by the intermediate value theorem, there exists $p_b^* > 0$ with $z_b(1/\overline{R}, p_b^*) = 0$. Because of Walras Law, the market for the consumption good in state g is cleared as well.

We have established:

Proposition 4.1
An equilibrium exists.

Since the only household is locally non-satiated, the first welfare theorem applies. Moreover, if $a' = (c'_g, c'_b, y'_F, y'_M)$ and $a'' = (c''_g, c''_b, y''_F, y''_M)$ denote two equilibrium outcomes, then, because of the first welfare theorem, the only household must attain the same utility level in both cases, that is $u(c'_g, c'_b) = u(c''_g, c''_b)$. Suppose $a' \neq a''$. Then they differ in all coordinates due to the particular features of the model. Because of the convexity of the consumption set and both technologies, the convex combination $\frac{1}{2}a' + \frac{1}{2}a''$ is also feasible. But because of the strict convexity of the household's preferences for bundles (c_g, c_b), $u(\frac{1}{2}(c'_g, c'_b) + \frac{1}{2}(c''_g, c''_b)) > \frac{1}{2}u(c'_g, c'_b) + \frac{1}{2}u(c''_g, c''_b) = u(c'_g, c'_b)$, contradicting the optimality of equilibrium consumption. Hence to the contrary, $a' = a''$. We have shown:

Proposition 4.2
Equilibrium allocations are efficient and unique.

The above uniqueness argument further shows:

Corollary 4.1
The Arrow-Debreu equilibrium allocation is the only Pareto optimal allocation.

It is useful to collect some of the findings obtained during the foregoing analysis:

Corollary 4.2
At equilibrium, (4.1), (4.2)*,* $y_F \in (0, W)$*, and* (4.9) *have to hold.*

We conclude this section with some remarks on the role of the Inada conditions. First, one might be concerned that the second Inada condition at $K_F = W$ is not maintained if W changes—unless f would be altered as well. Imposing the Inada conditions on f helps simplify the analysis. But observe that if the economy has an equilibrium with $0 < y_F < W$, then it also has an equilibrium with the same outcomes $p_g, p_b, c_g, c_b, y_F, y_M$ when *ceteris paribus* f is replaced by another production function $\bar{f}$ satisfying decreasing returns to scale, $\bar{f}'(y_F) = f'(y_F)$, and $\bar{f}(y_F) = f(y_F)$. This observation does not require (or rule out) any Inada conditions for $\bar{f}$. An example is $\bar{f}(K_F) = f(K_F)$ for $K_F < y_F$ and $\bar{f}(K_F) = 2(\sqrt{K_F} - \sqrt{y_F})\sqrt{y_F} f'(y_F) + f(y_F)$ for $K_F \geq y_F$.

Second, existence, uniqueness and efficiency of equilibria still obtain if the Inada condition at 0 is violated while the one at W is satisfied. However, then $y_F = 0$ can but need not occur in equilibrium. In case both Inada conditions fail to hold, $y_F = 0$ and $y_F = W$ are possible equilibrium outcomes. Equilibrium is unique and efficient provided it exists. General existence in that case remains an open question. Next, we will provide some examples illustrating these facts.

4.3.5 Examples

We first present one example that satisfies all assumptions. Then, we present another example in which the Inada condition at 0 is violated. In Appendix C.1, we provide three further examples in which one or both Inada conditions are violated and which entail corner solutions. In all examples, we treat the investment good as numéraire.

■ **Example 1:** $0 < y_F < W$ **when both Inada conditions are satisfied.**
Let $W = 1$, $f(K_F) = 2\sqrt{K_F} - K_F$, $\theta = 2$, $\sigma = 2/3$, $\underline{R} = 1/2$ and $\overline{R} = 2$. We obtain the following results:

$$y_F = \left(\frac{q}{1+q}\right)^2, \tag{4.10}$$

$$f(y_F) = \frac{2q+q^2}{(1+q)^2}, \tag{4.11}$$

$$y_M = 1 - \left(\frac{q}{1+q}\right)^2, \tag{4.12}$$

$$\Pi_F = \frac{q^2}{1+q}, \tag{4.13}$$

where $q = p_g + p_b$. Furthermore, we can see that $c_g = [2p_g]^{-1}[1 + \Pi_F]$ from (4.4). Combining this with (4.10) to (4.13) and market clearing conditions (4.6) and (4.7) yields

$$\left(1 + \frac{q^2}{1+q}\right) = 2p_g \left[2 + 2\frac{q}{1+q} - 3\left(\frac{q}{1+q}\right)^2\right],$$
$$1 + 2q + 2q^2 + q^3 - 2p_g\left(2 + 6q + q^2\right) = 0. \tag{4.14}$$

Combining (4.2) with (4.14), we can assert that the markets for the investment good and the consumption good in the good state are cleared at prices $p_g = 1/3$ and $p_b = 2/3$. By Walras law, market clearing in the bad state obtains as well. Hence, $(p_g, p_b) = (1/3, 2/3)$ constitutes the equilibrium. The allocation of the investment good to the production sectors is given by $y_F = 1/4$ and $y_M = 3/4$. Profit in the FT sector is $\Pi_F = 1/2$ and households consume $c_g = 9/4$ and $c_b = 9/8$.

■ **Example 2:** $0 < y_F < W$ **when** $f'(0) < \infty$**.**

We set $W = 1$, $\sigma = 1/2$, $\theta = 1/2$, $\underline{R} = 0$, $\overline{R} = 2$, and assume that $f(K_F) = 2(K_F - \frac{K_F^2}{2})$. We immediately obtain the following results:

$$y_F = 1 - \frac{1}{2q}, \tag{4.15}$$

$$f(y_F) = 1 - \frac{1}{4q^2}, \tag{4.16}$$

$$y_M = \frac{1}{2q}, \tag{4.17}$$

$$\Pi_F = q + \frac{1}{4q} - 1, \tag{4.18}$$

where $q = p_g + p_b$. Since this production function does not satisfy the Inada condition at 0, $f'(0) = 2 < \infty$,

$$p_g + p_b > \frac{1}{2} \tag{4.19}$$

must hold in order for y_F to be positive. For an equilibrium to exist, we need all three market clearing conditions to hold. If (4.15), (4.17) and (4.19) are satisfied, then the market for the investment good is cleared. It remains to clear the market for consumption in both states. Because of Walras law, it suffices to clear the market in the bad state. We set $p_g = 1/\overline{R}$ to meet (4.2). Substituting (4.5), $p_g = 1/\overline{R} = 1/2$, (4.16) and (4.18) in (4.8), we get

$$\begin{aligned} \left[2q^2 - q\right] \cdot [q^2 - \frac{1}{4}] &= q^3 + \frac{1}{4}q \text{ or} \\ 4q^4 - 4q^3 - q^2 &= 0, \end{aligned}$$

which has roots 0 and $\frac{1}{2}(1 \pm \sqrt{2})$. Hence $q = \frac{1}{2}(1 + \sqrt{2})$, $p_g = \frac{1}{2}$, $p_b = \frac{1}{2}\sqrt{2}$, $y_F = 2 - \sqrt{2}$, $y_M = \sqrt{2} - 1$ will do. Profit in the FT sector is $\Pi_F = \sqrt{2} - 1$, households consume $c_g = 4(\sqrt{2} - 1)$ and $c_b = 2(\sqrt{2} - 1)$.

4.3.6 Radner Equilibrium – Equivalence Result

We have derived a frictionless general equilibrium model under uncertainty in the spirit of Arrow and Debreu (see Debreu (1959)). We cannot readily compare the equilibrium prices for contingent goods with returns we will obtain in the financial intermediation case. It is therefore helpful to transform the contingent goods setup from above into one with assets (also called Radner equilibrium in reference to Radner (1982)). Let us introduce two assets with the following returns:

Asset	Price in $t = 1$	Return in state g	Return in state b	
a_1	q_1	R_S	R_S	(4.20)
a_2	q_2	$\overline{R}$	$\underline{R}$,	(4.21)

where R_S ($R_S > 0$) is an arbitrary safe return.

Remark: Throughout the chapter, R_F denotes the marginal product of the FT technology and R_S is the return on safe assets.

Proposition 4.3
The Radner equilibrium defined by the asset structure given by (4.20) *and* (4.21) *is equivalent to the Arrow-Debreu equilibrium we have derived above.*

For a general proof of the equivalence of Arrow-Debreu and Radner equilibria, see Mas Colell et al. (1995), Proposition 19.D.1.

Notice that in our model, there are no future spot markets. We can express the two assets as bundles $a_1 = (R_S, R_S)$ and $a_2 = (\overline{R}, \underline{R})$ in the Arrow-Debreu setting. Hence

$$q_1 = R_S p_g + R_S p_b,\ q_2 = \overline{R} p_g + \underline{R} p_b. \tag{4.22}$$

The matrix of coefficients

$$\mathbb{M} = \begin{pmatrix} R_S & R_S \\ \overline{R} & \underline{R} \end{pmatrix}$$

has inverse

$$\mathbb{M}^{-1} = \frac{1}{R_S(\underline{R} - \overline{R})} \cdot \begin{pmatrix} \underline{R} & -R_S \\ -\overline{R} & R_S \end{pmatrix} = \frac{1}{R_S(\overline{R} - \underline{R})} \cdot \begin{pmatrix} -\underline{R} & R_S \\ \overline{R} & -R_S \end{pmatrix}.$$

Hence

$$\begin{aligned} p_g &= \frac{1}{R_S(\overline{R} - \underline{R})} \cdot (-\underline{R} q_1 + R_S q_2), \\ p_b &= \frac{1}{R_S(\overline{R} - \underline{R})} \cdot (\overline{R} q_1 - R_S q_2). \end{aligned}$$

We conclude this section by the observation that the equilibrium asset price of a_2 in the Radner equilibrium is unity. This follows from (4.22) and (4.2). Hence,

Corollary 4.3
The Radner equilibrium with the asset structure given by (4.20) *and* (4.21) *involves* $q_2 = 1$ *and* $q_1 = \frac{R_S}{R_F^*}$, *where* $R_F^* := f'(y_F^*)$ *is the equilibrium return in FT in the Arrow-Debreu setting.*

4.4 Allocation with Financial Intermediation

Up to this point, we have assumed absence of any frictions and distortions in the economy and analyzed equilibria without considering financial intermediation. In this section, we are going to abandon the assumption of frictionless trade.

4.4.1 Frictions and Distortions

We assume that households cannot directly invest in MT as financing of entrepreneurs e_M is plagued by moral hazard.[10] Banks can alleviate this moral hazard problem by monitoring borrowers and enforcing contractual obligations. As was previously assumed for entrepreneurs and the production technologies, we assume that there is a continuum of banks that have access to a monitoring technology operated by bank managers. Bank managers play only a passive role in our model by operating the monitoring technology.

Banks are funded by households through equity acquisition and deposits. Banks take all funds they receive from households and lend to entrepreneurs e_M or invest in FT. Banks monitor entrepreneurs and maximize expected profits. The details of bank behavior are set out in Section 4.4.4. Furthermore, we assume that deposits are guaranteed by governments in case banks default and that the rescue funds needed for bailouts are raised via taxes. Hence there are two possible distortions—deposit guarantees and taxation — and one financial friction due to moral hazard present in our model.

We make three additional assumptions that promise to be favorable to the validity of a macroeconomic version of the Modigliani-Miller Theorem, that is, that the capital structure of banks may be irrelevant for welfare. First, we assume that banks can eliminate the moral hazard friction completely when investing in the MT technology and that monitoring costs are zero.[11] Consequently, MT becomes simply a risky technology banks can invest in. Second, there is no moral hazard associated with bank managers.[12] Third, taxation is lump-sum and thus non-distortionary. Figure 4.1 gives an overview of the model

[10] See Freixas and Rochet (2008) for an overview of the microeconomic foundations.
[11] This assumption is more stringent than needed. For instance, our results can be extended to situations when entrepreneurs in MT can only pledge a fraction of the output to bankers even if they are monitored. In such circumstances, however, market equilibria have to be compared to appropriate second-best allocations. (Details are available upon request.)
[12] They perform the monitoring activities without compensation.

with frictions and distortions present and banks intermediating funds.

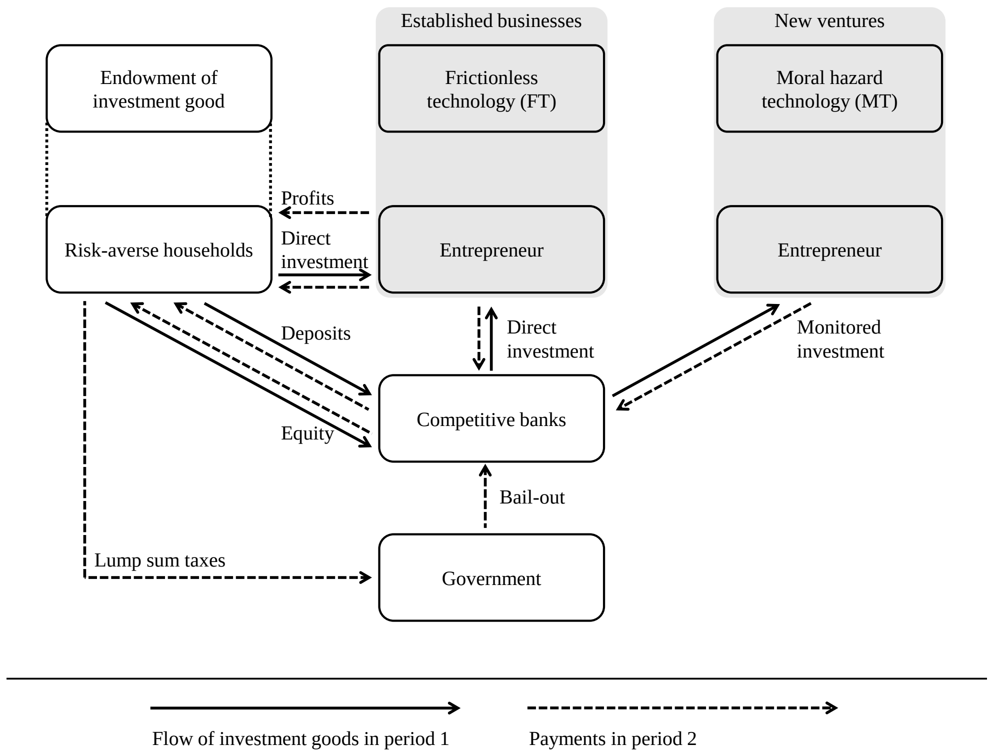

Figure 4.1: Model setup with financial intermediation.

All agents in our economy are price (or contract) takers and thus perfect competition prevails in all markets. Next we characterize the optimal choices of all three agents—households, entrepreneurs, and banks—given the aforementioned friction and distortions.

4.4.2 Optimal Choices of Households

Due to the moral hazard friction, households cannot or would not directly finance entrepreneur e_M. They can, however, lend to entrepreneur e_F if investment returns are more attractive than those of bank deposits.[13]

In this subsection, we investigate the portfolio choice of households. For this purpose, we denote by R_F the return on investment $K_{F,h}$ in FT, by R_D the return on deposits D and by $\overline{R}_E$ and $\underline{R}_E$ the returns on bank equity E in the good and bad state, respectively.[14] Hence part of initial wealth W can be saved risk-free, paying out $R_S = \max\{R_F, R_D\}$ per unit of investment. Alternatively, a household can purchase bank equity with return

[13] If households are indifferent between depositing money at a bank or investing in FT, the allocation of funds to these two risk-free assets is determined by equilibrium requirements.

[14] D and E denote the amount of investment goods households supply to banks in the form of safe deposits and equity, respectively. $K_{F,h}$ denotes the amount of investment goods households supply to firms in FT.

$\overline{R}_E$ or $\underline{R}_E$. In period two, it consumes its returns from both investments after having received its share of profits from the firm operating the FT technology and paid the tax T (if any).[15]

The solution to the households' optimal portfolio choice problem can be expressed by means of a variable γ, the optimal share of wealth held in risk-free assets. A fraction of risk-free assets consists of bank deposits, while the rest accounts for direct investment in FT. The first-order conditions for the households' optimal portfolio choice yield (see Appendix C.2):

Lemma 4.1

$$\gamma = \frac{(1/W)[\Pi_F(1-A_1)+TA_1]+\overline{R}_E - A_1\underline{R}_E}{\overline{R}_E - R_S + A_1(R_S - \underline{R}_E)}, \tag{4.23}$$
$$\text{where } A_1 := \left[\frac{\sigma(\overline{R}_E - R_S)}{(1-\sigma)(R_S - \underline{R}_E)}\right]^{\frac{1}{\theta}}.$$

Observe that $A_1 > 0$ holds if $\overline{R}_E > R_S > \underline{R}_E$ and $A_1 > 1$ holds if $\sigma\overline{R}_E + (1-\sigma)\underline{R}_E > R_S$. The variables Π_F, T, $\overline{R}_E$, $\underline{R}_E$ and R_S are determined in equilibrium. In turn, they determine A_1 and γ. We will show that in equilibrium $0 < \gamma \leq 1$.

Households will supply their wealth as follows:

$$\begin{aligned} D &= \lambda\gamma W, \\ K_{F,h} &= (1-\lambda)\gamma W, \\ E &= (1-\gamma)W. \end{aligned}$$

Here λ denotes the share of risk-free assets held in the form of deposits and $1-\lambda$ denotes the share held in the form of direct investment in FT. We have

$$\lambda = \begin{cases} 0 & \text{if } R_F > R_D, \\ 1 & \text{if } R_F < R_D, \\ \in [0,1] & \text{if } R_F = R_D. \end{cases} \tag{4.24}$$

4.4.3 Optimal Choices of Entrepreneurs

As in the Arrow-Debreu case, entrepreneurs are passive in the sense that they only run the technologies. Again, entrepreneurs – as agents of their firm – maximize profits. But

[15] As profits of entrepreneurs e_M will be zero in equilibrium, we neglect them in this subsection already.

instead of maximizing present value, they are going to maximize future value in this section.[16] In order to do so, they borrow in period one.

Entrepreneur e_F solves the following problem:

$$\max \{\Pi_F(K_F) = f(K_F) - R_F K_F\}, \tag{4.25}$$

where R_F is the repayment obligation (principal plus interest) per unit at which she can borrow funds from banks and households (see below). The entrepreneur optimally raises the amount K_F of funds in period one. In lieu of (4.1) we get

$$K_F = f'^{-1}(R_F). \tag{4.26}$$

Entrepreneur e_M solves the following problem:

$$\begin{aligned} &\max \left\{\Pi_M(K_M) = \left[\sigma(\overline{R} - \overline{R}_M) + (1-\sigma)(\underline{R} - \underline{R}_M)\right] K_M\right\} \\ &\text{s.t.} \qquad \sigma(\overline{R} - \overline{R}_M)K_M \geq 0, \\ &\qquad (1-\sigma)(\underline{R} - \underline{R}_M)K_M \geq 0. \end{aligned}$$

Due to moral hazard (see Section 4.4.1), banks monitor this entrepreneur. Therefore, they are able to offer state contingent repayment rates $\overline{R}_M = 1 + \overline{r}_M$ and $\underline{R}_M = 1 + \underline{r}_M$, where $\overline{r}_M$ and $\underline{r}_M$ are the state contingent interest rates. The two constraints mean that the entrepreneur is able to fulfill his repayment obligation in both states. Moreover, we assume that perfect monitoring prevails and banks can enforce the terms of the loan contract: The entrepreneur cannot cheat, threaten to voluntarily default or renegotiate the credit terms in period 2. The production function is linear and, therefore, profits will be zero in equilibrium. Otherwise, entrepreneur e_M will either demand no funds at all from banks or an infinite amount. As a result, we need $\overline{R}_M = \overline{R}$ and $\underline{R}_M = \underline{R}$ in any potential equilibrium. Consequently, the optimal choice of funds raised in period one is $K_M \in [0, \infty]$. In equilibrium, we have again (4.9).

4.4.4 Optimal Choices of Banks

There is a continuum of banks $v \in [0, 1]$ that are financed by equity e_v and interest bearing deposits d_v.[17] They can lend $l_{F,v}$ to entrepreneur e_F and $l_{M,v}$ to entrepreneur e_M. The typical balance sheet of a bank v in period $t = 1$ looks like:

---

[16] For convenience, we use the same symbols Π_F and Π_M to denote the future value of profits.

[17] Equity is outside equity in our model since households are passive shareholders. As stressed in Section 4.4.1, there is no moral hazard of bank managers and thus no need to have inside equity. For foundations of counter-cyclical capital ratios in the presence of inside equity and moral hazard of bankers, see

$l_{F,v}$	d_v
$l_{M,v}$	e_v
a_v	o_v

Table 4.1: Bank balance sheet

Here, a_v and o_v stand for total assets (*activa*) and total liabilities (*passiva*, obligations), respectively. Assets a_v equal liabilities o_v in period $t = 1$. Initially, banks are only a label or index. After they have received equity, the objective of banks is to maximize expected profits or, equivalently, return on equity (ROE).[18] The objective of a bank without equity is questionable. However, bank equity is positive in the equilibria depicted in Propositions 4.4, 4.5 and 4.6. In Proposition 4.7, we assume that bank equity is non-zero so that maximization of the expected return on equity is a meaningful objective.

We observe that the maximization of ROE is equivalent to shareholder value (SV) maximization. SV maximization is usually defined as the maximization of the current value of the firm, which can be derived by discounting the firm's free cash flows minus the cost of non-equity liabilities. In our two-period case, the objective of banks maximizing expected SV would read as

$$\max_{\alpha} \left\{ \mathbb{E}[SV(\alpha)] = \rho \mathbb{E}\left[\max\left\{ 0, \left((\alpha \tilde{R} + (1-\alpha) R_F)(d_v + e_v) - R_F d_v \right) \right\} \right] \right\},$$

where the discount factor is given by $\rho = \frac{1}{R_F}$. As one can readily see, this maximization problem is equivalent to ROE maximization (cf. Equation (4.28) below).

Eventually, note that in our case—in which banks take d_v and e_v as given—the maximization of ROE is also equivalent to the maximization of the utility of shareholders. First, the investment plan of one particular individual bank—that is, its choice of α—is spanned by the asset structure in our economy, which is determined by the return on other banks' equity and the return on safe bonds. Second, we have assumed that banks are perfectly competitive. By perfect competition we understand that an individual bank takes all prices as constants, that is, its investment decision does not alter prices in our economy. The only effect of a change of a bank's investment decision will be on the budget constraint of its shareholders.[19] Therefore, all shareholders will unanimously agree that

Gersbach and Rochet (2012b).

[18] We stress that there are two equivalent ways to specify the objective of banks when banks are bailed out in case of default. First, banks maximize expected profits. Since deposits are guaranteed by the government, banks anticipate that profits in case of default are zero. Second, banks maximize the expected return on equity (ROE) and are subject to limited liability and thus return on equity in case of default is zero as well.

[19] This follows from the fact that neither does such a change open up new insurance possibilities (the investment plan is already spanned by the economy's asset structure) nor does the bank exert any market

the bank maximizes its current value. As we have just seen, this is equivalent to ROE maximization.

Since banks are only labels in the beginning, we may assume that all banks receive the same amount of equity and deposits.[20] Hence, total assets a_v are the same for all banks. Therefore, we proceed as if there is only one representative bank receiving D deposits and E equity, and we drop the subscript v in the following. Then a_v becomes simply a etc., and all variables in banking are understood as aggregate quantities. In Chapter 5, we will examine the situation in which individual banks are founded with different amounts of equity and decide individually what amount of deposits to accept. We shall also analyze equilibria when an individual bank could deviate from the equilibrium debt-equity ratio by simultaneously changing its debt and equity—but would not benefit from doing so.

Let us denote by $\alpha \in [0, 1]$ the fraction of its total funds that a bank has invested in risky loans to entrepreneur e_M. Then we can express the amount l_M of loans to entrepreneur e_M as $\alpha(D + E)$ and the amount l_F of funds provided to entrepreneur e_F as $(1 - \alpha)(D + E)$.

An important remark is in order. D and E are the amount of investment goods banks receive in the form of deposits and equity, respectively. D and E are also the amount of deposits and equity contracts. Of course, we have to check in any equilibrium that the prices of deposits and equity are 1, justifying the use of D and E in these two meanings. In Proposition 4.6 and Proposition 4.7, we will have to differentiate explicitly the amounts of contracts and amounts of investment goods banks receive. Then D and E denote the amount of contracts and $p_d D$ and $p_e E$ are the amount of investment goods banks receive when p_d and p_e are the prices of deposits and equity in units of the investment good, respectively.

Perfect competition in the banking sector ensures that banks lend to e_F at the same rate R_F as households.[21] For entrepreneur e_M, repayment rates are $\overline{R}$ and $\underline{R}$, respectively (see above). Furthermore, perfect competition leads to

$$R_D = R_F, \tag{4.27}$$

that is, banks borrow and lend at the same (endogenous) risk-free rate.[22]

power, that is, all prices remain constant.

[20] Alternatively, one can assume that banks receive the same ratio of debt and equity but may be of different size.

[21] More precisely, there exists no equilibrium in which those returns can be different and both households and banks invest a positive amount in FT.

[22] Again, there is no equilibrium in which households invest in FT and in bank deposits in which $R_D \neq R_F$.

Banks' objective is

$$\max_{\alpha}\left\{\mathbb{E}\left[ROE(\alpha)\right]=\mathbb{E}\left[\max\left\{0,\frac{\left[\alpha\tilde{R}+(1-\alpha)R_F\right](D+E)-R_F D}{E}\right\}\right]\right\}. \quad (4.28)$$

Recall that $\tilde{R}$ is the random return in MT. Let us define $B_1 := \sigma\overline{R}+(1-\sigma)\underline{R}-R_F$ and $B_2 := [\sigma\overline{R}-R_F](D+E)+(1-\sigma)R_F D$. We obtain the following optimal values for α:[23]

$$\begin{array}{rcl}
B_1 > 0 & \Rightarrow & \alpha = 1\\
B_2 > 0 & \Rightarrow & \alpha = 1\\
B_1 < 0 \text{ and } B_2 = 0 & \Rightarrow & \alpha \in \{0,1\}\\
B_1 = 0 \text{ and } B_2 \leq 0 & \Rightarrow & \alpha \in [0,1]\\
B_1 < 0 \text{ and } B_2 < 0 & \Rightarrow & \alpha = 0
\end{array}$$

Total supply of funds is

$$L_M = \alpha(D+E) \text{ and} \quad (4.29)$$

$$L_F = (1-\alpha)(D+E) \quad (4.30)$$

for the MT and the FT sector, respectively. Next, we will prove existence of equilibria.

4.4.5 Equilibria

We distinguish between different equilibria depending on whether defaults happen with positive probability or not. Note that $K_F = K_{F,h} + L_F$ and $K_M = L_M$ in the financial intermediation case are equivalent to the variables y_F and y_M, respectively, in the Arrow-Debreu case. Throughout this section, we will use the equilibrium values obtained in the Arrow-Debreu setting. To avoid confusion, these equilibrium values are denoted by p_g^*, p_b^*, c_g^*, c_b^*, y_F^*, y_M^* and R_F^*.

Equilibria without default

We first consider equilibria with financial intermediation, yet without defaults and $T = 0$. This corresponds to the frictionless case except for the condition that investment in the risky technology can only take place through banks. The next proposition establishes existence of an equilibrium with financial intermediation that is equivalent to the Arrow-Debreu equilibrium derived in Section 4.3.

[23] For a derivation of the optimal values of α, see Appendix C.3.

Proposition 4.4
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$. Then there exists an equilibrium with financial intermediation where the investment in FT is y_F^*, the investment in the risky technology is y_M^*, $D = 0$, banks only invest in the risky technology and never default.

The proof of Proposition 4.4 can be found in Appendix C.4. This equilibrium corresponds to a banking system in which all banks are funded by equity only.[24]

Proposition 4.4 means that the efficient Arrow-Debreu equilibrium allocation is still an equilibrium outcome when households cannot directly invest in the risky technology and banks are maximizing return on equity. When banks are funded by equity only, the return on equity is solely determined by the return of the risky technology. Intuitively, this can be interpreted as the removal of financial frictions without changing households' investment options from the Arrow-Debreu setup (that is, the variant with assets; see Section 4.3.6). We stress that the result hinges on the fact that banks can perfectly monitor entrepreneur e_M at no cost, can charge entrepreneur e_M state-contingent interest rates and are perfectly competitive. Next we investigate to what extent this particular equilibrium is unique.

Proposition 4.5
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$. Then the equilibrium with financial intermediation and no default in Proposition 4.4 is unique if $\underline{R} = 0$. In case $\underline{R} > 0$, there exists an equilibrium with financial intermediation for each $D \in [0, y_M^* \cdot \underline{R}/R_F^*]$ where the investment in FT is y_F^*, the investment in the risky technology is $y_M^* = E + D$, banks only invest in the risky technology and never default.

The proof of Proposition 4.5 is given in Appendix C.4. These equilibria correspond to a stable banking system in which banks are funded by equity and deposits.

Proposition 4.5 states that up to a critical debt-equity ratio, the capital structure of banks is irrelevant to aggregate investment and risk. Banks' debt-equity ratio is low enough so that losses are absorbed by equity holders and there are no defaults. Banks raise and invest the socially optimal amount of resources. Intuitively, the more a bank is financed with debt, the riskier its equity becomes. Facing riskier investment choices, risk-averse households desire more risk-free debt and less risky equity. The extra amount of risk-free debt required due to increased risk equals exactly the amount of deposits that have increased the risk of equity in the first place. We next investigate the case where the debt-equity ratio exceeds the critical level.

[24] The deposit return is indeterminate. Apart from $R_D = R_F^*$, any values $R_D < R_F^*$ can occur in equilibrium. They do not affect the allocation.

Equilibria with default

In the following, we explore equilibria where banks default in the bad state and consequently $T > 0$ has to hold. We consider again the case where the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$.

Proposition 4.6
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$. Then there exist equilibria with financial intermediation where the investment in FT is strictly smaller than y_F^*, the investment in the risky technology is $E + D$, banks only invest in the risky technology and default in the bad state. The resulting equilibrium allocation is inefficient.

The proof of Proposition 4.6 can be found in Appendix C.4. These equilibria describe a fragile banking system. The debt-equity ratio of banks is too high in the sense that equity does not suffice to absorb losses in the bad state.

Proposition 4.6 means that above a certain debt-equity ratio, inefficient equilibria arise. While too little is invested in the FT sector, there is over-investment in the risky technology. Within this class of equilibria, banks raise too much funds. They achieve high returns on equity in the good state and default in the bad state. In unfettered markets, the macroeconomic version of the Modigliani-Miller Theorem fails to hold. Some capital structures of banks alter aggregate investment and risk: welfare is lower than in the Arrow-Debreu allocation. This is remarkable insofar as we assume no monitoring costs and taxes are lump-sum.

4.4.6 Examples

Next, we reconsider the examples from Section 4.3 and adopt them to the case with financial intermediation. This allows to illustrate all main findings.

■ **Example 1'**

Recall that $W = 1$, $f(K_F) = 2\sqrt{K_F} - K_F$, $\sigma = 2/3$, $\theta = 2$, $\underline{R} = 1/2$ and $\overline{R} = 2$. We obtain

$$K_F = \left(\frac{1}{1+R_F}\right)^2, \tag{4.31}$$

$$f(K_F) = \frac{1}{1+R_F}\left[2 - \frac{1}{1+R_F}\right], \tag{4.32}$$

$$K_M = 1 - \left(\frac{1}{1+R_F}\right)^2, \tag{4.33}$$

$$\Pi_F = \frac{1}{1+R_F}. \tag{4.34}$$

Efficient Equilibria

We first consider the case without any deposits. We set $R_F = R_F^* = 1/(p_g^* + p_b^*)$ and thus $R_F = 1$. Entrepreneur e_F optimally chooses $K_F = 1/4$, implying $\Pi_F = 1/2$. $K_M = 3/4$ is an optimal choice for entrepreneur e_M. Provided $D = 0$, we can assert that $T = 0$ and returns on equity are $\overline{R}_E = \overline{R}$ and $\underline{R}_E = \underline{R}$. Thus we are given $B_1 = 1/2 > 0$. Banks optimally choose $\alpha = 1$ and invest in the risky technology only. Applying (4.23), we conclude that households optimally choose $\gamma = 1/4$, that is, they optimally invest one quarter of their wealth in riskless assets. For $D = 0$, they invest $K_F = 1/4$ directly in FT and $E = 3/4$ in bank equity. The resulting equilibrium yields the same allocation as in the Arrow-Debreu case. We obtain $y_F = 1/4$ and $y_M = 3/4$. Households consume $c_g = 9/4$ and $c_b = 9/8$.

Next we investigate an efficient equilibrium with deposits. Proposition 4.5 implies that for allocations with total amount of deposits below a certain threshold, the efficient Arrow-Debreu allocation is attained. Here we need $D \leq 3/8$. Again, we set $R_F = R_F^* = 1$, implying $K_F = 1/4$ and $\Pi_F = 1/2$. We set $D = 1/4$. As $B_1 = 1/2 > 0$, banks invest in the risky technology only. Return on equity is given by $\overline{R}_E = 5/2$ and $\underline{R}_E = 1/4$. Applying (4.23), we obtain that households optimally choose $\gamma = 1/2$. Thus they invest $E = 1/2$ in bank equity, $D = 1/4$ in deposits and $K_F = 1/4$ directly in the frictionless technology. The allocation of investment goods to the production sectors is still the same as in the Arrow-Debreu case and given by $y_F = 1/4$ and $y_M = 3/4$. Households consume $c_g = 9/4$ and $c_b = 9/8$.

Inefficient Equilibria

Proposition 4.6 states that there exist inefficient equilibria in which banks attract too many resources and default in the bad state. We illustrate this class of equilibria by setting $R_F = 5/4 > R_F^*$. Entrepreneur e_F optimally chooses $K_F = 16/81$, implying $\Pi_F = 4/9$.

Since $B_1 = 1/4 > 0$, banks only invest in the risky technology. Return on equity is given by $\overline{R}_E = 2 + \frac{3D}{4E}$ and $\underline{R}_E = 0$, as banks default in the bad state. Taxes are given by $T = \frac{3}{4}D - \frac{1}{2}E$. Applying (4.23), we can write the market clearing condition for equity as

$$E = 1 - \frac{\left[\frac{27D-18E-16}{36}\right]\left[\frac{6}{5}\frac{D+E}{E}\right]^{1/2} + \frac{88E+27D}{36E}}{\frac{27}{36}\left[1+\frac{D}{E}\right] + \frac{45}{36}\left[\frac{6}{5}\frac{D+E}{E}\right]^{1/2}}. \tag{4.35}$$

Since banks invest in the risky technology only, we can assert that $E = 65/81 - D$. Combining this with (4.35) and simplifying, we obtain

$$\left(59\sqrt{\frac{78}{65-81D}} - 124\right)(81D - 65) = 0.$$

An inefficient equilibrium exists in which households invest $E = \frac{45253}{207576} \approx 0.22$ in bank equity, $D = \frac{363961}{622728} \approx 0.58$ in deposits and $K_F = \frac{16}{81} \approx 0.20$ directly in the frictionless technology. Bank bailouts in the bad state are financed via lump-sum taxes $T = \frac{273455}{830304} \approx 0.33$. We obtain $y_F = \frac{16}{81} \approx 0.20$ and $y_M = \frac{65}{81} \approx 0.80$ and households consume $c_g = \frac{62}{27} \approx 2.30$ and $c_b = \frac{59}{54} \approx 1.09$.

■ Example 2'

Recall that $W = 1$, $\sigma = 1/2$, $\theta = 1/2$, $\underline{R} = 0$, $\overline{R} = 2$, and $f(K_F) = 2(K_F - \frac{K_F^2}{2})$. As $f'(0) = 2 < \infty$, for K_F to be positive

$$R_F < 2 \tag{4.36}$$

must hold. We obtain the following results:

$$K_F = 1 - \frac{1}{2}R_F, \tag{4.37}$$

$$f(K_F) = 1 - \frac{1}{4}R_F^2, \tag{4.38}$$

$$\Pi_F = 1 + \frac{1}{4}R_F^2 - R_F. \tag{4.39}$$

Efficient Equilibrium

We set $R_F = R_F^* = 1/(p_g^* + p_b^*)$ and thus $R_F = 2\sqrt{2} - 2$. Entrepreneur e_F optimally chooses $K_F = 2 - \sqrt{2}$, implying $\Pi_F = 6 - 4\sqrt{2}$.[25] $K_M = \sqrt{2} - 1$ is an optimal choice for entrepreneur e_M. Provided $D = 0$, we can assert that $T = 0$ and returns on equity

[25] Note that this profit is denoted in period two consumption goods. Hence, it cannot be readily compared to the present value profit obtained in the Arrow-Debreu case, which is denoted in period one investment goods.

are $\overline{R}_E = \overline{R}$ and $\underline{R}_E = \underline{R}$. Since $B_1 = 3 - 2\sqrt{2} > 0$, banks optimally choose $\alpha = 1$, that is, invest in the risky technology only. Applying (4.23), we obtain that households optimally choose $\gamma = 2 - \sqrt{2}$. For $D = 0$, they invest $K_F = 2 - \sqrt{2}$ directly in FT and $E = \sqrt{2} - 1$ in bank equity. The resulting allocation is the same as in the Arrow-Debreu case. We obtain $y_F = 2 - \sqrt{2}$ and $y_M = \sqrt{2} - 1$. Households consume $c_g = 4(\sqrt{2} - 1)$ and $c_b = 2(\sqrt{2} - 1)$. This is the only efficient equilibrium in this example as banks will default in the bad state with any positive amount of deposits.

Inefficient Equilibria

Proposition 4.6 states that there exist inefficient equilibria in which banks attract too many resources and default in the bad state. We illustrate this class of equilibria by setting $R_F = 1 > R_F^*$. Entrepreneurs optimally choose $K_F = 1/2$, implying $\Pi_F = 1/4$. Since $B_1 = 0 \geq 0$ for every positive amount of D, investing in the risky technology only is an optimal choice for banks. Return on equity is given by $\overline{R}_E = 2 + D/E$ and $\underline{R}_E = 0$, as banks default in the bad state. Taxes are given by $T = D$. Applying (4.23), we can write the market clearing condition for equity as

$$E = 1 - \frac{\frac{1}{4} + \left[D - \frac{1}{4}\right]\left[\frac{D+E}{E}\right]^2 + \frac{D+2E}{E}}{\left[\frac{D+E}{E}\right]\left[\frac{D+2E}{E}\right]}. \tag{4.40}$$

Since banks invest in the risky technology only, we can assert that $E = 1/2 - D$. Combining this with (4.40) and simplifying, we obtain

$$7D^2 - 7D + 1 = 0.$$

An inefficient equilibrium exists in which households invest $D = \frac{1}{2}(1 - \sqrt{\frac{3}{7}}) \approx 0.17$ in deposits, $E = \frac{1}{2}\sqrt{\frac{3}{7}} \approx 0.33$ in bank equity and $K_F = \frac{1}{2}$ directly in the frictionless technology. Bank bailouts in the bad state are financed via lump-sum taxes $T = \frac{1}{2}(1 - \sqrt{\frac{3}{7}}) \approx 0.17$. We obtain $y_F = \frac{1}{2}$ and $y_M = \frac{1}{2}$. Households consume $c_g = \frac{7}{4}$ and $c_b = \frac{3}{4}$.

4.5 Bank Regulation

We next introduce and discuss two regulatory measures that can eliminate all inefficient equilibria.[26]

[26] A third regulatory measure could be private insurance along the lines of Gersbach (2009), in which banks need to buy insurance against default in the private market place. An entirely different policy approach would be to tax risky investments made by banks and to use these revenues to bail out banks in case of default.

4.5.1 Bank Capital Regulation

We have shown that the macroeconomic version of the Modigliani-Miller Theorem fails to hold in unfettered markets. Above a certain debt-equity ratio in the banking sector, banks' capital structure is relevant as aggregate investment can deviate from the socially optimal level. From Propositions 4.5 and 4.6 we obtain:

Corollary 4.4
The class of inefficient equilibria can be eliminated by imposing a minimum bank capital requirement in the form of an upper bound on the debt-equity ratio:

$$\frac{D}{E} \leq \varphi := \frac{\underline{R}}{R_F^* - \underline{R}}. \tag{4.41}$$

We note that at the regulatory debt-equity ratio we have

$$\frac{D}{E} = \frac{\underline{R}}{R_F^* - \underline{R}} = \frac{\frac{y_M^* \underline{R}}{R_F^*}}{y_M^* - \frac{y_M^* \underline{R}}{R_F^*}}.$$

In this case, D and E correspond to the critical values of the maximal debt-equity ratio that can be supported in an equilibrium that yields the same allocations as the Arrow-Debreu equilibrium. Hence, first-best allocations are guaranteed if banks are required to operate with debt-equity ratios below $\frac{\underline{R}}{R_F^* - \underline{R}}$. Given this constraint, the macroeconomic version of the Modigliani-Miller Theorem holds. The capital structure of banks is irrelevant and equilibria are efficient. We further note that the regulatory capital requirement can also be expressed in terms of a minimum requirement for the ratio of equity to assets:

$$\frac{E}{y_M^*} \geq \frac{y_M^* - \frac{y_M^* \underline{R}}{R_F^*}}{y_M^*} = \frac{R_F^* - \underline{R}}{R_F^*}.$$

An important consequence of Corollary 4.4 is that for a given risk-free interest rate and a given amount of deposits, banks have to be funded the more by equity, the lower are the returns of the risky technology in the bad state. This is intuitive as the interest on deposits determines banks' repayment obligations and the returns of the risky technology determines how much funds banks have available to meet those obligations.

We conclude the discussion of optimal bank capital regulation with two remarks. First, bank capital regulation in the spirit of the one displayed in Corollary 4.4 can be interpreted as a risk-sensitive capital requirement as it is calculated using the returns of the asset in the bad state. Second, an important consequence of our results is that while more stringent capital requirements can lower the return on bank equity, they do not impose any social costs. Thus, stricter capital requirements than φ, which do not rely on precise measurements of the asset risks, will also implement first-best allocations.[27]

4.5.2 Commitment to Bankruptcy

We conclude the regulatory section with the observation that Pareto efficiency could also be achieved by forcing failing banks into bankruptcy when bankruptcy costs are zero. This means that default of banks does not impede efficiency if bankruptcy costs are zero and the government can commit itself not to intervene.

Proposition 4.7
Suppose costs of bank bankruptcy are zero independently of how many banks fail. Suppose further that bank equity is non-zero so that maximization of the expected return on equity is a meaningful objective. Then the allocation in any equilibrium is efficient if the regulator forces all failing banks into bankruptcy.

The proof of Proposition 4.7 is given in Appendix C.4. Here we provide the intuition. First, if debt-equity ratios of banks are low, there are no defaults. Return on bank equity and on deposits is such that all equilibria without default are equivalent to Radner equilibria as characterized in Proposition 4.3. Hence, all equilibria without default continue to be equilibria. Second, if debt-equity ratios are too high and banks default in the bad state, the return on deposits adjusts since banks are no longer bailed out. Return on bank equity and on deposits will be such that all equilibria with default are ultimately equivalent to Radner equilibria.

4.6 Conclusion

Incorporating a banking sector into a general equilibrium model proves a challenge that can be dealt with. The most intriguing finding is that efficient and inefficient equilibria can coexist despite minimal market frictions and perfect competition among banks as well as all other market participants. In inefficient equilibria, the capital structure of the banking sector distorts the optimal risk allocation in the economy and the macroeconomic version of the Modigliani-Miller Theorem fails to hold. Regulatory measures such as minimal capital requirements can eliminate these inefficient equilibria.

There are several potential extensions to our model. First, we could introduce heterogeneous households with respect to risk aversion. While this extension promises valuable

[27] In our model, even extremely low bounds on debt-equity ratios are consistent with Pareto-efficiency.

insights into distributional effects of different capital structures, they will not fundamentally alter the core insight of the model. Second, the special role of bank deposits as a medium of exchange is well known and could be introduced. When deposits provide payment services above their role as a store of value, the debt-equity ratio in unregulated markets will likely remain above some level, that is, banks funded by equity only will not emerge in equilibrium. However, this does not alter the policy guideline for keeping the debt-equity ratio in the banking sector below a certain threshold in order to avoid an inefficient investment allocation in the economy. Finally, one could incorporate banks with market power. In that case, inefficient equilibrium outcomes are to be expected, and it would become a further challenge to compare the inefficiencies associated with various policy regimes.

5 Banking in General Equilibrium: Extensions and Generalizations

5.1 Introduction

In this chapter, we extend the analysis presented in Chapter 4. First, we provide a detailed account of the set of equilibria arising in our baseline model. We begin by characterizing the inefficient equilibria more precisely. Then, we investigate the effect of a change in macroeconomic risk and a shift in risk aversion on equilibrium values.

Second, we look at different ways how banks determine their levels of equity and deposits. In particular, we relax the assumption that all banks are funded equally and that the individual debt-equity ratio is determined by the aggregate debt-equity ratio of banks. On the one hand, we examine equilibria when banks choose to issue their liability claims sequentially. On the other hand, the consequences of individual banks deviating from the aggregate debt-equity ratio in equilibrium is investigated.

Third, the assumption of risk-averse households is abandoned. We determine both frictionless equilibria and equilibria with financial intermediation when households are risk-neutral.

Before we proceed with our extended analysis, let us restate some of the key results from the baseline model for the ease of presentation.

Key Results from Chapter 4

The frictionless allocation can be characterized by the following market clearing conditions:

$$y_F(p_g, p_b) + y_M(p_g, p_b) - W = 0, \tag{5.1}$$

$$z_g := c_g(p_g, p_b) - f(y_F(p_g, p_b)) - y_M(p_g, p_b)\overline{R} = 0, \tag{5.2}$$

$$z_b := c_b(p_g, p_b) - f(y_F(p_g, p_b)) - y_M(p_g, p_b)\underline{R} = 0. \tag{5.3}$$

Recall that the equilibrium condition

$$p_g\overline{R} + p_b\underline{R} = 1 \tag{5.4}$$

has to hold. Further, we derived

Corollary 5.1
The Radner equilibrium with the asset structure given by $\{q_1 : R_S, R_S\}$ *and* $\{q_2 : \overline{R}, \underline{R}\}$ *involves* $q_2 = 1$ *and* $q_1 = \frac{R_S}{R_F^*}$*, where* $R_F^* := f'(y_F^*)$ *is the equilibrium return in FT in the Arrow-Debreu setting.*

In the case with moral hazard frictions and with financial intermediation, we derived the following three propositions describing possible equilibria:

Proposition 5.1
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$*. Then there exists an equilibrium with financial intermediation where the investment in FT is* y_F^**, the investment in the risky technology is* y_M^**,* $D = 0$*, banks only invest in the risky technology and never default.*

Proposition 5.2
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$*. Then the equilibrium with financial intermediation and no default in Proposition 5.1 is unique if* $\underline{R} = 0$*. In case* $\underline{R} > 0$*, there exists an equilibrium with financial intermediation for each* $D \in [0, y_M^* \cdot \underline{R}/R_F^*]$ *where the investment in FT is* y_F^**, the investment in the risky technology is* $y_M^* = E + D$*, banks only invest in the risky technology and never default.*

Proposition 5.3
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$*. Then there exist equilibria with financial intermediation where the investment in FT is strictly smaller than* y_F^**, the investment in the risky technology is* $E + D$*, banks only invest in the risky technology and default in the bad state. The resulting equilibrium allocation is inefficient.*

Finally, recall that imposing a bank capital regulation can ensure the validity of the macroeconomic version of the Modigliani-Miller Theorem:

Corollary 5.2
The class of inefficient equilibria can be eliminated by imposing a minimum bank capital requirement in the form of an upper bound on the debt-equity ratio:

$$\frac{D}{E} \leq \varphi := \frac{\underline{R}}{R_F^* - \underline{R}}. \tag{5.5}$$

5.2 Nature of Equilibria

We start our detailed analysis by taking a closer look at the inefficient equilibria that might arise with financial intermediation. Second, we examine the effect of a change in macroeconomic risk. Finally, we explore the impact on equilibrium values when we alter the degree of households' risk aversion.

5.2.1 Extended Characterization of Inefficient Equilibria

In what follows, we study the set of inefficient equilibria in the case with financial intermediation. We begin by further specifying Proposition 5.3.

Proposition 5.4
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$. Then there exists a continuum of equilibria with financial intermediation where the investment in FT is strictly smaller than y_F^* and greater than or equal to $f'^{-1}(\mathbb{E}[\widetilde{R}])$, the investment in the risky technology is $E + D$, banks only invest in the risky technology and default in the bad state. The resulting equilibrium allocation is inefficient.

The proof of Proposition 5.4 can be found in Appendix D. The proposition explicitly states that there is a continuum of inefficient equilibria. This generalizes Proposition 5.3, in which we only showed that an inefficient equilibrium exists.

We next go into more detail regarding the continuum of equilibria characterized by this proposition. We show that the equilibria can be indexed by the debt-equity ratios of banks. In particular, we prove that the debt-equity ratios of banks are increasing in the equilibrium return of the safe asset R_F.

Proposition 5.5
Let $\{\hat{E}, \hat{D}, \hat{K}_F, \hat{K}_M, \hat{R}_F\}$ and $\{\hat{\hat{E}}, \hat{\hat{D}}, \hat{\hat{K}}_F, \hat{\hat{K}}_M, \hat{\hat{R}}_F\}$ denote two distinct inefficient equilibria with financial intermediation in the spirit of Proposition 5.4. Further, let $\hat{R}_F < \hat{\hat{R}}_F$. Then the debt-equity ratio of banks is higher in the second equilibrium, in particular, $\hat{E} > \hat{\hat{E}}$ and $\hat{D} < \hat{\hat{D}}$.

The proof of Proposition 5.5 is given in Appendix D. While interesting in itself, Proposition 5.5 will be especially helpful in showing that there are equilibria where $R_F > \mathbb{E}[\widetilde{R}]$. Before we do so, let us show that banks are never willing to invest in MT if $R_F > \overline{R}$:

Proposition 5.6
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$. *Then there exist no equilibria with financial intermediation where investment in the frictionless technology is less than* $f'^{-1}(\overline{R})$.

The proof of Proposition 5.6 can be found in Appendix D. This result is quite intuitive: banks are not willing to invest in MT if the safe return on FT is higher than the highest possible return in MT. Rather counterintuitive, however, is the fact that depending on the level of equity and deposits, banks might be willing to only invest in MT, even as $R_F \to \overline{R}$. Observe that

$$B_2 = [\sigma\overline{R} - R_F](D + E) + (1 - \sigma)R_F D > 0$$

can be rewritten as $[\sigma\overline{R} - R_F]E + \sigma[\overline{R} - R_F]D > 0$. As long as $R_F < \overline{R}$ and $E << D$, we obtain $B_2 > 0$, and banks optimally choose $\alpha = 1$. We next show:

Proposition 5.7
Suppose the Arrow-Debreu equilibrium allocation satisfies $0 < y_F^* < W$. *Then there exist equilibria with financial intermediation where the investment in FT is strictly smaller than* $f'^{-1}(\mathbb{E}[\widetilde{R}])$ *and investment in the risky technology is* $E + D$. *Although the return in FT is* $R_F > \mathbb{E}[\widetilde{R}]$, *banks only invest in the risky technology and default in the bad state. The resulting equilibrium allocation is inefficient.*

The proof of Proposition 5.7 is given in Appendix D. This proposition is remarkable. It states that banks might be willing to invest all their funds in the risky technology even if the expected return on this technology is lower than the safe return in FT. Note that debt-equity ratios are high in this case. Hence, this result can be interpreted as a variant of the debt-overhang problem, which can induce firms to take excessive risks (for a recent discussion, see Chapter 9 in Admati and Hellwig (2013b)).

5.2.2 Change in Macroeconomic Risk

In this section, we investigate the impact of a change in macroeconomic risk—that is, the parameter σ in our model—on equilibrium values. The equilibrium is described by the price pair $\{p_g^*, p_b^*\}$. Applying (5.4), we can express p_b^* as

$$p_b^*(p_g^*) = \frac{1 - \overline{R}p_g^*}{\underline{R}}. \tag{5.6}$$

Hence, the equilibrium can be fully characterized by p_g^*. For the ease of notation, let p^* denote the equilibrium value of p_g^*.

Let us investigate how changing σ affects equilibrium consumption in the goods state,

$$\frac{dc_g(\sigma, p^*(\sigma))}{d\sigma} = \frac{\partial c_g(\sigma, p^*(\sigma))}{\partial \sigma} + \frac{\partial c_g(\sigma, p^*(\sigma))}{\partial p^*}\frac{dp^*(\sigma)}{d\sigma}. \tag{5.7}$$

Since we do not have an explicit expression for $p^*(\sigma)$, we have to determine $\frac{dp^*(\sigma)}{d\sigma}$ implicitly. Substituting (5.1) into (5.2) and considering the fact that this expression depends on σ, we obtain

$$z_g(\sigma, p^*(\sigma)) = c_g(\sigma, p^*(\sigma)) - q(p^*(\sigma)) = 0,$$
$$\text{where } q(p^*(\sigma)) = f(y_F(p^*(\sigma))) - \overline{R}[W - y_F(p^*(\sigma))].$$

Taking the total derivative of $z_g(\sigma, p^*(\sigma))$ with respect to σ yields

$$\frac{dz_g(\sigma, p^*(\sigma))}{d\sigma} = \frac{\partial c_g(\sigma, p^*(\sigma))}{\partial \sigma} + \frac{\partial c_g(\sigma, p^*(\sigma))}{\partial p^*}\frac{dp^*(\sigma)}{d\sigma} - \frac{\partial q(p^*(\sigma))}{\partial p^*}\frac{dp^*(\sigma)}{d\sigma} = 0. \tag{5.8}$$

Observe that $z_g(\sigma, p^*(\sigma))$ is a continuously differentiable function on a ball around the equilibrium values of σ and p^*.

If the partial derivative $\frac{\partial z_g(\sigma, p^*(\sigma))}{\partial p^*}$ is non-zero, we can rearrange (5.8) to obtain an expression for $\frac{dp^*(\sigma)}{d\sigma}$.[1] In turn, we can rewrite (5.7) as

$$\frac{dc_g(\sigma, p^*(\sigma))}{d\sigma} = -\frac{\frac{\partial c_g(\sigma, p^*(\sigma))}{\partial \sigma}\frac{\partial q(p^*(\sigma))}{\partial p^*}}{\frac{\partial c_g(\sigma, p^*(\sigma))}{\partial p^*} - \frac{\partial q(p^*(\sigma))}{\partial p^*}}. \tag{5.9}$$

We are now in a position to show:

Proposition 5.8

An increase in macroeconomic risk, meaning a decrease in the likelihood σ of the good state to prevail, leads to

(i) a decrease in consumption in the good state c_g and investment in MT

(ii) an increase in consumption in the bad state c_b and investment in FT

if $\theta < 1$.

The proof is given in Appendix D. Proposition 5.8 is intuitive. It implies that households are investing less in the risky technology if the returns in this technology are less

[1] Essentially, we are applying the Implicit Function Theorem to obtain an expression for $\frac{dp^*(\sigma)}{d\sigma}$.

favorable.

5.2.3 Change in Risk Aversion

Let us next investigate the impact of a change in the relative risk aversion of households on equilibrium values. In particular, let us examine how changing θ affects consumption in the good state,

$$\frac{dc_g(\theta, p^*(\theta))}{d\theta} = \frac{\partial c_g(\theta, p^*(\theta))}{\partial \theta} + \frac{\partial c_g(\theta, p^*(\theta))}{\partial p^*}\frac{dp^*(\theta)}{d\theta}. \tag{5.10}$$

Since we do not have an explicit expression for $p^*(\theta)$, we have to determine $\frac{dp^*(\theta)}{d\theta}$ implicitly. Substituting (5.1) into (5.2) and considering the fact that this expression depends on θ, we obtain

$$\begin{aligned} z_g(\theta, p^*(\theta)) &= c_g(\theta, p^*(\theta)) - q(p^*(\theta)) = 0, \\ \text{where } q(p^*(\theta)) &= f(y_F(p^*(\theta))) - \overline{R}[W - y_F(p^*(\theta))]. \end{aligned}$$

Taking the total derivative of $z_g(\theta, p^*(\theta))$ with respect to θ yields

$$\frac{dz_g(\theta, p^*(\theta))}{d\theta} = \frac{\partial c_g(\theta, p^*(\theta))}{\partial \theta} + \frac{\partial c_g(\theta, p^*(\theta))}{\partial p^*}\frac{dp^*(\theta)}{d\theta} - \frac{\partial q(p^*(\theta))}{\partial p^*}\frac{dp^*(\theta)}{d\theta} = 0, \tag{5.11}$$

Observe that $z_g(\theta, p^*(\theta))$ is a continuously differentiable function on a ball around the equilibrium values of θ and p^*.

If the partial derivative $\frac{\partial z_g(\theta,p^*(\theta))}{\partial p^*}$ is non-zero, we can rearrange (5.11) to obtain an expression for $\frac{dp^*(\theta)}{d\theta}$.[2] In turn, we can rewrite (5.10) as

$$\frac{dc_g(\theta, p^*(\theta))}{d\theta} = -\frac{\frac{\partial c_g(\theta,p^*(\theta))}{\partial \theta}\frac{\partial q(p^*(\theta))}{\partial p^*}}{\frac{\partial z_g(\theta,p^*(\theta))}{\partial p^*}}. \tag{5.12}$$

We are now in a position to show

Proposition 5.9
An increase in the degree of relative risk aversion leads to

(i) a decrease in consumption in the good state c_g and investment in MT

(ii) an increase in consumption in the bad state c_b and investment in FT

if $\theta < 1$.

[2] Again, we are essentially applying the Implicit Function Theorem to obtain an expression for $\frac{dp^*(\theta)}{d\theta}$.

The proof is given in Appendix D. Proposition 5.9 is intuitive as it implies that households invest less in the risky technology if they are more risk-averse.

5.3 Banks – Determination of the Capital Structure

In Chapter 4, we have assumed that all banks receive the same amount of equity E and deposits D. Alternatively, one could also assume that banks sequentially issue their liability claims, an assumption that is standard in the corporate finance literature. We investigate the case where banks are first founded with equity and then decide how much deposits to accept. Furthermore, we also examine the situation in which banks can raise additional equity before deciding how much deposits to accept. Alternatively, one can take a static rather than a sequential perspective and investigate whether the equilibria characterized in Chapter 4 persist if a particular bank attempts to individually deviate from the equilibrium debt-equity ratio.

5.3.1 Sequential Issuance of Liability Claims by Individual Bank

We show that all equilibria arising under Propositions 5.1 to 5.3 remain equilibria if banks sequentially issue their liability claims.

First Case—Equity Issuance Once

Let us define e as the amount of equity any particular individual bank was founded with and d the amount of deposits this particular bank issues. The aggregate values are denoted by E and D, respectively. The timing of events is depicted in Figure 5.1.

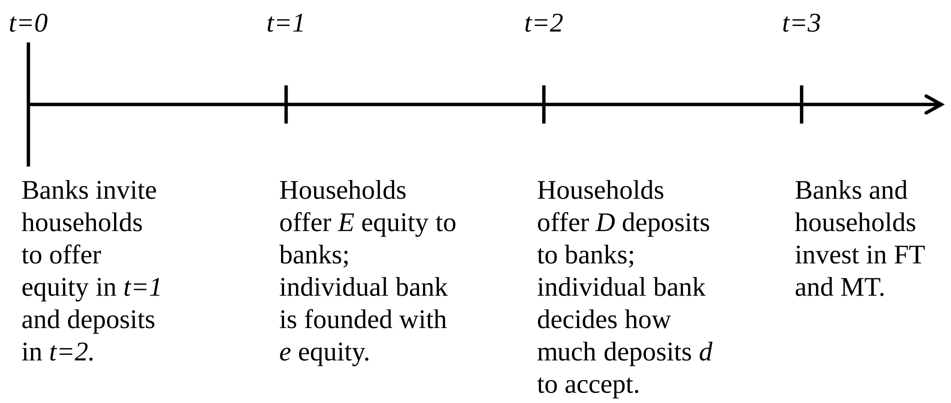

Figure 5.1: Timing of events.

Banks are perfectly competitive: they are contract and price takers. Prices of deposits and equity are one, and banks offer the prevailing rate of return on safe assets R_F for their deposits. Eventually, we need to assume some tie-breaking rule as depositors are indifferent at which bank they deposit their resources. If banks wish to acquire more deposits than being offered by households, we assume that depositors distribute themselves across banks according to the distribution of bank equity.[3]

Before we proceed, it is helpful to state the following corollary.

Corollary 5.3
Given $R_F < \mathbb{E}[\widetilde{R}]$, the expected ROE for an individual bank is increasing in the level of deposits d for every given level of equity e.

Corollary 5.3 follows immediately from the definition of the expected ROE. We next prove that the efficient equilibria in the spirit of Proposition 5.1 and 5.2 remain equilibria under sequential issuance of liability claims by banks.

Proposition 5.10 (Efficient Equilibria)
There exists a continuum of equilibria with financial intermediation and sequential issuance of liability claims where $D \in [0, y_M^* \cdot \underline{R}/R_F^*]$ and $E \in [\frac{R_F^*-\underline{R}}{R_F^*} y_M^*, y_M^*]$. The investment in FT is y_F^* and the investment in the risky technology is $y_M^* = E + D$. Banks sequentially issue their liability claims, only invest in the risky technology and never default.

Proof of Proposition 5.10
Let us fix the return of the safe asset at R_F^*. Further, suppose households offer $E \in [\frac{R_F^*-\underline{R}}{R_F^*} y_M^*, y_M^*]$ to banks at $t = 1$. An individual bank receives e equity from households.

In period $t = 2$, let households offer D deposits to banks with $D = y_M^* - E$. An individual bank decides to accept an amount d of deposits. Due to the tie-breaking rule discussed above, the individual bank can only choose to accept an amount of deposits $d \in [0, \frac{D}{E}e]$. Corollary 5.3 immediately yields that the bank optimally chooses $d = \frac{D}{E}e$.

In period $t = 3$, the bank optimally chooses $\alpha = 1$ since $B_1 > 0$. All banks invest in MT only. As a result, the debt-equity ratio is the same across banks and one unit of bank equity yields $[(E + D)\overline{R} - DR_F^*]/E$ in the good state and $[(E + D)\underline{R} - DR_F^*]/E$ in the bad state.

Given these returns, households optimally invest E in bank equity, D in bank deposits, and their remaining wealth $W - E - D = y_F^*$ in FT. $\square$

[3] The behavior of depositors can be further rationalized when we allow for an arbitrary small probability that they are not bailed out in case of default.

Finally, we show that all inefficient equilibria in the spirit of Proposition 5.3 remain equilibria if banks sequentially issue their liability claims.

Proposition 5.11 (Inefficient Equilibria)
There exists a continuum of equilibria with financial intermediation and sequential issuance of liability claims where the investment in FT is strictly smaller than y_F^*. Investment in the risky technology is $E+D$, banks only invest in the risky technology and default in the bad state. The resulting equilibrium allocation is inefficient.

Proof of Proposition 5.11
Let us fix the return on the safe asset at R_F such that $R_F > R_F^*$ and $R_F < \mathbb{E}[\widetilde{R}]$. Further, let $\hat{E}$ and $\hat{D}$ denote the total values of bank equity and deposits in an equilibrium characterized by Proposition 5.3. Suppose households offer $\hat{E}$ to banks at $t = 1$, and an individual bank receives $\hat{e}$ equity from households.

In period $t = 2$, let households offer $\hat{D}$ deposits. An individual bank decides to accept an amount $\hat{d}$ of deposits. Due to the tie-breaking rule discussed above, the individual bank can only choose to accept an amount of deposits $\hat{d} \in [0, \frac{\hat{D}}{\hat{E}}\hat{e}]$. Corollary 5.3 immediately yields that the bank optimally chooses $\hat{d} = \frac{\hat{D}}{\hat{E}}\hat{e}$.

In period $t = 3$, the bank optimally chooses $\alpha = 1$ since $B_1 > 0$; all banks invest in MT only. As a result, the debt-equity ratio is the same across banks and one unit of bank equity yields $[(\hat{E}+\hat{D})\overline{R} - \hat{D}R_F]/\hat{E}$ in the good state and zero in the bad state; the lump-sum tax is $T = R_F\hat{D} - \underline{R}(\hat{E}+\hat{D})$. Given these returns and taxes, households optimally invest $\hat{E}$ in bank equity, $\hat{D}$ in deposits, and their remaining wealth $W - \hat{E} - \hat{D}$ in FT; the resulting allocation is inefficient (cf. Proposition 5.3). This completes the proof. □

Second Case—Equity Issuance Twice

We next show that all equilibria discussed in the previous section also remain equilibria if bank equity is issued twice. Let us define e_1 the amount of equity any particular individual bank was founded with and e_2 the amount of additional equity this bank raises later. Further, let d still denote the amount of deposits the bank decides to accept, and the aggregate values are denoted by E and D, respectively. Households decide to initially found banks with ηE equity and to offer $(1-\eta)E$ equity to banks later with $\eta \in (0,1)$. The timing of events is depicted in Figure 5.2.

Banks are still perfectly competitive. Furthermore, we assume the same tie-breaking rule as we did above for the case when banks taken together wish to acquire more deposits than being offered by the public.

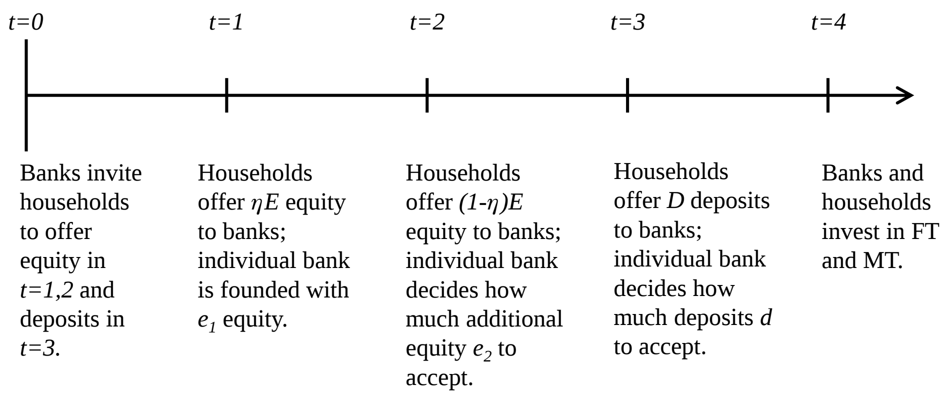

Figure 5.2: Timing of events.

Proposition 5.12

All equilibria under Proposition 5.10 and 5.11 remain equilibria if banks issue equity twice.

Proof of Proposition 5.12

Due to the tie-breaking rule, a bank can chose to accept d deposits in period $t = 3$ with $d \in [0, \frac{D}{E}(e_1 + e_2)]$. From Corollary 5.3, we can infer that an individual bank always chooses $d = \frac{D}{E}(e_1 + e_2)$ in period $t = 3$.

If a bank rejects any additional equity in period $t = 2$, the bank chooses $d' = \frac{D}{E}e_1$ deposits in period $t = 3$ such that its debt-equity ratio equals D/E. If a bank accepts $e_2 > 0$ equity in period $t = 2$, it will chose $d'' = \frac{D}{E}(e_1 + e_2)$ deposits in period $t = 3$ such that its debt-equity ratio still equals D/E.[4] Hence, a bank will be indifferent in accepting any additional equity in period $t = 3$.

Therefore, all equilibria under Proposition 5.10 and 5.11 remain equilibria regardless of households' choice of η. $\square$

[4] Observe that due to $B_1 > 0$, banks always choose $\alpha = 1$. Hence, the expected ROE in the efficient case is given by

$$\left(\mathbb{E}[\widetilde{R}] - R_F^*\right)\frac{d}{e} + \mathbb{E}[\widetilde{R}],$$

and by

$$\left(\overline{R} - R_F\right)\frac{d}{e} + \overline{R}$$

in the inefficient case. We can readily see that due to Corollary 5.3 and the tie-breaking rule, any individual bank's expected ROE is fully determined by the banks' aggregate debt-equity ratio.

5.3.2 Simultaneous Issuance of Liability Claims by Individual Bank

Next, we examine whether an individual bank has an incentive to deviate from the equilibrium debt-equity ratio, *ceteris paribus*. We first look at efficient and then turn to inefficient equilibria.

Efficient Equilibria

Let us assume the economy is in an equilibrium that attains the first-best Arrow-Debreu allocation (cf. Proposition 5.1 and 5.2). Banks are all identically funded by debt d and equity e. They invest all their funds in the risky technology. Since a single bank has mass zero, we obtain $e + d = D + E = y_M^*$. Return on riskless assets is R_F^* and $K_F = y_F^*$ is invested in the FT technology. Is there an incentive to deviate for an individual bank?

■ *Step 1: The Asset Return Matrix*

The return on assets in this economy can be described as follows:

Asset	Price in $t = 1$	Return in state g	Return in state b
$\{a_d, a_{K_F}\}$	q_1	R_F^*	R_F^*
$\{a_e\}$	q_2	$\dfrac{\overline{R}(q_2 e + q_1 d) - R_F^* d}{e}$	$\dfrac{\underline{R}(q_2 e + q_1 d) - R_F^* d}{e}$.

Due to Corollary 5.1, we obtain $q_1 = 1$ and $q_2 = 1$.

Let us next assume that one bank deviates from e to e' and from d to d'.

■ *Step 2: Suppose* $\frac{\underline{R}(q_e' e' + d') - R_F^* d'}{e'} \geq 0$

In this case, the deviating bank never defaults and the deposit is risk-free—even absent deposit insurance. By a no-arbitrage argument, we obtain a price of 1 for d'. The new equity asset can be characterized as

Asset	Price in $t = 1$	Return in state g	Return in state b
$\{a_{e'}\}$	1	$\dfrac{\overline{R}(q_e' e' + d') - R_F^* d'}{q_e' e'}$	$\dfrac{\underline{R}(q_e' e' + d') - R_F^* d'}{q_e' e'}$.

Both amounts e' and d' are set by the deviating bank; the price q_e' will adjust such that the asset markets are cleared, that is, such that there are no possibilities for arbitrage.

By buying $e/(e + d)$ equity and $d/(e + d)$ deposit contracts of a non-deviating bank, households obtain one unit of the following asset:

Asset	Price in $t=1$	Return in state g	Return in state b
$\{a_b\}$	1	$\overline{R}$	$\underline{R}$.

If households buy $q_e'e'/(q_e'e'+d')$ equity and $d'/(q_e'e'+d')$ deposit contracts of the deviating bank, they hold one unit of the same asset a_b. Therefore, the value of the price q_e' does not matter as long as $q_e' \geq \frac{R_F^*-\underline{R}}{\underline{R}}\frac{d'}{e'}$, that is, as long as banks do not default. For every given q_e', the ROE of the deviating bank is decreasing in e' and increasing in d'. Hence, the bank will optimally choose a debt-equity ratio of $\frac{d'}{e'} = \frac{\underline{R}q_e'}{R_F^*-\underline{R}}$. If we set $q_e' = 1$, the deviating bank will choose a debt-equity ratio equal to φ. The first-best allocation still prevails.

■ *Step 3: Suppose* $\frac{\underline{R}(q_e'e'+d')-R_F^*d'}{e'} < 0$

In this case, the deviating bank defaults in the bad state. Due to deposit insurance, the return on d' remains R_F^* and the price for one unit of deposit is still one. The new equity asset can be characterized as

Asset	Price in $t=1$	Return in state g	Return in state b
$\{a_{e'}\}$	1	$\dfrac{\overline{R}(q_e'e'+d')-R_F^*d'}{q_e'e'}$	0.

By buying $e/(e+d)$ equity and $d/(e+d)$ deposit contracts of a non-deviating bank, households still obtain one unit of asset a_b. If households buy $q_e'e'/(q_e'e'+d')$ equity and $d'/(q_e'e'+d')$ deposit contracts of the deviating bank, they hold one unit of the following asset:

Asset	Price in $t=1$	Return in state g	Return in state b
$\{a_{b'}\}$	1	$\overline{R}$	$\dfrac{R_F^*d'}{q_e'e'+d'}$.

A no-arbitrage argument implies a price $q_e' = \frac{R_F^*-\underline{R}}{\underline{R}}\frac{d'}{e'}$. Hence, the deviating bank cannot increase its return on equity any further than if it chooses a debt-equity ratio of φ. If it chooses a debt-equity ratio above φ, the price of its equity will adjust such that the ROE remains constant.

■ *Step 4: Unique equilibrium*

There is a unique efficient equilibrium $\{E, D, R_F^*, y_F^*, y_M^*\}$. All banks choose a debt-equity ratio $D/E = \varphi$. The equilibrium is efficient.

Inefficient Equilibria

Let us assume the economy is in an inefficient equilibrium in the spirit of Proposition 5.3. Banks are all identically funded by debt d and equity e. They invest all their funds in the risky technology. As a single bank has mass zero, we obtain $d+e = D+E > y_M^*$. Return on riskless assets is $R_F > R_F^*$ and $K_F < y_F^*$ is invested in the FT technology. Is there an incentive to deviate from this equilibrium allocation for an individual bank?

■ *Step 1: The Asset Return Matrix*
The return on assets in this economy can be described as follows:

Asset	Price in $t = 1$	Return in state g	Return in state b
$\{a_d, a_{K_F}\}$	q_1	R_F	R_F
$\{a_e\}$	q_2	$\dfrac{\overline{R}(q_2 e + q_1 d) - R_F d}{e}$	$0.$

Again, we obtain $q_1 = 1$ and $q_2 = 1$ in equilibrium. Let us next assume that one bank deviates from e and d to e' and d', respectively.

■ *Step 2: Suppose* $\frac{\overline{R}(q_e' e' + d') - R_F d'}{e'} < 0$
Due to deposit insurance, the return on deposits remains R_F and the price for one unit of deposit is still one. The new equity asset can be characterized as

Asset	Price in $t = 1$	Return in state g	Return in state b
$\{a_{e'}\}$	1	$\dfrac{\overline{R}(q_e' e' + d') - R_F d'}{q_e' e'}$	$0.$

Both amounts e' and d' are set by the deviating bank; the price q_e' will adjust such that the asset markets are cleared.

By buying $e/(e+d)$ equity and $d/(e+d)$ deposit contracts of a non-deviating bank, households obtain one unit of the following asset:

Asset	Price in $t = 1$	Return in state g	Return in state b
$\{a_b\}$	1	$\overline{R}$	$R_F \dfrac{d}{e+d}.$

By buying $q_e' e'/(q_e' e' + d')$ equity and $d'/(q_e' e' + d')$ deposit contracts of the deviating bank, households obtain one unit of the following asset:

Asset	Price in $t = 1$	Return in state g	Return in state b
$\{a_{b'}\}$	1	$\overline{R}$	$R_F \dfrac{d'}{q_e' e' + d'}.$

Hence, a no arbitrage argument implies a price of $q_e' = \varphi'/\widetilde{\varphi}$, with $\varphi' := d'/e'$ and $\widetilde{\varphi} := d/e$ being the debt-equity ratio chosen by the deviating bank and all other banks, respectively. As a result, the deviating bank cannot achieve a higher ROE by deviating from the equilibrium. The price of its equity adjusts such that the ROE remains constant.

■ *Step 3: Suppose* $\frac{\underline{R}(q_e'e'+d')-R_F d'}{e'} \geq 0$

The return on deposits remains R_F and the price for one unit of deposits is still one. The new equity asset can be characterized as

Asset	Price in $t=1$	Return in state g	Return in state b
$\{a_{e'}\}$	1	$\dfrac{\overline{R}(q_e'e'+d')-R_F d'}{q_e'e'}$	$\dfrac{\underline{R}(q_e'e'+d')-R_F d'}{q_e'e'}$.

We need $q_e' \geq \frac{(R_F-\underline{R})d}{\underline{R}e}$ as otherwise, the deviating bank would default in the bad state and we would be in the case described in Step 2. By buying $q_e'e'/(q_e'e'+d')$ equity and $d'/(q_e'e'+d')$ deposit contracts of the deviating bank, households obtain one unit of the following asset:

Asset	Price in $t=1$	Return in state g	Return in state b
$\{a_{b'}\}$	1	$\overline{R}$	$\underline{R}$.

Furthermore, asset a_b is still available. Comparing these two assets, we readily see that there is no price $q_e' \geq \frac{(R_F-\underline{R})d}{\underline{R}e}$ at which households would be willing to hold e'.[5]

■ *Step 4: Continuum of Equilibria*

All equilibria under Proposition 5.3 remain equilibria if banks can set their debt-equity level individually.

5.4 Households – Risk Neutral Preferences

In this section, we investigate the influence of households' attitude towards risk on equilibria in both the Arrow-Debreu and the financial intermediation case. While we have examined a change in risk-aversion on equilibrium values in Section 5.2.3, we are dealing with a different attitude towards risk in this section, namely, the case where households are risk neutral. This is a much more profound change as it is *a priori* not clear, whether any existence and uniqueness results from Chapter 4 can be replicated.

[5] Observe that $R_F \frac{d}{e+d} > \underline{R}$ by definition of the equilibrium, that is, $\underline{R}(d+e) - R_F d < 0$ since banks default in the bad state.

5.4.1 Model Setup

The preferences of a risk-neutral household can be represented by a utility function of a linear form $u(c) = c$. Hence, households face the following utility maximization problem:

$$\max_{c_g, c_b} \{u_h(c_g, c_b) = \sigma c_g + (1-\sigma)c_b\}$$
$$\text{s.t. } W + \Pi_F + \Pi_M \geq p_g c_g + p_b c_b.$$

All other model fundamentals from the baseline model presented in Chapter 4 are left unchanged.

5.4.2 Frictionless Economy

Since preferences are linear, we get the following non-differentiable demand functions for risk-neutral households:

$$\begin{aligned}
&c_g(p_g,p_b) = \frac{I}{p_g} && \text{and} && c_b(p_g,p_b) = 0 && \text{if} && p_g < \frac{\sigma}{1-\sigma}p_b \\
&c_g(p_g,p_b) = 0 && \text{and} && c_b(p_g,p_b) = \frac{I}{p_b} && \text{if} && p_g > \frac{\sigma}{1-\sigma}p_b \\
&c_g(p_g,p_b) = q\frac{I}{p_g} && \text{and} && c_b(p_g,p_b) = (1-q)\frac{I}{p_b} && \text{if} && p_g = \frac{\sigma}{1-\sigma}p_b
\end{aligned} \tag{5.13}$$

with $I := W + \Pi_F + \Pi_M$ and $q \in [0,1]$.

The objective of entrepreneurs and their investment good demand, respectively, remains unchanged. In particular, the equilibrium conditions (5.1) to (5.4) still hold.

Combining the Inada condition and $y_F \in (0, W)$, with the market clearing conditions (5.1) to (5.3), we can readily infer that in any equilibrium

$$p_g = \frac{\sigma}{1-\sigma}p_b$$

must hold. Combining this with equilibrium condition (5.4), we obtain the following equilibrium prices

$$\{p_g^*, p_b^*\} = \{\frac{\sigma}{\mathbb{E}[\widetilde{R}]}, \frac{1-\sigma}{\mathbb{E}[\widetilde{R}]}.\}. \tag{5.14}$$

We have established:

Proposition 5.13
A unique equilibrium exists. Equilibrium prices are given by (5.14).

In an equilibrium with risk-neutral households, the safe return for investing in FT will be equal to the expected return for investing in MT, that is, $R_F^* = \mathbb{E}[\widetilde{R}]$. Equilibrium consumption is given by

$$c_g^* = f\left(f'^{-1}(\mathbb{E}[\widetilde{R}])\right) + \overline{R}(W - f'^{-1}(\mathbb{E}[\widetilde{R}]))$$
$$c_b^* = f\left(f'^{-1}(\mathbb{E}[\widetilde{R}])\right) + \underline{R}(W - f'^{-1}(\mathbb{E}[\widetilde{R}])).$$

Households will consume more in the good state and less in the bad state than if they were risk-averse.

5.4.3 Allocation with Financial Intermediation

Let us next investigate the allocation with financial intermediation. Households cannot or would not directly finance entrepreneur e_M due to moral hazard frictions (for a discussion, see Chapter 4). As we only changed households' preferences, the optimal choices of banks and entrepreneurs remain the same.

Recall that R_F denotes the return on investment K_F in FT, R_D denotes the return on deposits D, and $\overline{R}_E$ and $\underline{R}_E$ denote the returns on bank equity E in the good and bad state, respectively. Hence, part of initial wealth W can be saved risk-free, paying out $R_S = \max\{R_F, R_D\}$ per unit of investment.

Households' objective reads as follows

$$\max_{\gamma}\left\{u_h(\gamma) = \left(\sigma[(1-\gamma)\overline{R}_E + \gamma R_S] + (1-\sigma)[(1-\gamma)\underline{R}_E + \gamma R_S - T]\right)\right\}.$$

The optimal portfolio choice of households can be characterized by

$$\begin{aligned}
\gamma &= 0 &\quad \text{if} \quad & R_S < \sigma\overline{R}_E + (1-\sigma)\underline{R}_E,\\
\gamma &= 1 &\quad \text{if} \quad & R_S > \sigma\overline{R}_E + (1-\sigma)\underline{R}_E,\\
\gamma &\in [0,1] &\quad \text{if} \quad & R_S = \sigma\overline{R}_E + (1-\sigma)\underline{R}_E.
\end{aligned}$$

Hence, households will supply their wealth as follows:

$$\begin{aligned}
&D = \lambda\gamma W,\\
&K_{F,h} = (1-\lambda)\gamma W,\\
&E = (1-\gamma)W.
\end{aligned}$$

Here λ denotes the share of risk-free assets held in the form of deposits and $1-\lambda$ denotes the share held in the form of direct investment in FT. We have

$$\lambda = \begin{cases} 0 & \text{if } R_F > R_D, \\ 1 & \text{if } R_F < R_D, \\ \in [0,1] & \text{if } R_F = R_D. \end{cases} \tag{5.15}$$

Due to risk neutrality, the lump-sum tax $T \geq 0$ levied in the bad state in order to bail out banks does not affect households' optimal portfolio choice. Further, we need $R_S \leq \sigma\overline{R}_E + (1-\sigma)\underline{R}_E$ for banks to exist, that is, $E > 0$. Finally, note that λ will be part of the equilibrium. If $R_F = R_D$, then households choose D and $K_{F,h}$ such that an equilibrium prevails.

The next proposition establishes the existence of an equilibrium with financial intermediation that is equivalent to the frictionless case.

Proposition 5.14
There exists an equilibrium with financial intermediation where investment in FT is y_F^*, the investment in the risky technology is y_M^*, $D = 0$, banks invest in the risky technology only and never default.

The proof of Proposition 5.14 can be found in Appendix D. This equilibrium corresponds to a banking system in which all banks are funded by equity only. The efficient Arrow-Debreu equilibrium allocation is still an equilibrium outcome if there are moral hazard frictions and households are risk-neutral. Next, we investigate to what extent this particular equilibrium is unique.

Proposition 5.15
The equilibrium with financial intermediation and no default in Proposition 5.14 is unique if $\underline{R} = 0$. In case $\underline{R} > 0$, there exists an equilibrium with financial intermediation for each $D \in [0, y_M^* \cdot \underline{R}/R_F^*]$ where investment in FT is y_F^*, the investment in the risky technology is $y_M^* = E + D$, banks only invest in the risky technology and never default.

The proof of Proposition 5.15 is given in Appendix D. As with risk-averse households, the capital structure of banks is irrelevant to aggregate investment and risk up to a critical debt-equity ratio. Let us next turn to the case where the debt-equity ratio exceeds the critical level.

Proposition 5.16
There exist equilibria with financial intermediation where the investment in FT is strictly smaller than y_F^*, the investment in the risky technology is $E + D$, banks only invest in the risky technology and default in the bad state. The resulting equilibrium allocation is inefficient.

The proof of Proposition 5.16 is given in Appendix D. Above a certain debt-equity ratio, inefficient equilibria arise with financial intermediation if households are risk-neutral. Even with risk-neutral households, the macroeconomic version of the Modigliani-Miller Theorem fails to hold in unfettered markets.

In our baseline model, we derived that above a certain debt-equity ratio, inefficient equilibria arise. In Proposition 5.16 we find that this result is not driven by the preferences of households. The inefficiency arises due to the financial intermediation of banks. The special funding conditions of banks, that is, government guarantees of deposits, lead to over-investment in the risky technology and under-investment in the frictionless technology. These inefficient equilibria, in which banks raise too much funds, are also possible in a model with risk-neutral households.

5.5 Conclusion

In this chapter, we have extended various parts of our quantitative analysis in Chapter 4. We have analyzed the different equilibria in our baseline model in great detail. We found that even highly inefficient equilibria might be supported in our baseline model. Further, we have shown that equilibrium values behave intuitively; if risk aversion or macroeconomic risk is increasing, both investment in the risky technology and consumption in the bad state decreases. Then, we have investigated the case when banks can individually choose to issue their liability claims, and we have shown that both classes of equilibria still prevail. Finally, we have abandoned the assumption of risk-averse preferences. We were able to show that all results from Chapter 4 carry over.

6 Concluding Remarks

In our introduction, we formulated several research questions to guide our analysis. We started by asking *Research Question 1: What do we know already about the relationship between banking stability and economic welfare?* The short answer to this question is: not too much. Most research on banking is microeconomic in nature. This is surprising, as both economic history and empirical evidence strongly suggest to pay more attention to financial issues in macroeconomics. Only few economists investigated the relationship between banking stability and the macroeconomy. Hyman Minsky and Charles Kindleberger are probably the most prominent proponents. While both described the instability of banking systems, they did not analyze regulatory tools to prevent the occasional breakdowns of the system in a rigorous analytical framework.

The disregard of banking in modern macroeconomics is why the economy-wide repercussions of the Financial Crisis of 2007–08 took many economists by surprise. Figuratively speaking, one could say that economists have been *"Slapped by the Invisible Hand"* (Gorton, 2010). In a first act of self-defense, many economists sought guidance in the historical literature on the panic of 1907 and 1929. It is worth noting that old ideas were revived not only for crisis management, but also for the reform of the current financial architecture. To give an example, Narrow Banking—an early variant of which was proposed by Fisher (1935) after the Great Depression—was rediscovered by interest groups in different countries. To assess the macroeconomic effects of changes in the financial architecture, however, modern analytical models are still in high demand.

This brings us to *Research Question 2: How can we integrate banking into a macroeconomic model?* We answered this question by integrating financial intermediation by banks into a general equilibrium model with two production sectors and risk-averse households. Banks monitor borrowers in lending and are funded by deposits and (outside) equity. In our model, the government guarantees bank deposits, and bank bailouts are financed via lump-sum taxes if banks default.

Within our model, we have then tackled *Research Question 3: How does the capital structure of banks affect the allocation of goods and risk in the economy?* The Modigliani-Miller Theorem appears to be a good starting point for analyzing capital structures. Modigliani and Miller (1958) state that changes in the capital structure of a firm do not affect investment opportunities, the total risk of the firm's asset returns and overall funding costs. As such, we addressed the validity of a macroeconomic version of the Modigliani-Miller Theorem. By the 'macroeconomic version', we understand that the capital structures of banks do not affect economic welfare, that is, the optimal allocation of commodities and risk.

It turned out that in our model, the capital structure of banks is relevant for macroeconomic outcomes. The macroeconomic version of the Modigliani-Miller Theorem fails to hold. While capital structures featuring moderate debt-equity ratios do not affect economic welfare, inefficient equilibria arise above a certain debt-equity ratio. There is over-investment in the risky technology and under-investment in the frictionless technology. Banks attract more funds than in the efficient equilibrium, they generate high returns on equity in the good state and default in the bad state.

Our result suggests that policy-makers can implement welfare-improving regulation, which leads to *Research Question 4: What is the optimal regulation of banks?* In our model, inefficient equilibria can be avoided by imposing minimum capital requirements. In addition, given bankruptcy costs are zero, forcing insolvent banks into bankruptcy is another policy that can achieve efficiency. Are these results robust, or as we asked in *Research Question 5: How do changes in macroeconomic fundamentals alter the optimal design of banking regulation?* We were able to show that the results obtained from our baseline model are robust to various extensions and generalizations.

Our research supports policy efforts aimed at raising capital requirements significantly. One should bear in mind, however, that we do not consider liquidity issues explicitly. The focus of our analysis lies on the credit-side of banking—that is solvency—and not on the money-side of banking—that is liquidity.[1] Despite this limitation, it seems likely that regulatory initiatives such as Basel III and the Dodd-Frank Act are suboptimal. While the increase in bank capital requirements appears to be significant in relative terms, it is modest in absolute terms. Banks still operate with very low equity levels, compared to both earlier historical instances and non-financial companies.

This is surprising. Shortly after the Financial Crisis of 2007–08, the call to overhaul the financial architecture was heard everywhere. The crisis did not only disrupt the banking system but also the wider economy. It resulted in a severe economic contraction, the so-called *"Great Recession"*. Having caught a glimpse of the financial abyss, even the bankers themselves seemed ready for regulatory change.

Five years later, however, it appears that one cannot expect more than gradual patches for banking regulation. While capital requirements were only modestly raised, bank lob-

[1] For a narrative of the Financial Crisis of 2007–08 that almost exclusively focuses on liquidity issues, see, for example, Gorton (2010) or Mehrling (2012).

byists are back in business, trying to fend off every further regulatory tightening—with success. The initial political will to redesign the financial architecture quickly gave in to the same old arguments of the banking industry.[2]

While writing this thesis, we observed one full policy-cycle of banking. It started with a banking panic, which resulted in emergency measures by the government, led to a call for tighter regulation, and ended with minor regulatory fixes. Such an experience impacts on our suggestions for future research. In particular, we identify two areas of research that are of crucial importance for effective improvements of the financial architecture.

A first area of research belongs to the field of economic theory. More analytical work is needed to improve our understanding of the relationship between banking stability and economic welfare. The baseline model developed in this thesis can be further extended along various paths. First and foremost, by incorporating the liquidity aspect—the money-side of banking—into our model, one could live up to the holistic nature of banking. Second, turning our static model into a dynamic one would enhance our understanding of bank-driven business cycles. Third, in a dynamic model, one could let the government finance its bailouts not only by taxes but also by issuing debt. The coexistence of private and public debt would allow the analysis of the massive increase in public debt, a key feature of the period after the Financial Crisis of 2007–08.

A second area of research belongs to the political economy of banking. In fact, the lack of macroeconomic models of banking is an interesting issue in itself. Having reviewed the macroeconomic literature on banking extensively, we conjecture that the prominence of the *"Irrelevance View of Finance"* is not only owed to its rigorous theoretical foundation, but also to its support for particular interests. While we have extended the earlier microeconomic research by adopting a macroeconomic perspective, this second area of research would call for an even higher level of abstraction. An interdisciplinary approach might prove necessary, as analyzing the political economy of banking requires expertise in economic history, history of economic thought, and political economy—quite a challenge. Yet, an improvement of our understanding of the political economy of banking could be essential to translate economic research into a better financial architecture.

[2] For a discussion of some of the arguments, see Admati et al. (2011).

A Appendix to Chapter 2

A.1 Additional Figures – Liability Side of Non-Financial Firms

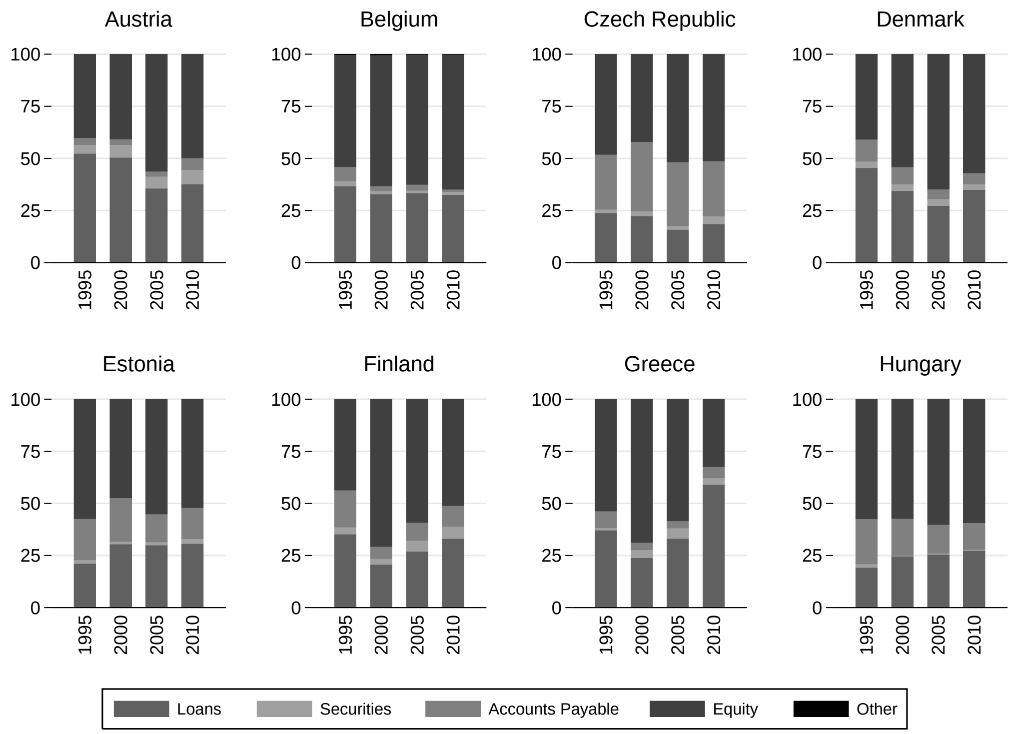

Figure A.1: Liability side of non-financial firms' balance sheets in the G7 countries, using national accounts data. *Source:* OECD (2010b). *Note:* All numbers are percentages of total liabilities. We use the annual series of non-consolidated stocks for non-financial corporations (OECD code: S11). The category "Others" contains 'Currency and deposits', 'Mutual funds shares', and 'Insurance technical reserves' (OECD codes: SAF2LINC, SAF52LINC, SAF6LINC).

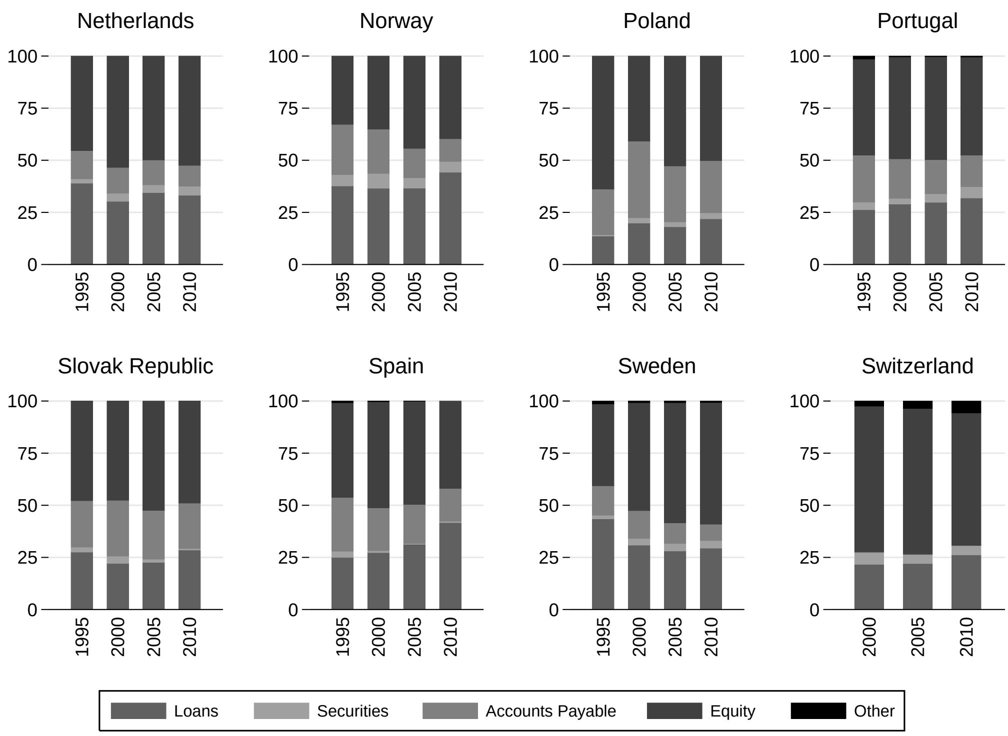

Figure A.2: Liability side of non-financial firms' balance sheets, using national accounts data. *Source* and *Note:* See Figure A.1 (p. 123).

A.2 Additional Figures – Asset Side of Banks

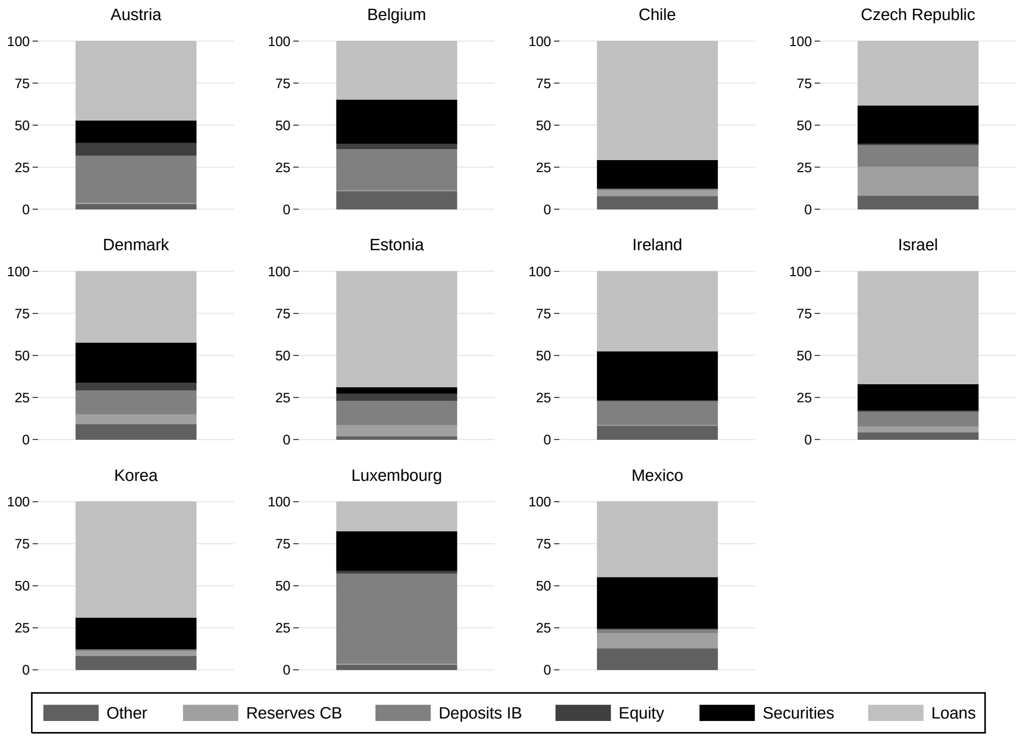

Figure A.3: The asset side of banks' balance sheets in 2004. *Source:* OECD (2010a). *Note:* All numbers are percentages. "CB" stands for Central Bank and "IB" for Interbank. "Other" is original series 18, "Reserves CB" is 14, "Deposits IB" is 15, "Equity" is 29, "Securities" is 17 minus 29, "Loans" is 16.

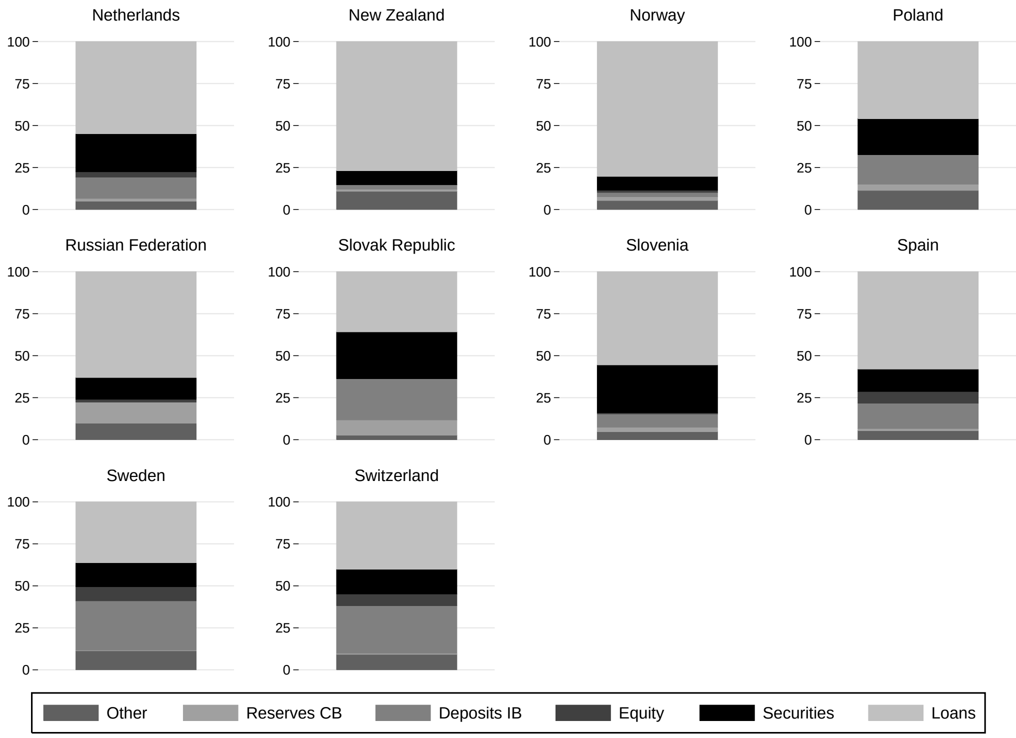

Figure A.4: The asset side of banks' balance sheets in 2004. *Source* and *Note:* See Figure A.3 (p. 125).

A.3 Additional Figures – Financial Assets of Households

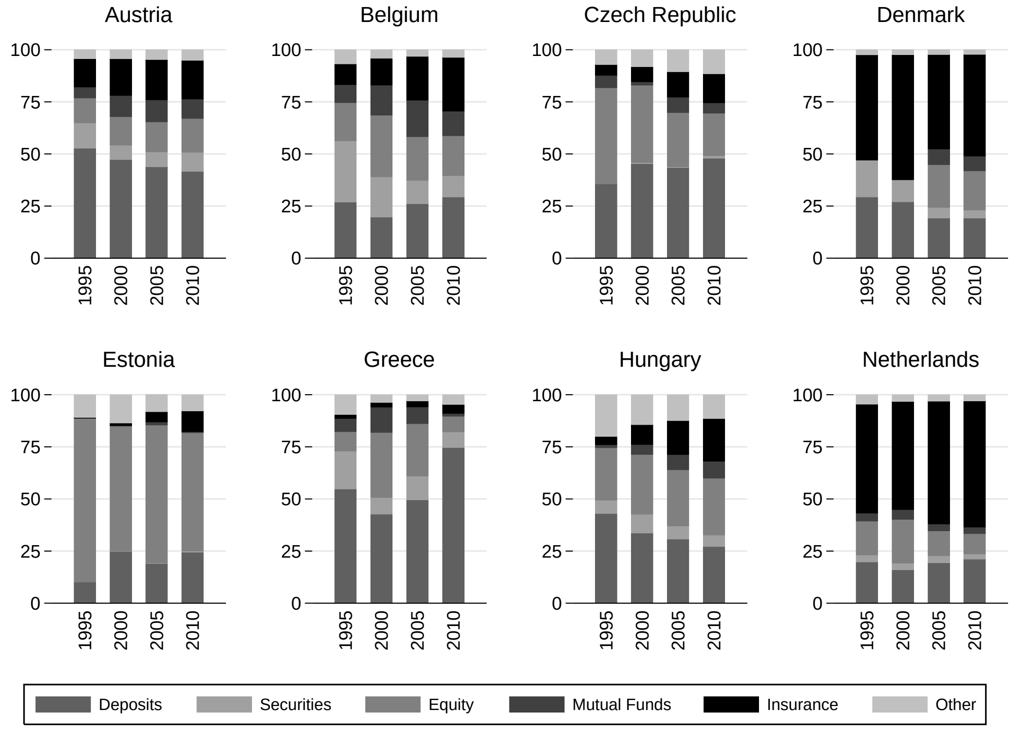

Figure A.5: Financial assets of households, using national accounts data. *Source:* OECD (2010b). *Note:* All numbers are percentages of total financial assets. We use the annual series of non-consolidated stocks for households and non-profit institutions serving households (OECD code: S14_S15). The category “Other” contains ‘Currency’, ‘Loans’, ‘Other accounts receivable’, and ‘Monetary gold and SDRs’ (OECD codes: SAF21ASNC, SAF4ASNC, SAF7ASNC, SAF1ASNC).

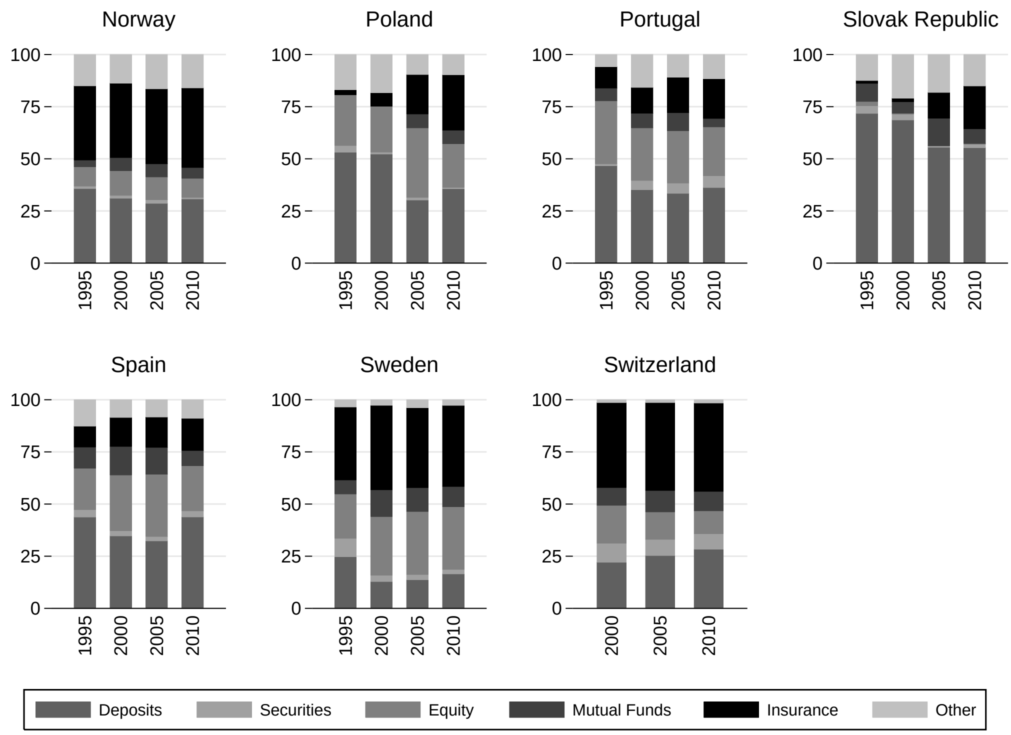

Figure A.6: Financial assets of households, using national accounts data. *Source* and *Note:* See Figure A.5 (p. 127).

A.4 Additional Figures – The Liability Side of Banks

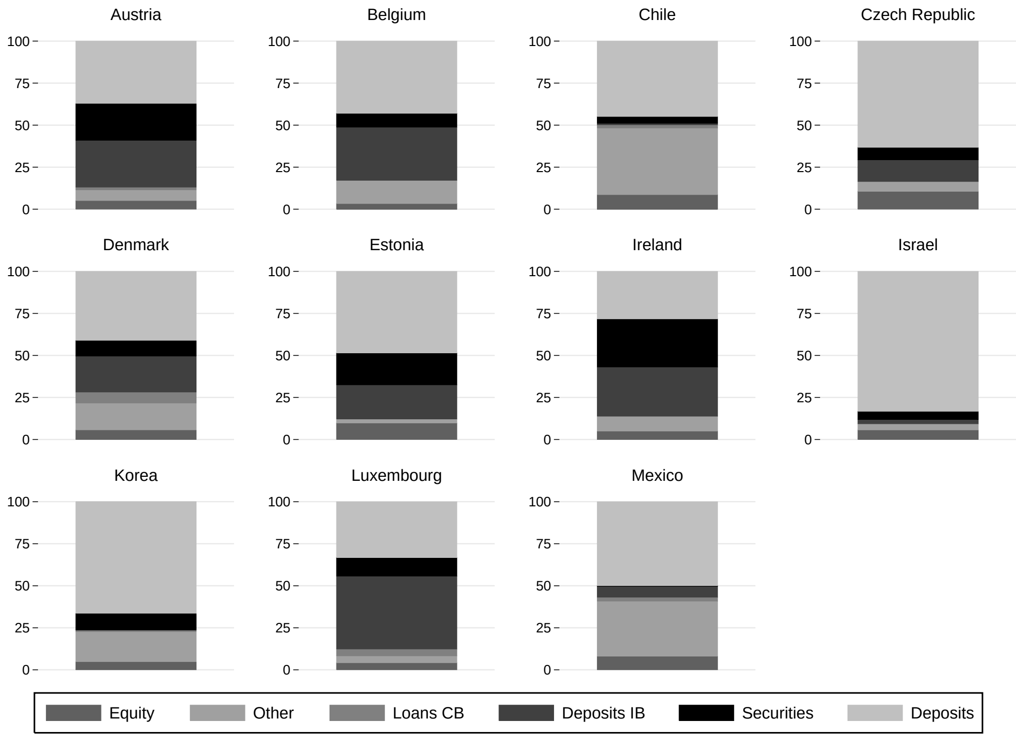

Figure A.7: The liability side of banks' balance sheets in 2004. *Source:* OECD (2010a). *Note:* All numbers are percentages. "CB" stands for Central Bank and "IB" for Interbank. "Equity" is original series 19, "Other" is 24, "Loans CB" is 20, "Deposits IB" is 21, "Securities" is 23, "Deposits" is 22.

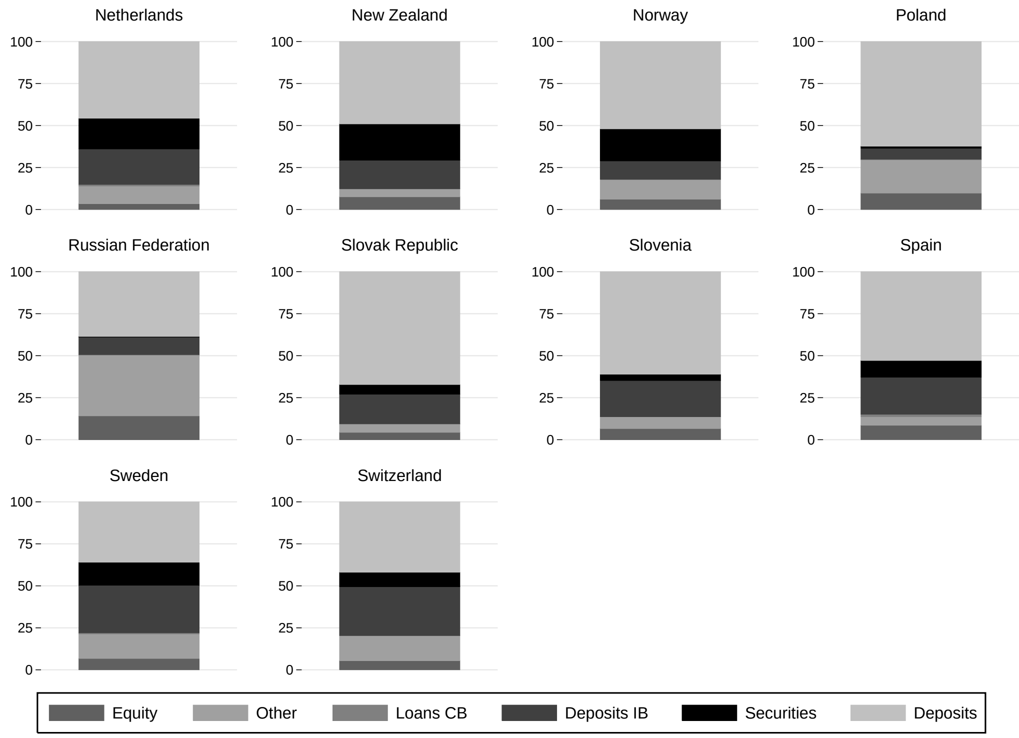

Figure A.8: The liability side of banks' balance sheets in 2004. *Source* and *Note:* See Figure A.7 (p. 129).

A.5 Additional Figures – Ratio of Deposits to GDP

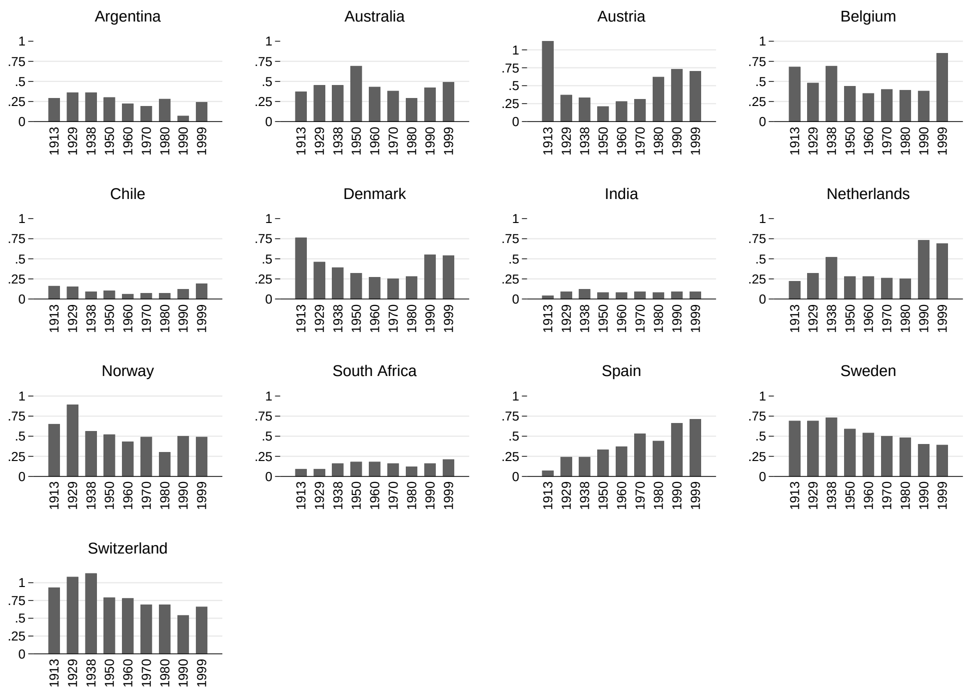

Figure A.9: Ratio of deposits to GDP from 1913 to 1999. *Source:* Rajan and Zingales (2003).

B Appendix to Chapter 3

B.1 Descriptive Statistics

Annual Data

Table B.1: Summary statistics, annual data, before 1950

	Obs.	Mean	SD	Min	5%	Median	95%	Max
g_rgdp	952	0.0143	0.0490	-0.230	-0.0720	0.0155	0.0933	0.230
g_rgdpbarro	952	0.0139	0.0483	-0.235	-0.0743	0.0152	0.0952	0.198
g_gdp	890	0.0374	0.0848	-0.274	-0.0865	0.0342	0.174	0.492
g_loans1	736	0.0600	0.119	-0.433	-0.0931	0.0492	0.264	0.886
g_bassets2	679	0.0585	0.0894	-0.226	-0.0544	0.0470	0.203	0.669
g_cpi	903	0.0138	0.0767	-0.196	-0.0880	0.00658	0.158	0.500
g_pop	952	0.00984	0.00843	-0.0719	0.00105	0.00906	0.0236	0.0500

Note: Yearly growth rates of original data.

Table B.2: Summary statistics, annual data, after 1950

	Obs.	Mean	SD	Min	5%	Median	95%	Max
g_rgdp	826	0.0271	0.0249	-0.0646	-0.0119	0.0256	0.0691	0.182
g_rgdpbarro	826	0.0269	0.0244	-0.0584	-0.0118	0.0254	0.0674	0.125
g_gdp	816	0.0859	0.0521	-0.0262	0.0166	0.0769	0.180	0.326
g_loans1	815	0.118	0.0817	-0.103	-0.000535	0.112	0.259	0.593
g_bassets2	813	0.114	0.0783	-0.155	0.000748	0.107	0.232	0.755
g_cpi	826	0.0466	0.0414	-0.0705	0.00236	0.0335	0.135	0.245
g_pop	826	0.00766	0.00601	-0.0110	0.000249	0.00686	0.0189	0.0440

Note: Yearly growth rates of original data.

Quarterly Data

Table B.3: Summary statistics, quarterly data

	Obs.	Mean	SD	Min	5%	Median	95%	Max
g_rgdp	3710	0.0303	0.0326	-0.0988	-0.0172	0.0288	0.0836	0.320
g_credit	4052	0.111	0.0895	-0.108	-0.00394	0.103	0.252	1.375
g_cpi	4143	0.0494	0.0470	-0.178	0.00405	0.0340	0.144	0.335
g_ppi	3479	0.0410	0.0566	-0.152	-0.0217	0.0298	0.147	0.463

Note: Four-quarter growth rates of original data as original real GDP series have been either available seasonally adjusted or not seasonally adjusted.

U.S. Data

Table B.4: Summary statistics, quarterly data, U.S.

	Obs.	Mean	SD	Min	5%	Median	95%	Max
grgdp	261	0.0321	0.0271	-0.0458	-0.0165	0.0310	0.0752	0.134
gcreditdef	261	0.0443	0.0785	-0.200	-0.0915	0.0531	0.168	0.287
gcreditcpi	261	0.0409	0.0779	-0.216	-0.0933	0.0491	0.165	0.274

Note: Four-quarter growth rates of original data as original real GDP series have been either available seasonally adjusted or not seasonally adjusted.

B.2 Additional Figures – Overview

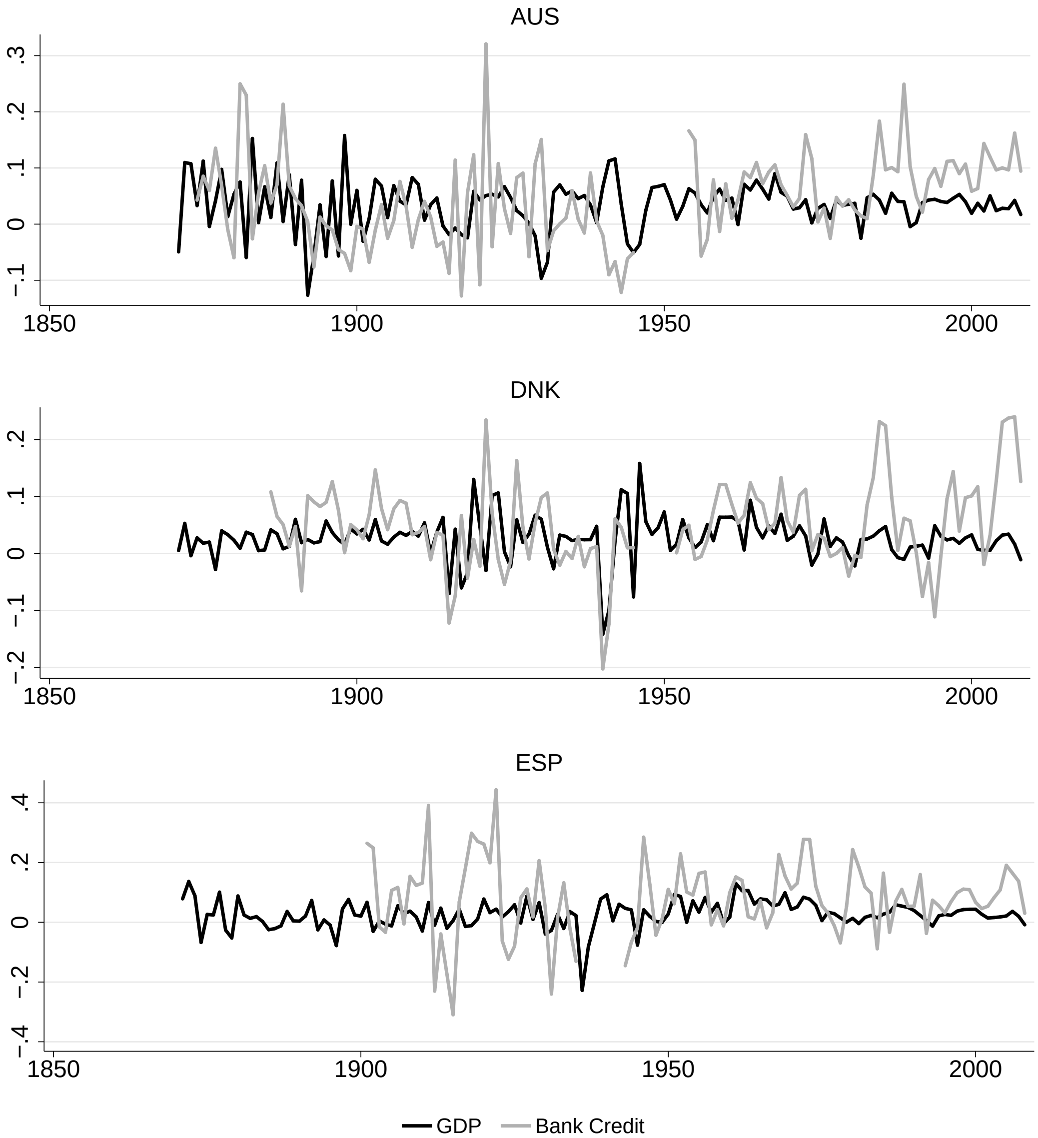

Figure B.1: Annual growth rates of real GDP and real bank credit. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009).

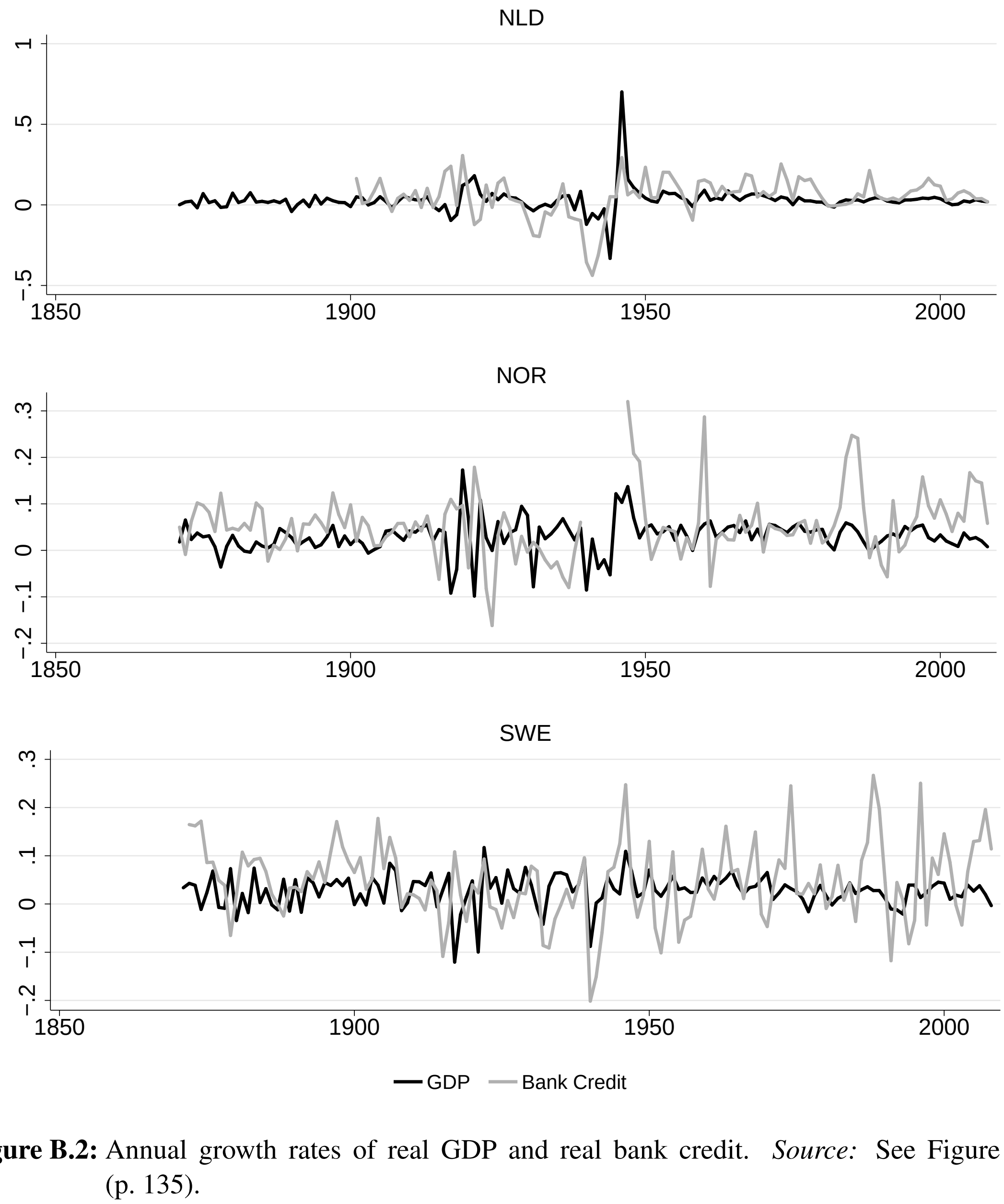

Figure B.2: Annual growth rates of real GDP and real bank credit. *Source:* See Figure B.1 (p. 135).

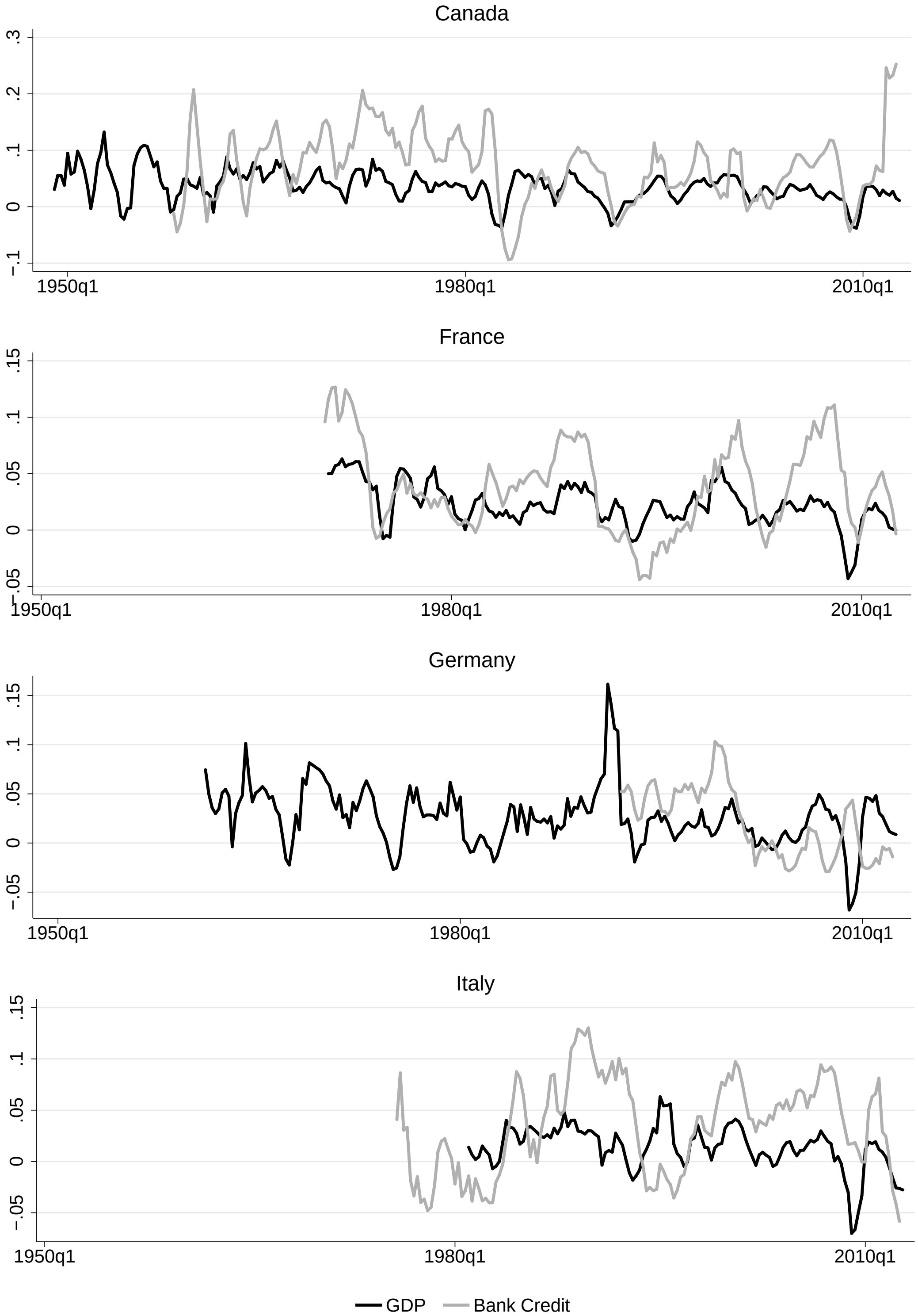

Figure B.3: Four-quarter growth rates of real GDP and real bank credit. *Source:* Own calculations. Bank credit data from Bank for International Settlements (2013), GDP data from International Monetary Fund (2013).

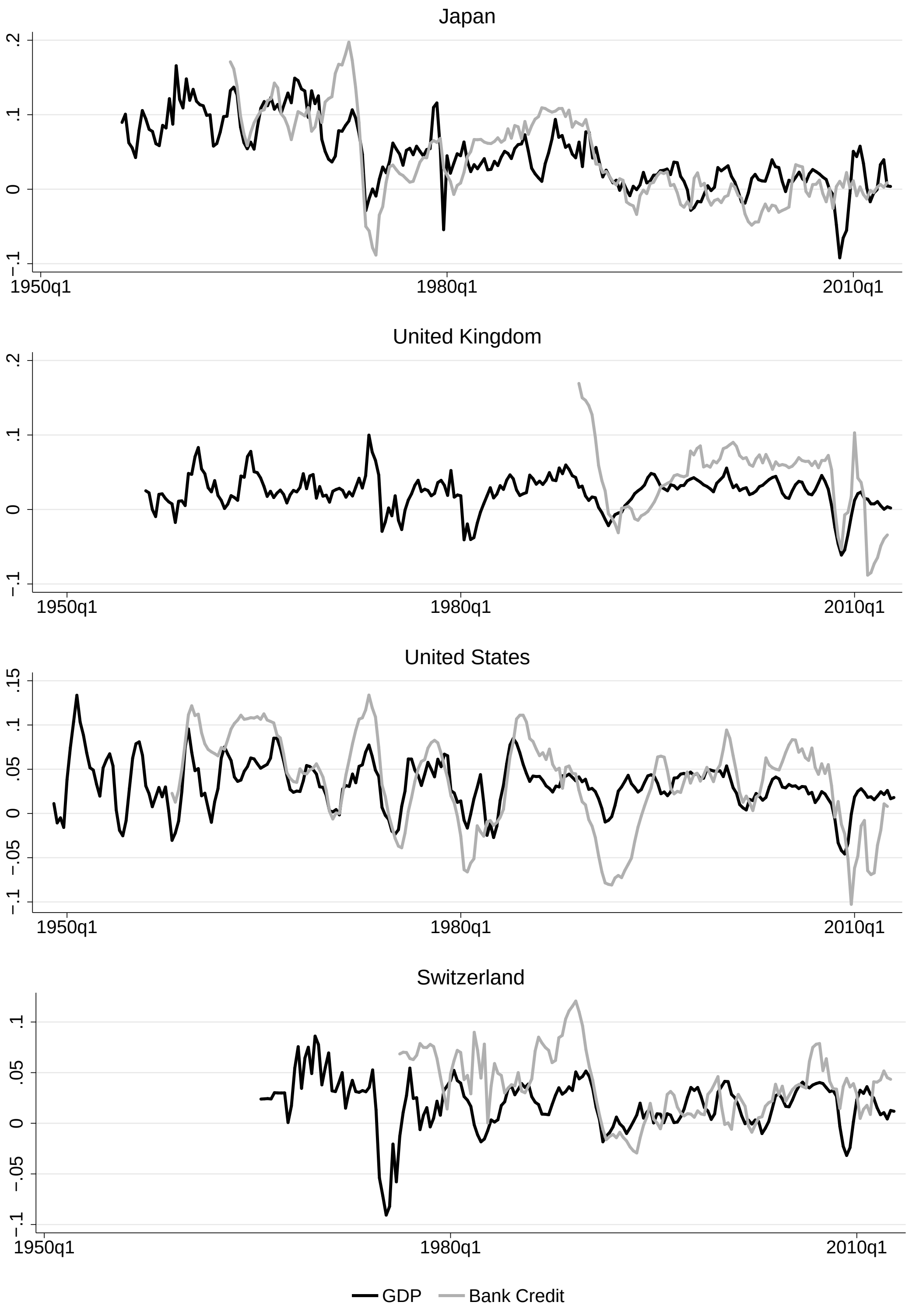

Figure B.4: Four-quarter growth rates of real GDP and real bank credit. *Source:* See Figure B.3 (p. 137).

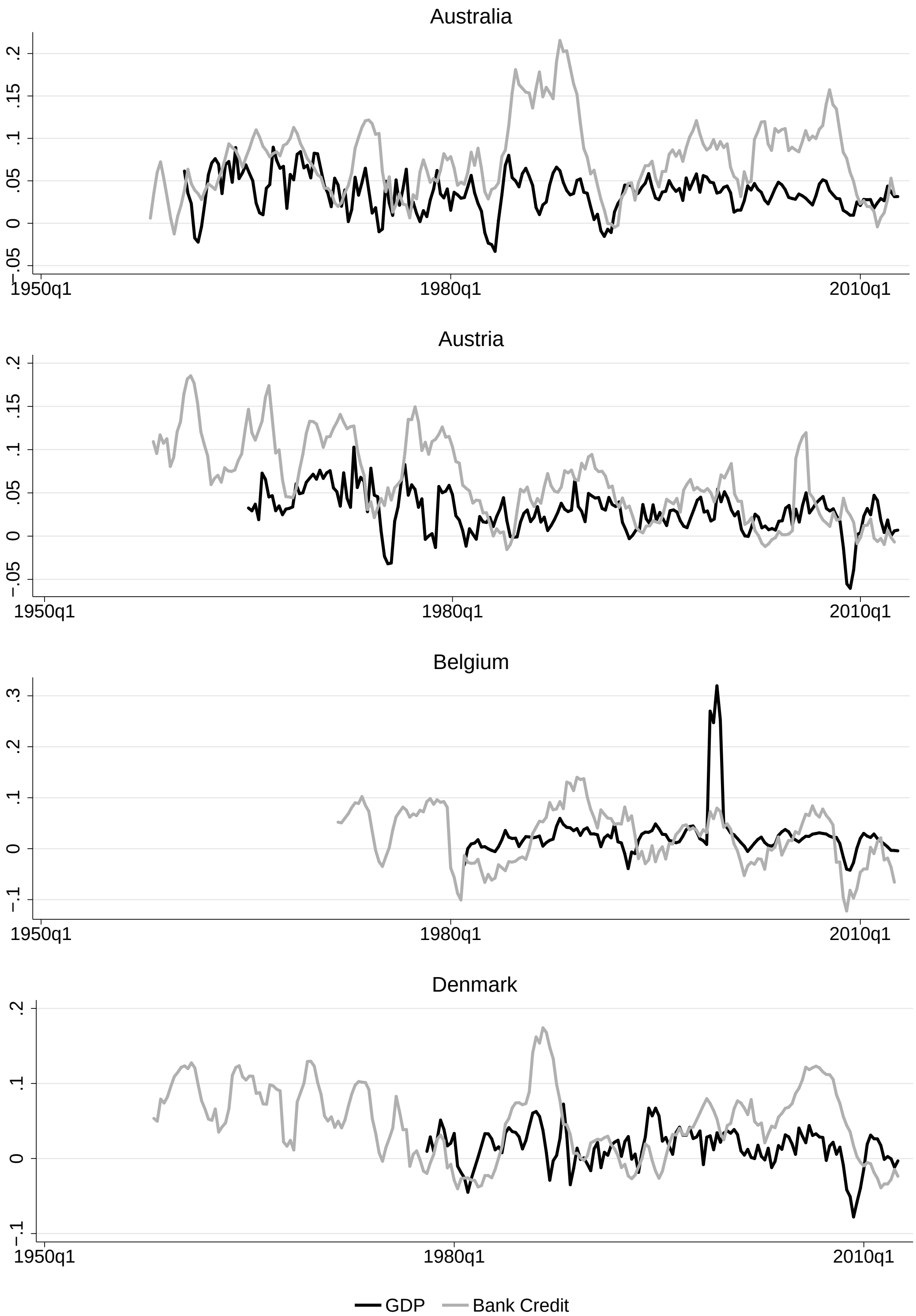

Figure B.5: Four-quarter growth rates of real GDP and real bank credit. *Source:* See Figure B.3 (p. 137).

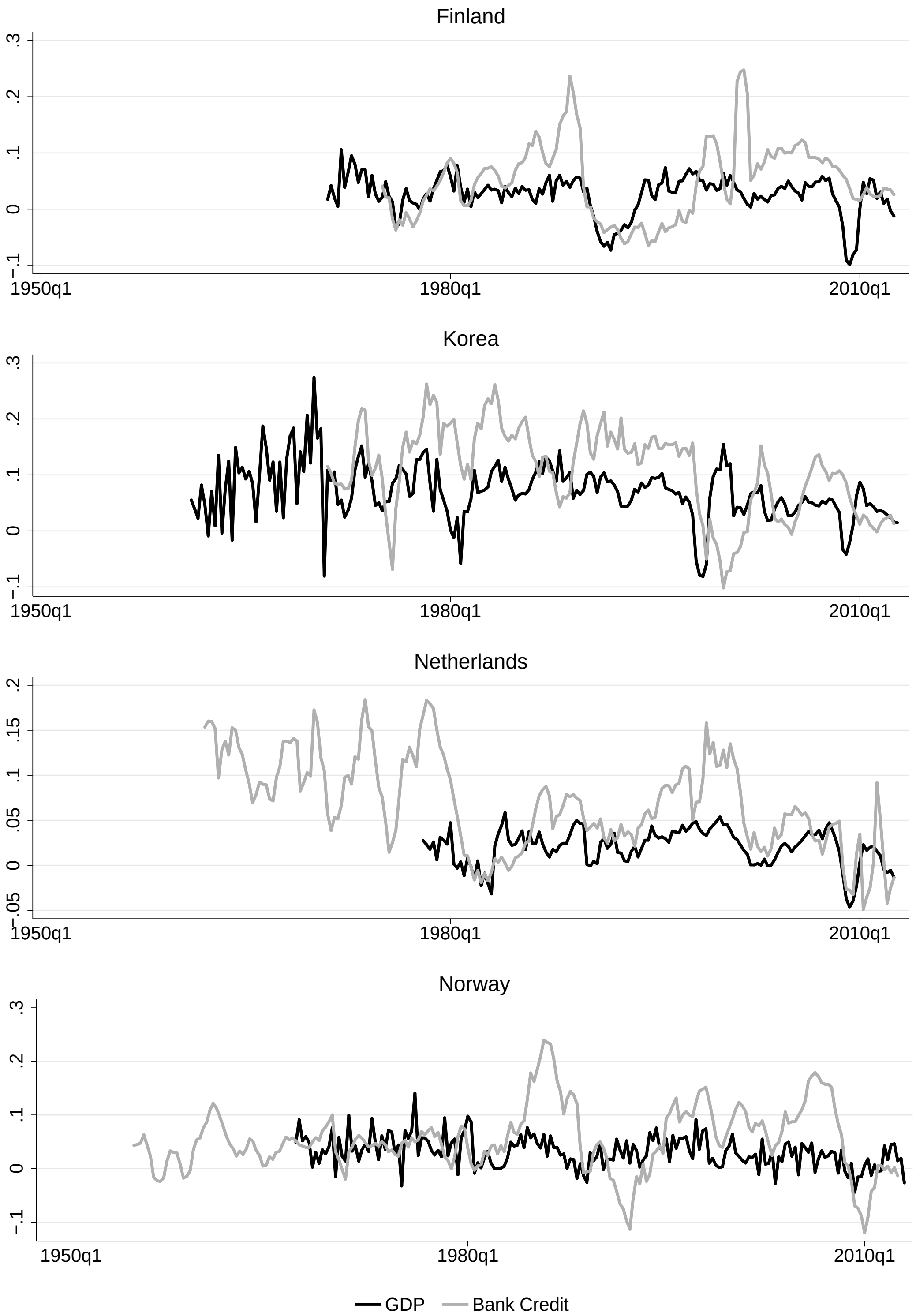

Figure B.6: Four-quarter growth rates of real GDP and real bank credit. *Source:* See Figure B.3 (p. 137).

Figure B.7: Four-quarter growth rates of real GDP and real bank credit. *Source:* See Figure B.3 (p. 137).

B.3 Additional Figures – Stylized Fact No. 1

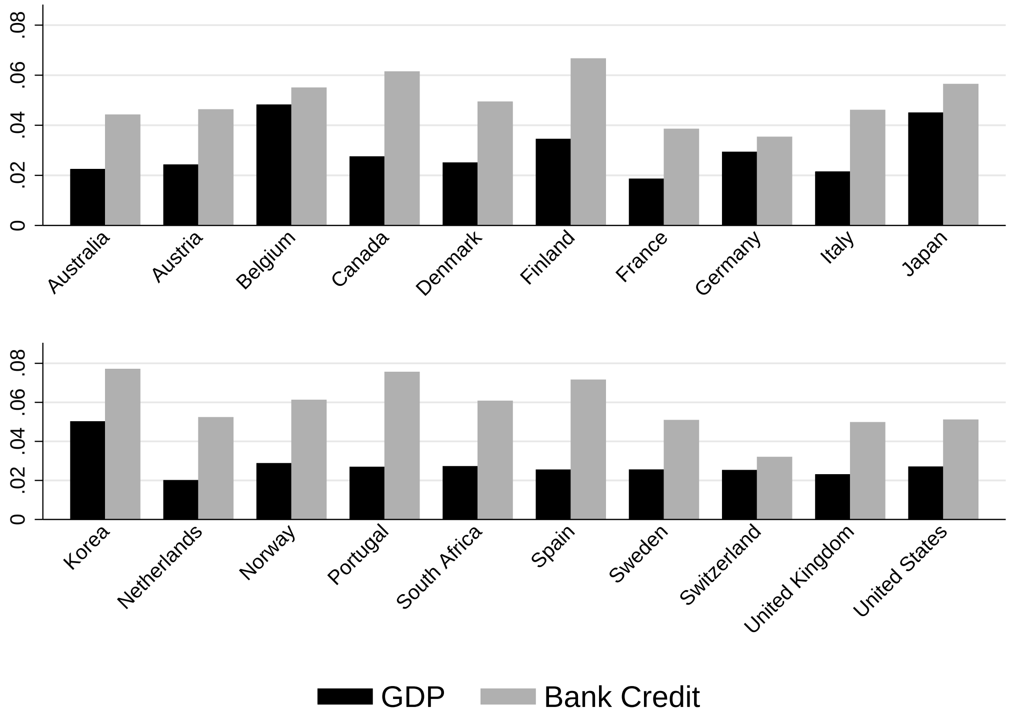

Figure B.8: Standard deviations of four-quarter growth rates of real GDP and real bank credit over the whole period of available data. *Source:* Own calculations. Bank credit data from Bank for International Settlements (2013), GDP data from International Monetary Fund (2013).

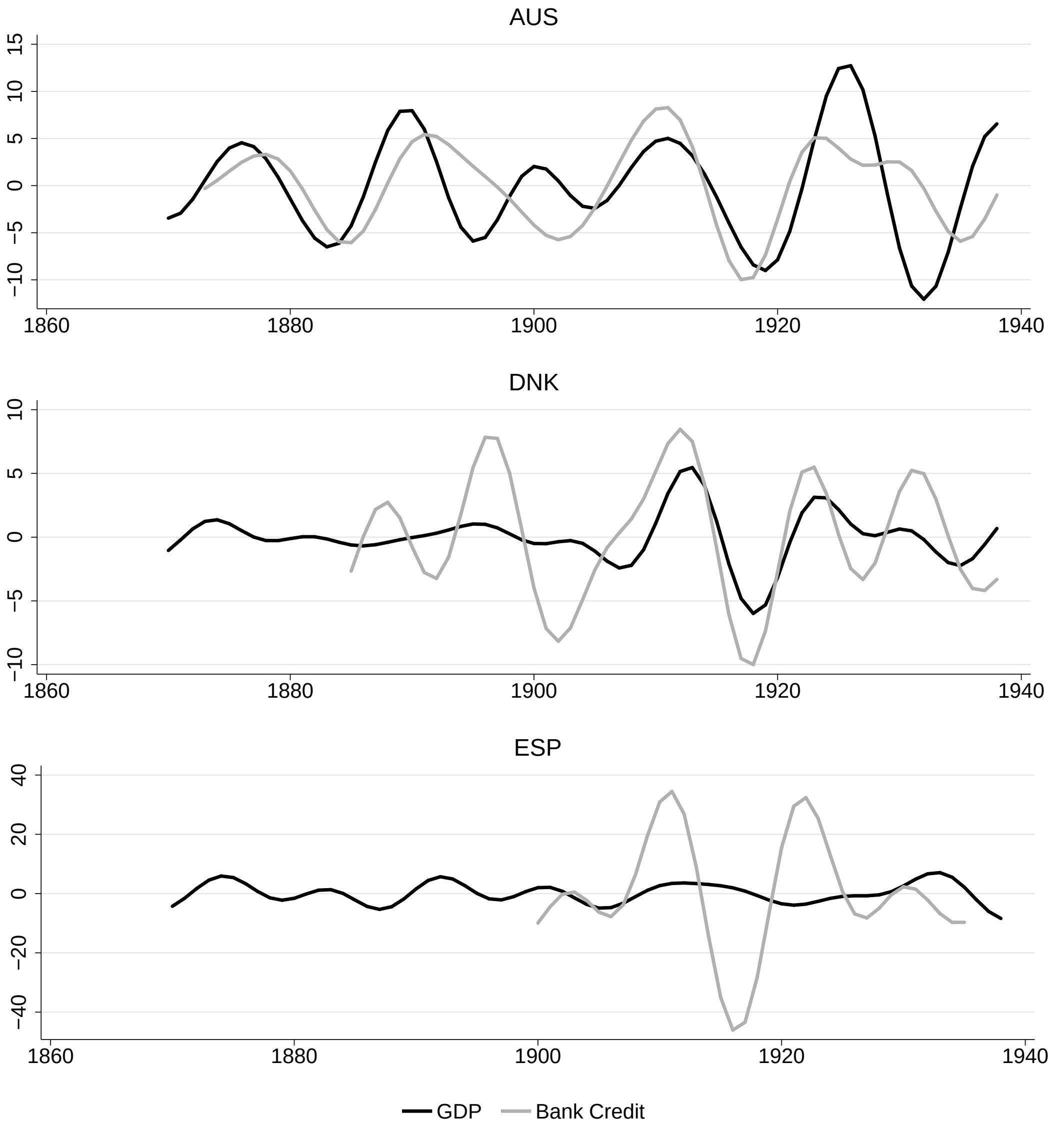

Figure B.9: Deviation from trend of real GDP and real bank credit before the Second World War. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009). *Note:* The trend component was generated using the band pass filter developed by Christiano and Fitzgerald (2003). We have filtered out stochastic cycles at periods smaller than eight and larger than twenty years.

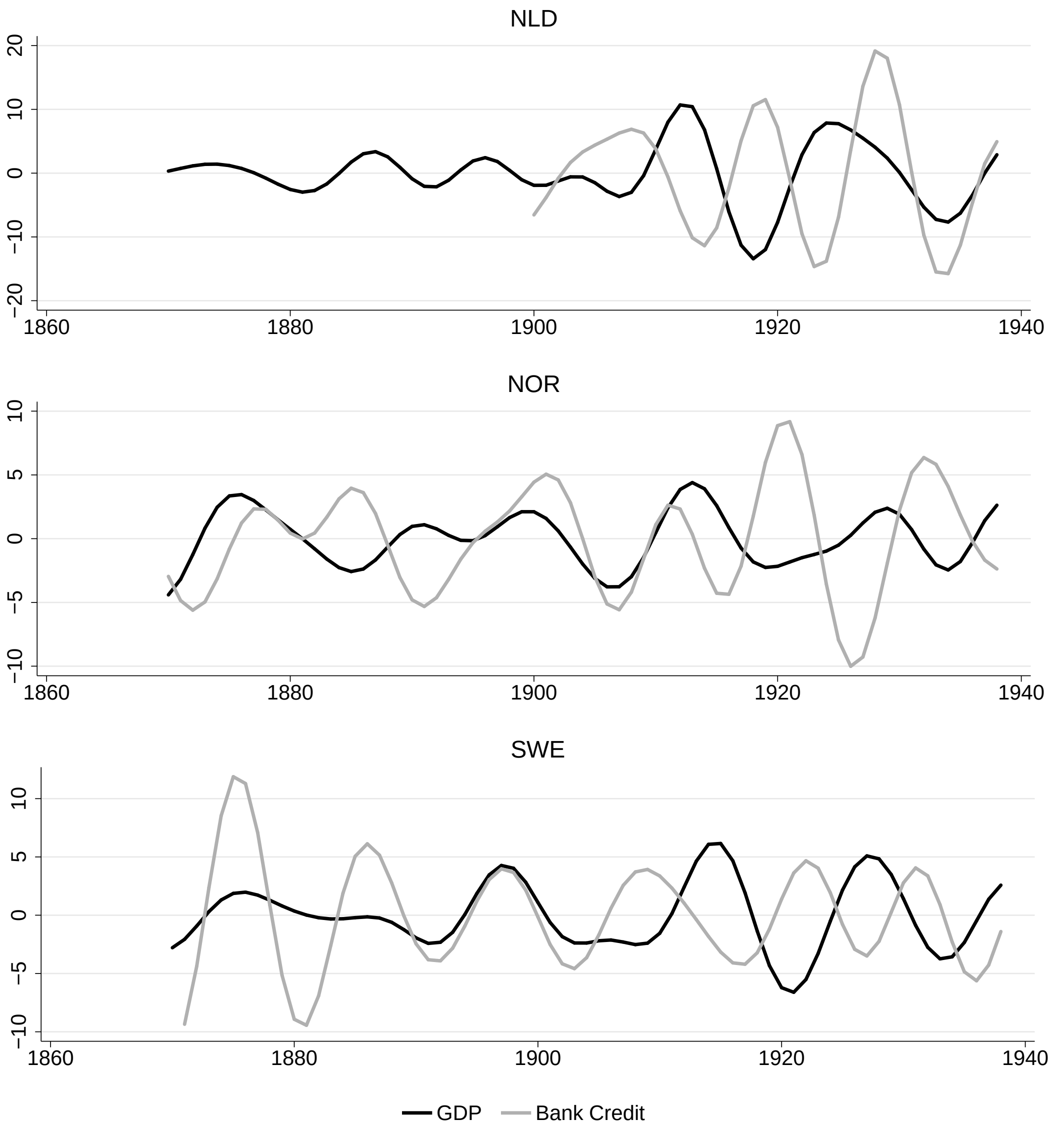

Figure B.10: Deviation from trend of real GDP and real bank credit before the First World War. *Source* and *Note:* See Figure B.9 (p. 143).

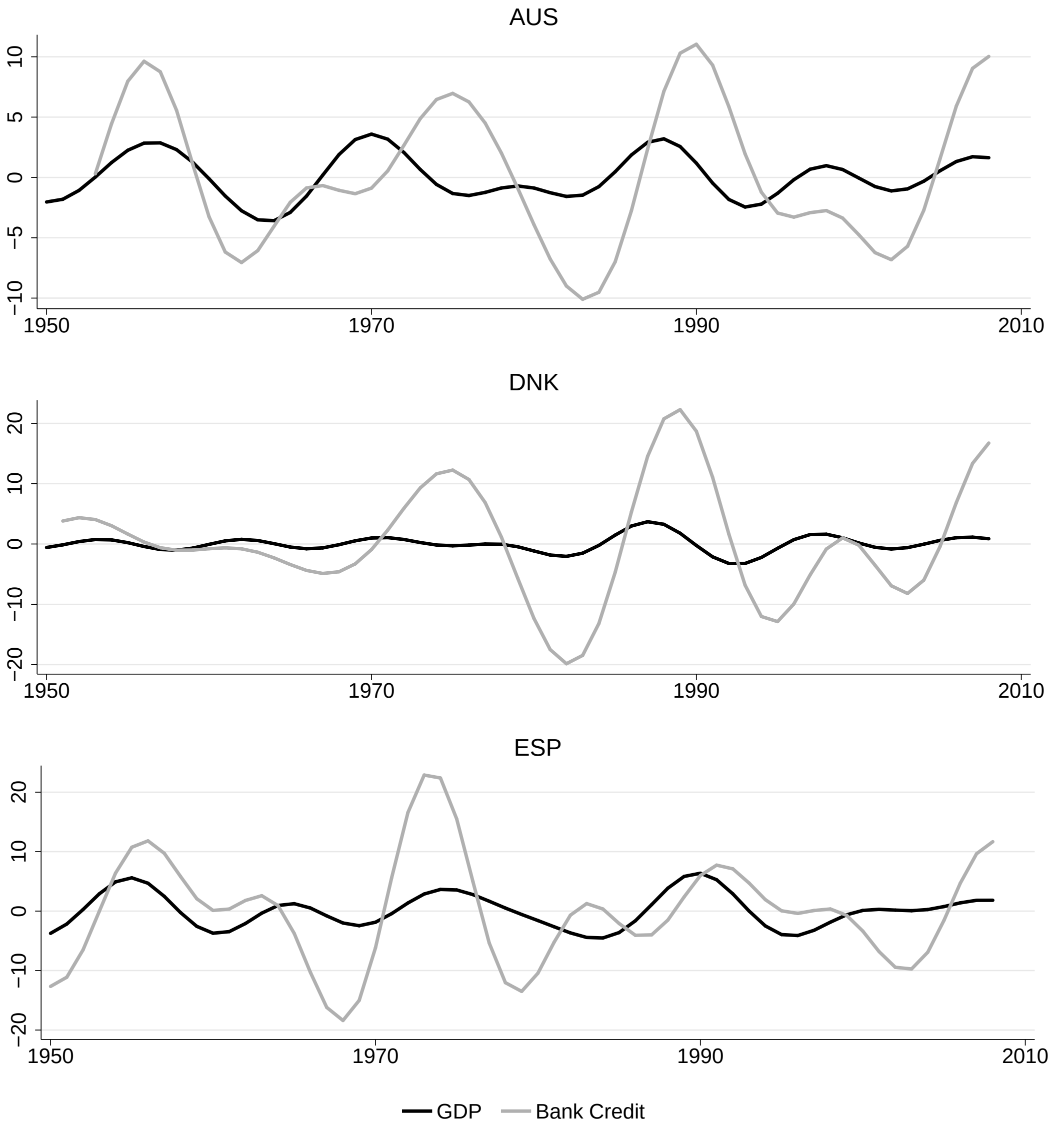

Figure B.11: Deviation from trend of real GDP and real bank credit after the Second World War. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009). *Note:* The trend component was generated using the band pass filter developed by Christiano and Fitzgerald (2003). We have filtered out stochastic cycles at periods smaller than eight and larger than twenty years.

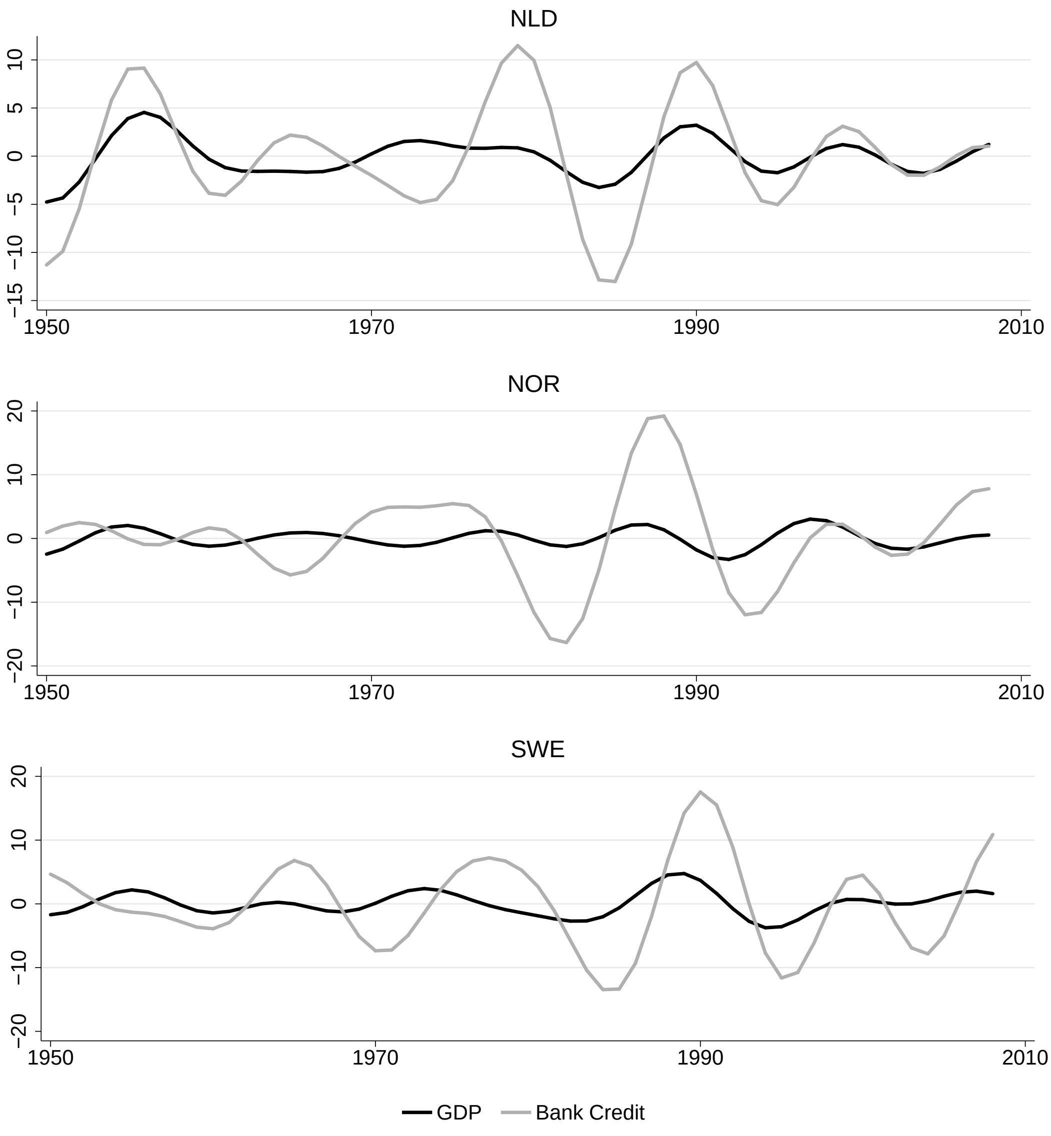

Figure B.12: Deviation from trend of real GDP and real bank credit after the Second World War.
Source and *Note:* See Figure B.11 (p. 145).

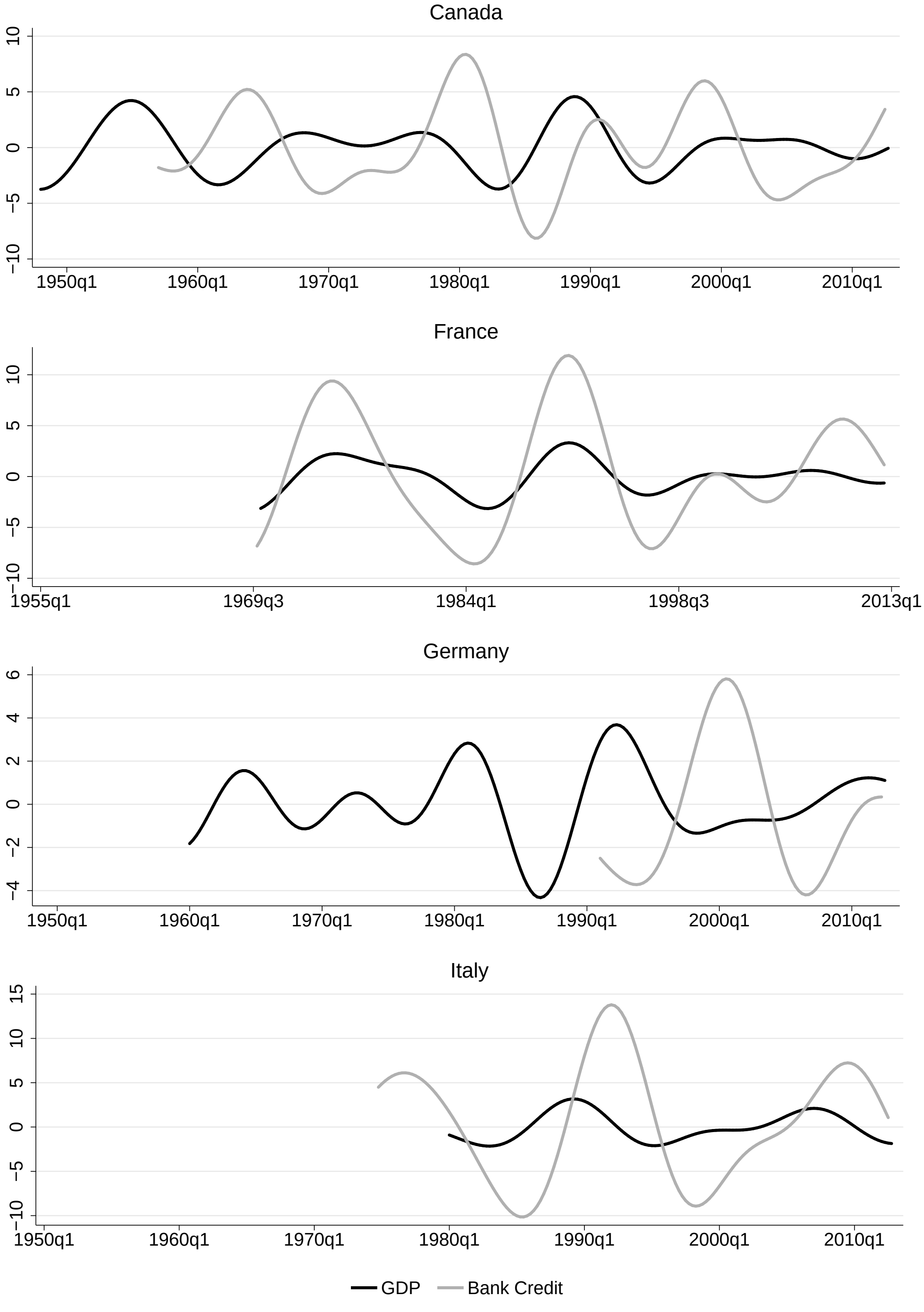

Figure B.13: Deviation from trend of real GDP and real bank credit. *Source:* Own calculations. Bank credit data from Bank for International Settlements (2013), GDP data from International Monetary Fund (2013). *Note:* The trend component was generated using the band pass filter developed by Christiano and Fitzgerald (2003). We filtered out stochastic cycles at periods smaller than eight and larger than twenty years.

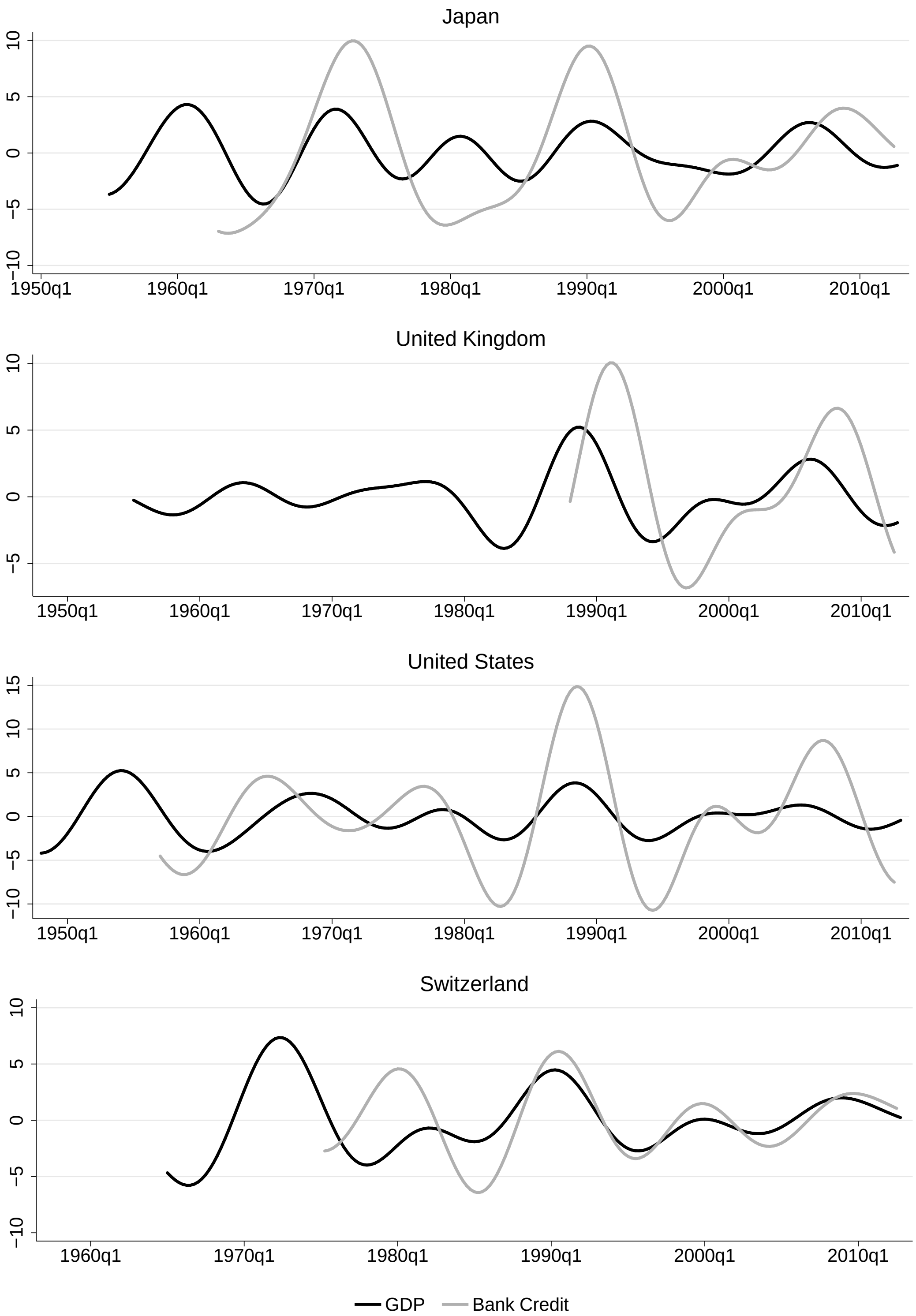

Figure B.14: Deviation from trend of real GDP and real bank credit. *Source* and *Note:* See Figure B.13 (p. 147).

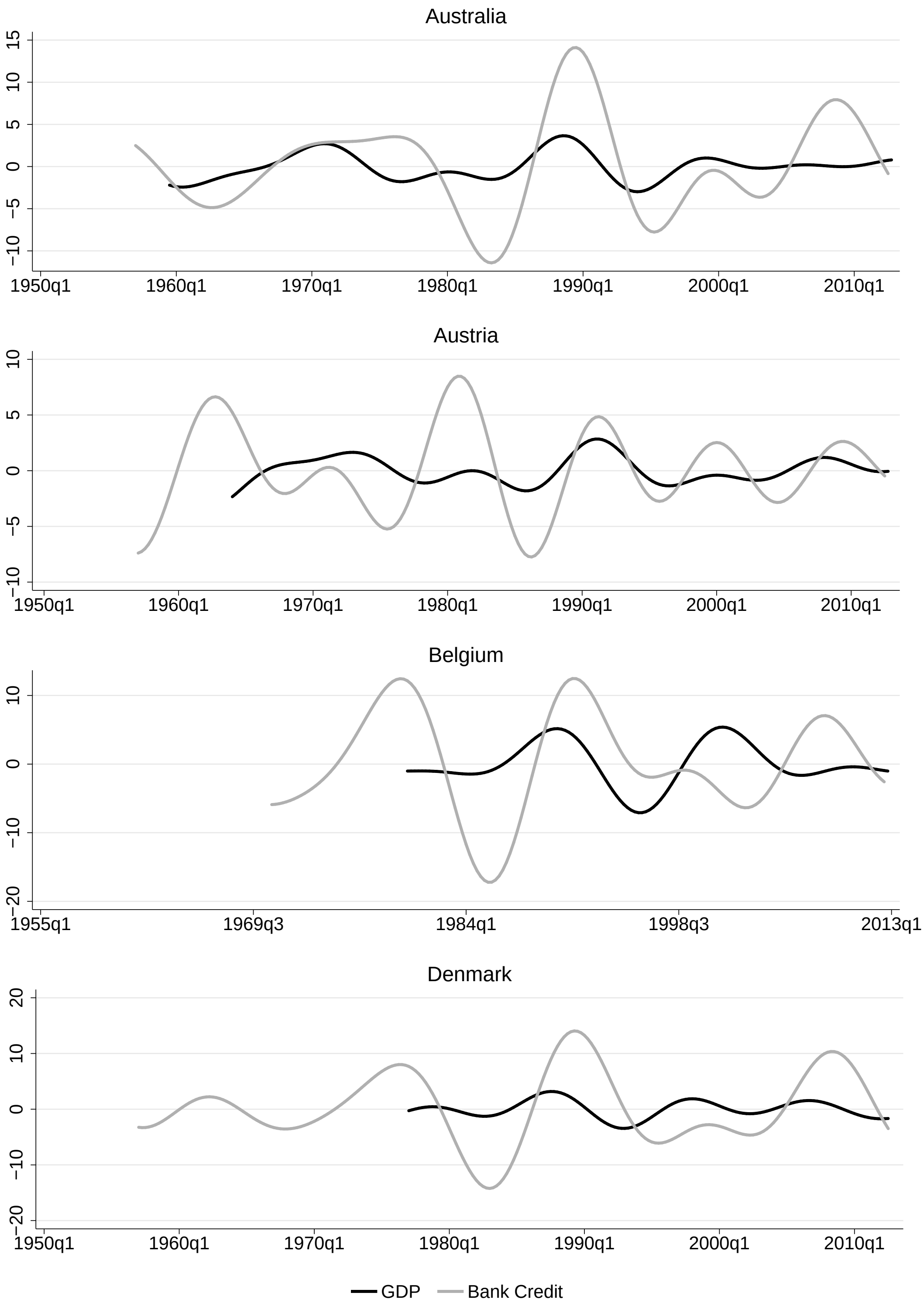

Figure B.15: Deviation from trend of real GDP and real bank credit. *Source* and *Note:* See Figure B.13 (p. 147).

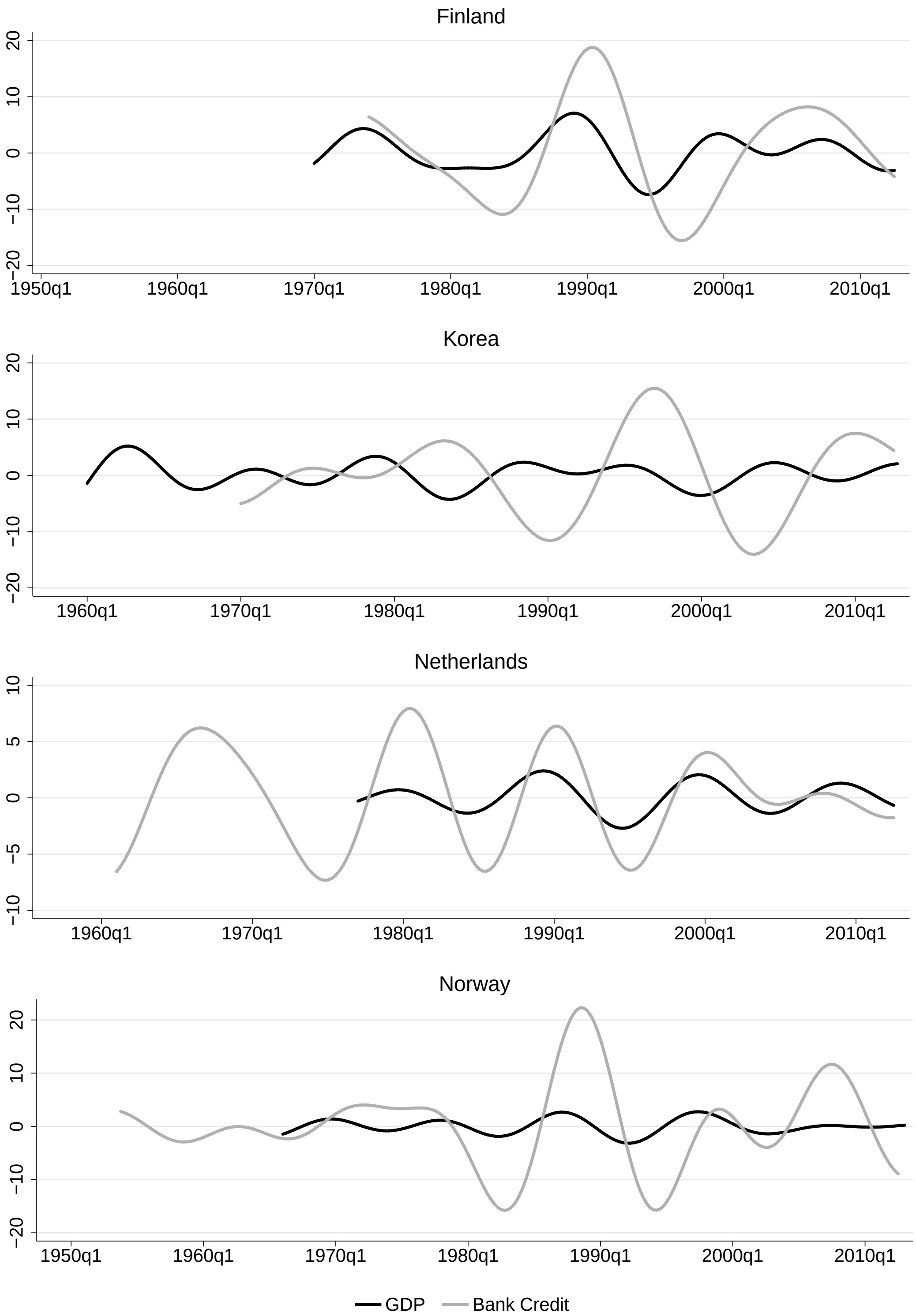

Figure B.16: Deviation from trend of real GDP and real bank credit. *Source* and *Note:* See Figure B.13 (p. 147).

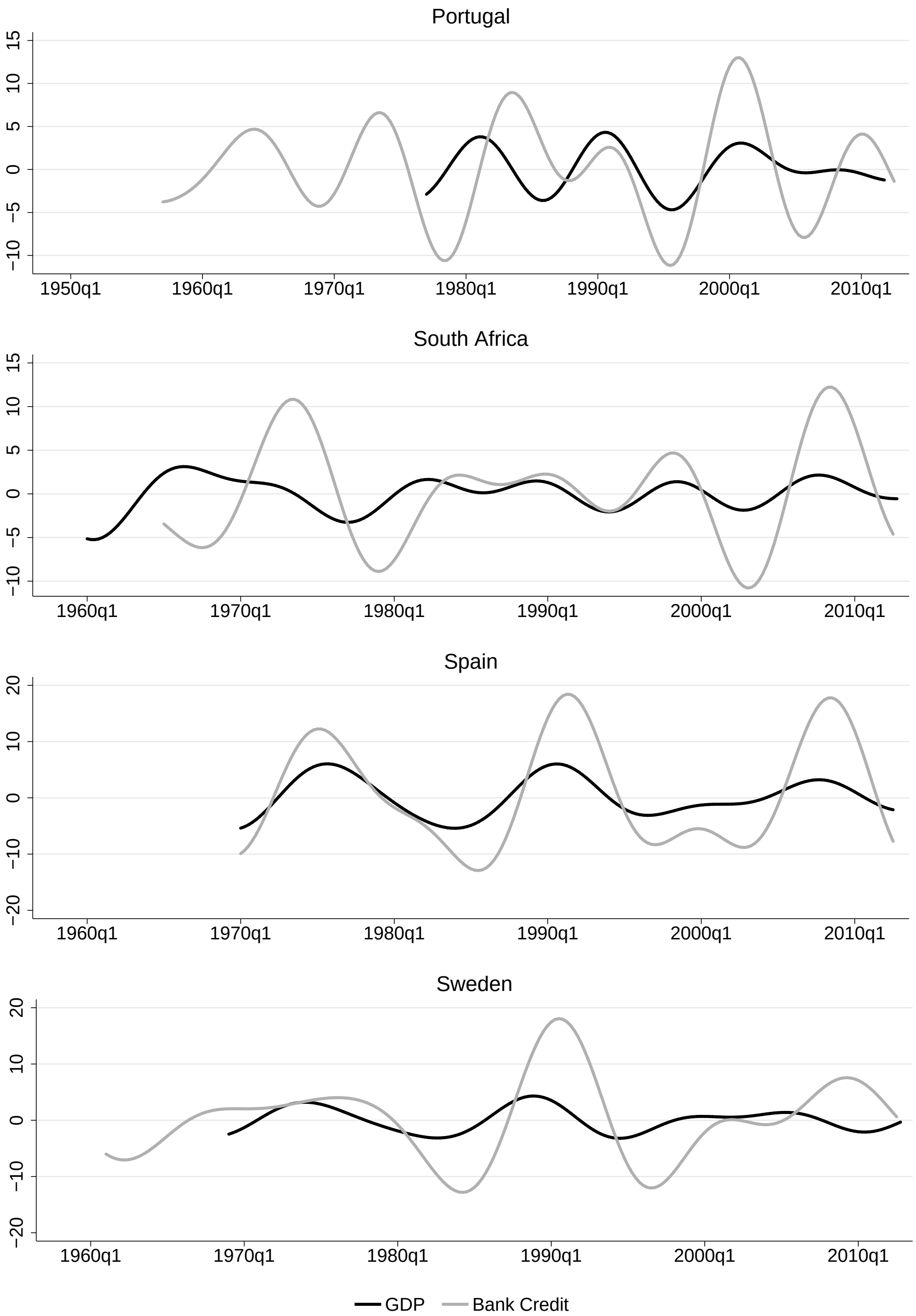

Figure B.17: Deviation from trend of real GDP and real bank credit. *Source* and *Note:* See Figure B.13 (p. 147).

B.4 Additional Figures – Stylized Fact No. 2

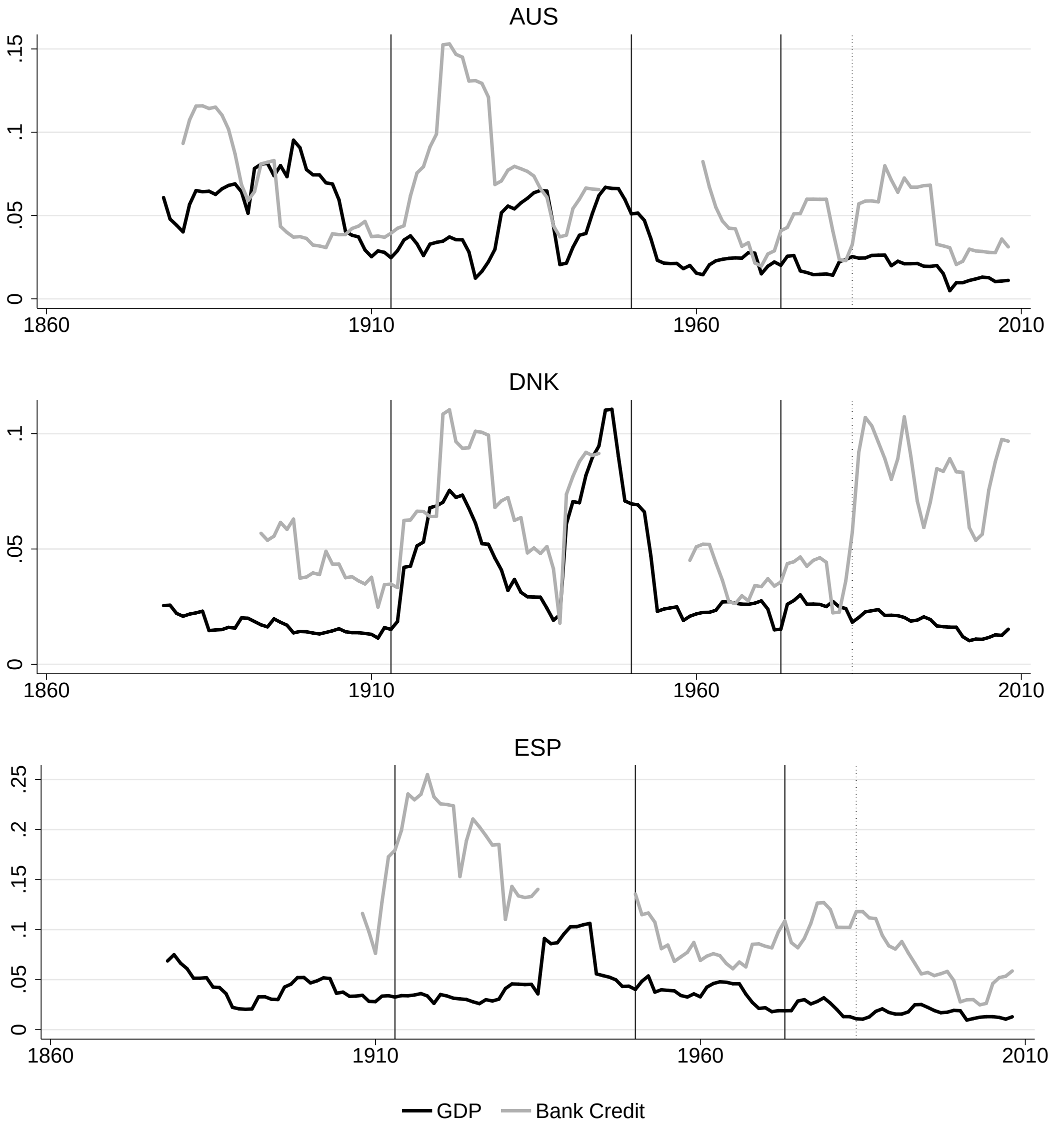

Figure B.18: Rolling standard deviation of real GDP and real bank credit over an eight year window. *Source:* Own calculations. Bank credit data from Schularick and Taylor (2012), GDP data from Barro (2009). *Note:* The reported value in every chart at year t is the standard deviation of the respective time series over the period $t-7$ to t. If there is one or more missing values in this period, there is no value for t. Vertical lines drawn at 1913, 1950, 1973, and 1984.

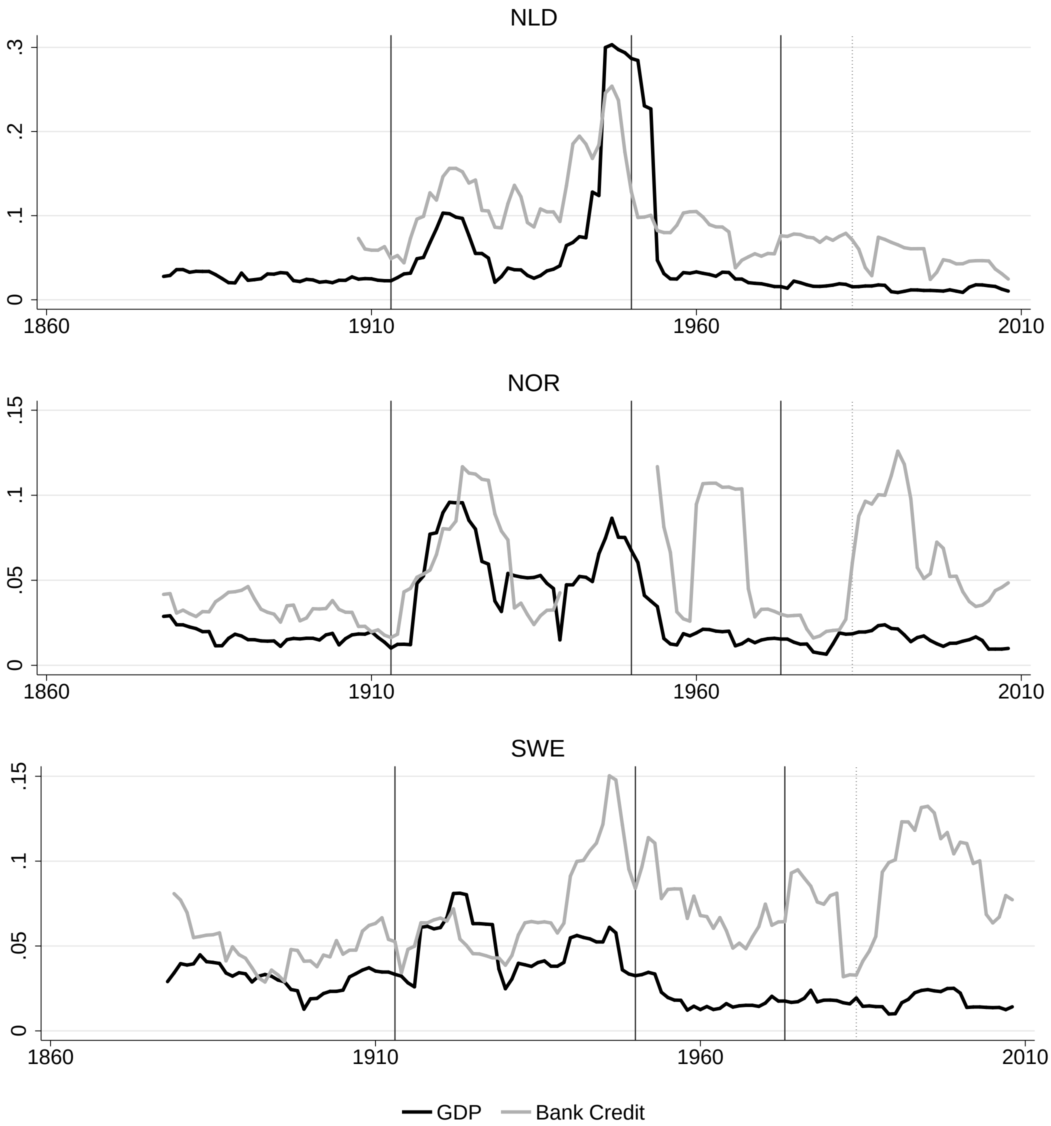

Figure B.19: Rolling standard deviation of real GDP and real bank credit over an eight year window. *Source* and *Note:* See Figure B.18 (p. 152).

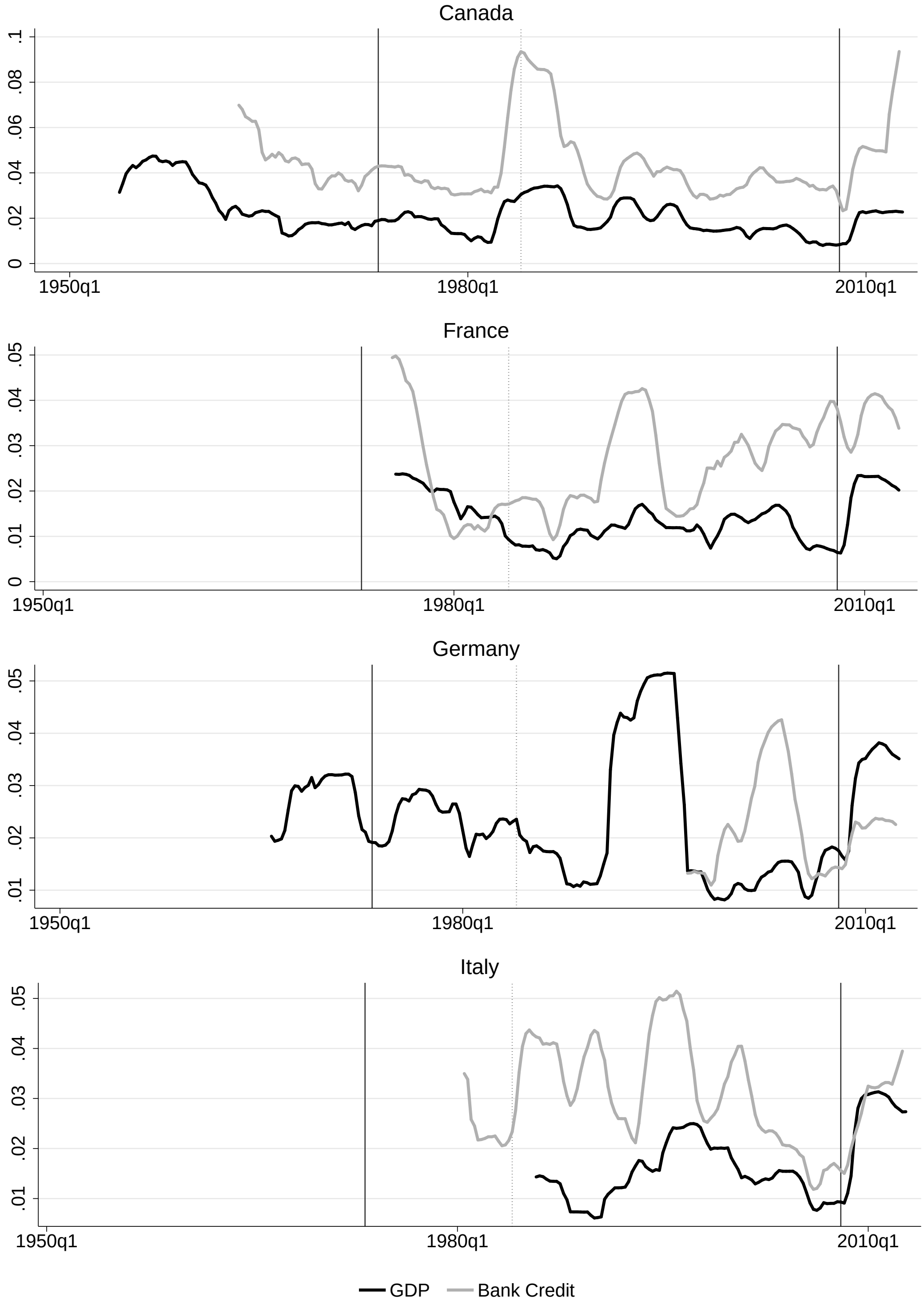

Figure B.20: Rolling standard deviation of real GDP and real bank credit over a twenty quarter window. *Source:* Own calculations. Bank credit data from Bank for International Settlements (2013), GDP data from International Monetary Fund (2013). *Note:* The reported value in every chart at year t is the standard deviation of the respective time series over the period $t-19$ to t. Horizontal lines drawn at 1973, 1984, and 2008.

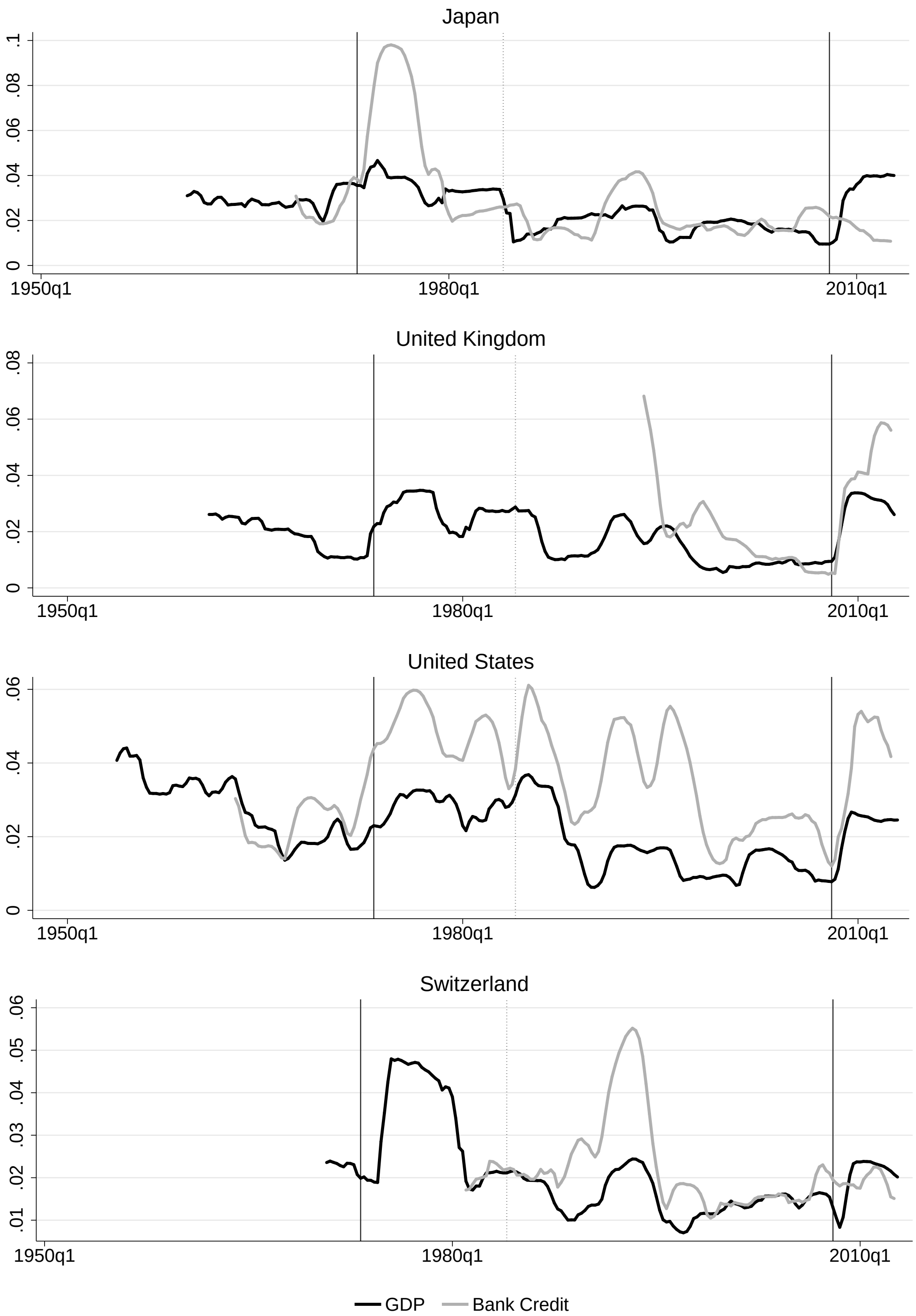

Figure B.21: Rolling standard deviation of real GDP and real bank credit over a twenty quarter window. *Source* and *Note:* See Figure B.20 (p. 154).

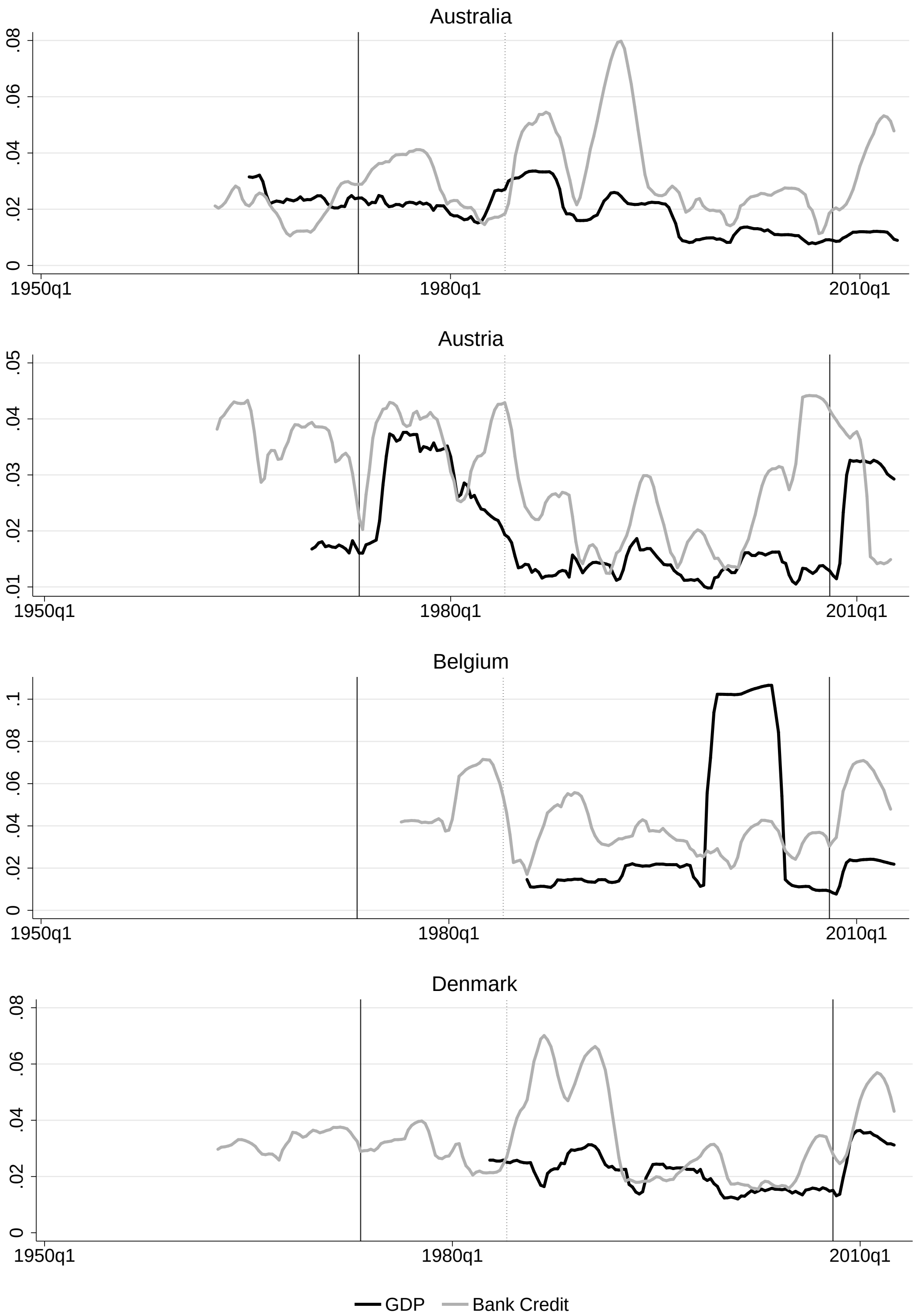

Figure B.22: Rolling standard deviation of real GDP and real bank credit over a twenty quarter window. *Source* and *Note:* See Figure B.20 (p. 154).

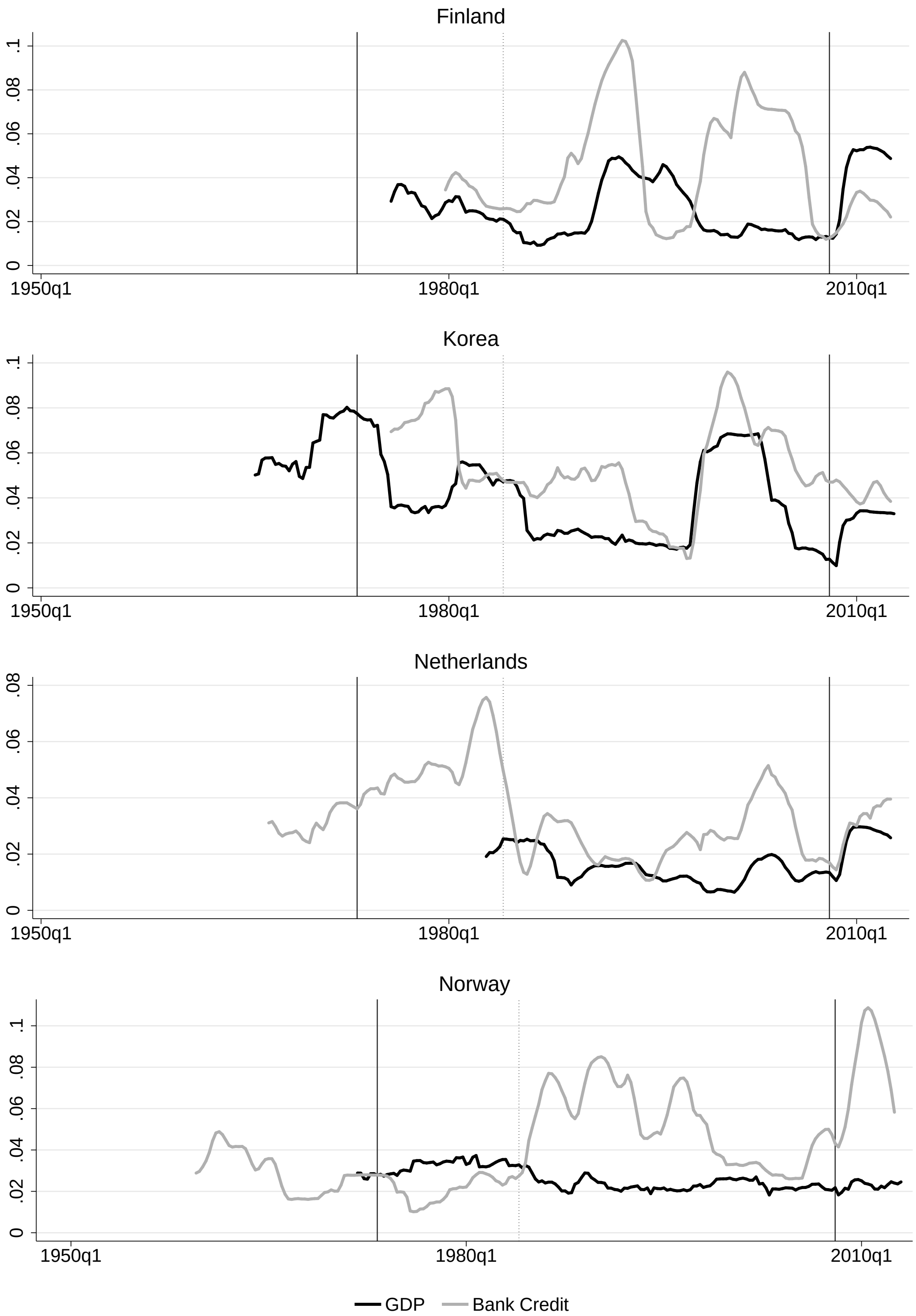

Figure B.23: Rolling standard deviation of real GDP and real bank credit over a twenty quarter window. *Source* and *Note:* See Figure B.20 (p. 154).

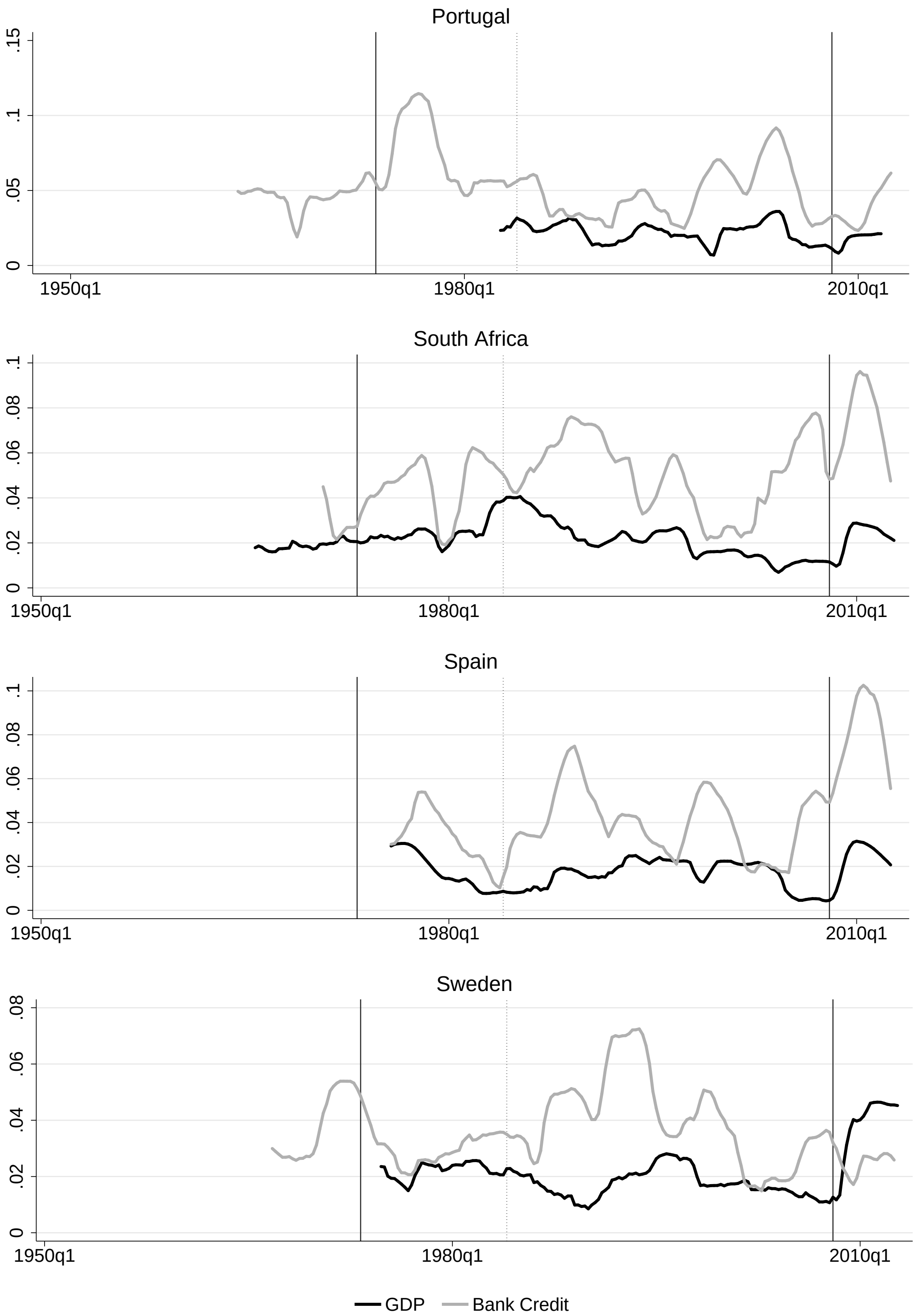

Figure B.24: Rolling standard deviation of real GDP and real bank credit over a twenty quarter window. *Source* and *Note:* See Figure B.20 (p. 154).

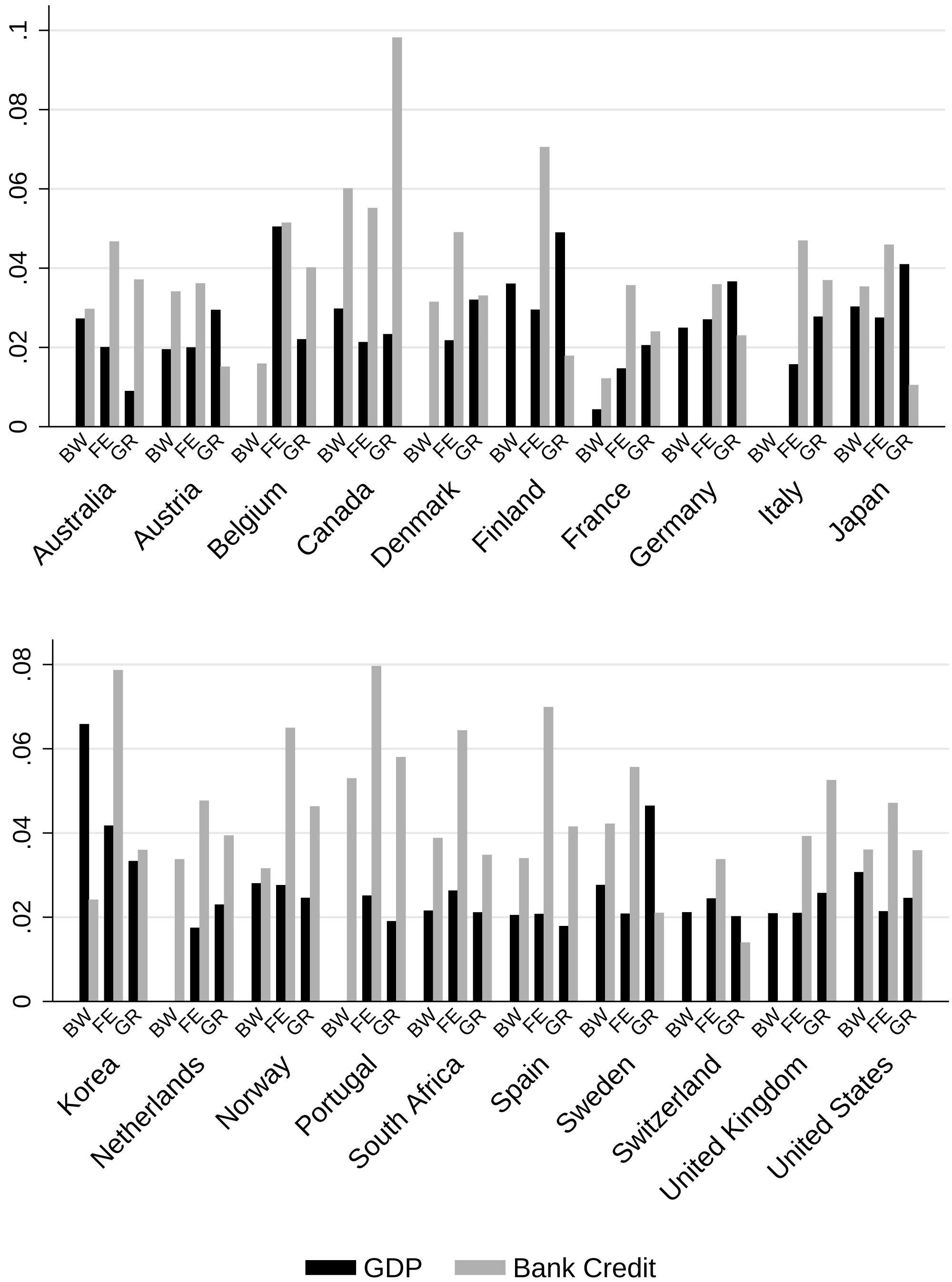

Figure B.25: Standard deviations of growth rates of real GDP and real bank credit. *Source:* Own calculations. Bank credit data from Bank for International Settlements (2013), GDP data from International Monetary Fund (2013). *Note:* BW: "Bretton-Woods", data for 1950-1973; FE: "Floating Exchange Rates", data for 1973-2008, GR: "Great Recession", data after 2008. The "Bretton-Woods" period cannot be compared to annual data for the same period since in some countries, the quarterly times series start later than 1950.

C Appendix to Chapter 4

C.1 Additional Examples

In the following three examples, the Inada conditions are violated and corner solutions emerge.

■ **Example A1:** $y_F = W$ **when** $f'(0) < \infty$ **and** $f'(W) > 0$**.**
We set $W = 1$, $\sigma = 0.5$, $\theta \in (0,1)$, $\underline{R} = 0$, $\overline{R} \in (0,3]$, and assume that $f(K_F) = K_F + \ln(1+K_F)$. Setting $p_g = p_b = 1/3$ will clear the market with $y_F = W$, $y_M = 0$. In this example, the returns in the risky sector are too low in order to attract any funds from households. Hence households invest in the safe technology FT only.

■ **Example A2:** $y_F = 0$ **when** $f'(0) < \infty$ **and** $f'(W) > 0$**.**
Let us use $f(K_F) = \frac{K_F}{1+K_F}$ instead of $f(K_F) = (K_F - \frac{1}{2}K_F^2)$ in Example 2. In this case,nmarkets are cleared with $y_F = 0$, $y_M = W$, that is, no investment in the safe technology. This example is similar to Example 2. Again, returns on investments in FT are so low that people prefer to invest in the risky technology only.

■ **Example A3:** $y_F = 0$ **when** $f'(0) < \infty$**.**
Let $W = 1$, $f(K_F) = (K_F - \frac{1}{2}K_F^2)$, $\theta = 1/2$, $\underline{R} = 2, \overline{R} = 3$. Then $p_g\overline{R} + p_b\underline{R} \leq 1$ implies $p_g + p_b < 1$. Suppose $p_g = \dfrac{1}{2\overline{R}}$, $p_b = \dfrac{1}{2\underline{R}}$. Then $p_g\overline{R} + p_b\underline{R} = 1$ and $p_g + p_b < 1$. Since $f'(0) = 1$, Π_F is maximized at $y_F = 0$. The market for the investment good is cleared when $y_M = W$. The resulting maximum profits are $\Pi_F = \Pi_M = 0$. Demand for consumption goods becomes

$$
\begin{aligned}
c_g(p_g, p_b) &= \left[p_g + \left(\frac{p_g}{p_b}\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b\right]^{-1} \cdot W, \text{ and} \\
c_b(p_g, p_b) &= \left[\left(\frac{p_b}{p_g}\frac{\sigma}{1-\sigma}\right)^{\frac{1}{\theta}} p_g + p_b\right]^{-1} \cdot W.
\end{aligned}
$$

Choose $\sigma \in (0,1)$ so that

$$\left(\frac{p_g}{p_b}\right)^{1-\theta} = \frac{\sigma}{1-\sigma}$$

and consequently,

$$\left(\frac{p_g}{p_b}\cdot\frac{1-\sigma}{\sigma}\right)^{1/\theta} = \frac{p_g}{p_b}.$$

Then $c_g = [2p_g]^{-1}\cdot W = W\overline{R}$, $c_b = [2p_b]^{-1}\cdot W = W\underline{R}$ and with $y_M = W$ all markets are cleared. In this example, returns on investments in FT are such that entrepreneurs prefer to invest in the risky MT technology only. This is possible because the Inada condition at zero is not satisfied.

C.2 Households' Optimal Portfolio Choice Problem

Household utility is given by

$$\begin{aligned} U(\gamma) &= \frac{1}{1-\theta}\left\{\sigma c_g^{1-\theta} + (1-\sigma)c_b^{1-\theta}\right\}, \\ \text{where } c_g &= W((1-\gamma)\overline{R}_E + \gamma R_S) + \Pi_F, \\ c_b &= W((1-\gamma)\underline{R}_E + \gamma R_S) + \Pi_F - T. \end{aligned}$$

The representative household solves the following problem:

$$\begin{aligned} \max_{\gamma} U(\gamma) = \frac{1}{1-\theta}\Big\{\sigma\left[W((1-\gamma)\overline{R}_E + \gamma R_S) + \Pi_F\right]^{1-\theta} \\ +(1-\sigma)\left[W((1-\gamma)\underline{R}_E + \gamma R_S) + \Pi_F - T\right]^{1-\theta}\Big\}. \end{aligned}$$

The first-order condition for γ is

$$\frac{\sigma(R_S - \overline{R}_E)}{c_g^\theta} + \frac{(1-\sigma)(R_S - \underline{R}_E)}{c_b^\theta} = 0. \tag{C.1}$$

Rearranging this expression, we obtain

$$\frac{c_g}{c_b} = A_1, \tag{C.2}$$

$$\text{where } A_1 := \left[\frac{\sigma(\overline{R}_E - R_S)}{(1-\sigma)(R_S - \underline{R}_E)}\right]^{\frac{1}{\theta}}.$$

Using c_b and c_g to get an expression for γ, we obtain

$$\left[W((1-\gamma)\overline{R}_E + \gamma R_S) + \Pi_F\right] = \left[W((1-\gamma)\underline{R}_E + \gamma R_S) + \Pi_F - T\right] A_1 \text{ or}$$

$$\gamma = \frac{(1/W)[\Pi_F(1-A_1) + TA_1)] + \overline{R}_E - A_1\underline{R}_E}{\overline{R}_E - R_S + A_1(R_S - \underline{R}_E)}.$$

C.3 Banks' Return on Equity Maximization Problem

We ignore the denominator E in $\mathbb{E}\,[ROE(\alpha)]$ and work with the bank's expected profit instead. Without limited liability, bank profits would be $\alpha[\overline{R} - R_F](D + E) + R_F E$ in the good state and $\alpha[\underline{R} - R_F](D + E) + R_F E$ in the bad state. In case $R_F \leq \underline{R}$, $\alpha = 1$ is optimal. In case $R_F \geq \overline{R}$, $\alpha = 0$ is optimal.

From hereon, we consider the case $\underline{R} < R_F < \overline{R}$. In that case, there is never a default in the good state. Let us focus on the bad state. At $\alpha = 0$, the bank makes a positive profit. At $\alpha = 1$, the bank's profit is $B_0 := \underline{R}(D + E) - R_F D$.

If $B_0 \geq 0$, the bank never defaults in either state and its expected profit is

$$\begin{aligned} & [\alpha\sigma\overline{R} + \alpha(1-\sigma)\underline{R} + (1-\alpha)R_F](D+E) - R_F D \\ = \;& \alpha[\sigma\overline{R} + (1-\sigma)\underline{R} - R_F](D+E) + R_F E \\ = \;& \alpha B_1(D+E) + R_F E. \end{aligned}$$

Hence,

$$\begin{array}{lll} \alpha = 0 & \text{is optimal if} & B_1 < 0, \\ \alpha = 1 & \text{is optimal if} & B_1 > 0, \\ \alpha \in [0,1] & \text{is optimal if} & B_1 = 0. \end{array}$$

Next we consider the case $B_0 < 0$. The bank breaks even in the bad state at $\widehat{\alpha} \in (0, 1)$ satisfying $\widehat{\alpha}[\underline{R} - R_F](D + E) + R_F E = 0$.

- If $B_1 > 0$, then the bank's expected profit is increasing in α in the entire interval $[0, 1]$ and $\alpha = 1$ is optimal.

- If $B_1 = 0$, then the bank's expected profit is constant in the interval $[0, \widehat{\alpha}]$ and increasing in the interval $[\widehat{\alpha}, 1]$ and, hence, $\alpha = 1$ is optimal.

- If $B_1 < 0$, then the bank's expected profit is decreasing in the interval $[0, \widehat{\alpha}]$ and increasing in the interval $[\widehat{\alpha}, 1]$. Therefore, the optimal α is obtained from comparing $\sigma \cdot \{[\overline{R} - R_F](D + E) + R_F E\}$, the expected profit when $\alpha = 1$, and $R_F E$, the expected profit when $\alpha = 0$.

The comparison of $\sigma \cdot \{[\overline{R} - R_F](D + E) + R_F E\}$ and $R_F E$ also provides the answer if $B_1 \geq 0$. Denote the difference

$$\begin{aligned} B_2 &= \sigma \cdot \{[\overline{R} - R_F](D+E) + R_F E\} - R_F E \\ &= [\sigma\overline{R} - R_F](D+E) + (1-\sigma)R_F D. \end{aligned}$$

Then $B_2 > 0$ means that $\alpha = 1$ is optimal, $B_2 < 0$ means that $\alpha = 0$ is optimal while $B_2 = 0$ means that both $\alpha = 0$ and $\alpha = 1$ are optimal. Eventually, note that $(1-\sigma)B_0 + B_2 = B_1(E+D)$. This allows for a characterization of the optimal choice of α with B_1 and B_2 only.

C.4 Proofs

C.4.1 Proof of Proposition 4.4

Let p_g^* and p_b^* be the Arrow-Debreu equilibrium prices. We set

$$R_F = \frac{1}{p_g^* + p_b^*}.$$

Since

$$f'(y_F^*) = \frac{1}{p_g^* + p_b^*},$$

it follows that $R_F = R_F^*$.

■ *Firms*

The two problems

$$\max_{K_F} (p_g^* + p_b^*) \cdot f(K_F) - K_F \text{ and}$$
$$\max_{K_F} f(K_F) - R_F^* K_F$$

have the same solution y_F^*. In the first problem, the firm maximizes the present value of profits whereas in the second problem, it maximizes the future value. Again, $\Pi_M = 0$ and $y_M^* = W - y_F^*$ is an optimal choice.

■ *Households*

For the household, investing in FT amounts to buying bonds with return $a_1 = (R_F^*, R_F^*)$ at price $q_1 = 1$. Buying equity in the bank amounts to buying shares in the risky asset with returns $a_2 = (\overline{R}, \underline{R})$ at price $q_2 = 1$. By (4.22), the market clearing asset prices in the corresponding Radner equilibrium are

$q_1 = R_F^*(p_g^* + p_b^*) = 1$ because of $R_F^* = 1/(p_g^* + p_b^*)$ and

$q_2 = \overline{R}p_g^* + \underline{R}p_b^* = 1$ because of (4.2).

Hence for the household, investing y_F^* in FT and y_M^* in equity is optimal and yields the same consumption bundle as in the Arrow-Debreu case, provided $D = 0$ and $l_F = 0$.

■ *Banks*

For the bank, $\overline{R}p_g^* + \underline{R}p_b^* = 1$ and $R_F^*(p_g^* + p_b^*) = 1$ imply $\underline{R} < R_F^* < \overline{R}$. If $D = 0$, then $\alpha = 1$ provided that $B_1 > 0$, that is,

$$\sigma\overline{R} + (1-\sigma)\underline{R} > R_F^* \text{ or}$$
$$\sigma(\overline{R} - R_F^*) + (1-\sigma)(\underline{R} - R_F^*) > 0. \tag{C.3}$$

To prove (C.3), note that (4.2) and $p_g^* R_F^* + p_b^* R_F^* = 1$ further imply $p_g^*(\overline{R} - R_F^*) + p_b^*(\underline{R} - R_F^*) = 0$. (C.3) follows if we can demonstrate that

$$\frac{\sigma}{1-\sigma} > \frac{p_g^*}{p_b^*}.$$

To see the latter, notice that $y_M^* > 0$ implies $c_g^* > c_b^*$ and, hence,

$$\left(\frac{p_b^*}{p_g^*} \cdot \frac{\sigma}{1-\sigma}\right)^{\frac{1}{\theta}} p_g^* + p_b^* > \left(\frac{p_g^*}{p_b^*} \cdot \frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b^* + p_g^* \text{ or}$$

$$\left(\frac{p_b^*}{p_g^*} \cdot \frac{\sigma}{1-\sigma}\right)^{\frac{1}{\theta}} \frac{p_g^*}{p_b^*} + 1 > \left(\frac{p_g^*}{p_b^*} \cdot \frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} + \frac{p_g^*}{p_b^*}$$

or, with $\pi = \frac{p_g^*}{p_b^*}, \tau = \frac{\sigma}{1-\sigma}$,

$$(\tau/\pi)^{\frac{1}{\theta}}\pi + 1 > (\pi/\tau)^{\frac{1}{\theta}} + \pi.$$

Suppose $\pi/\tau \geq 1$. Then lhs $\leq 1 + \pi$ and rhs $\geq 1 + \pi$, a contradiction. Hence to the contrary, $\pi/\tau < 1$ or $\pi < \tau$ or $\sigma/(1-\sigma) > p_g^*/p_b^*$. Consequently, (C.3) has to hold. It follows that $D = 0$ implies that $\alpha = 1$ is optimal. $\square$

C.4.2 Proof of Proposition 4.5

In order for y_F^* to solve $\max f(K_F) - R_F K_F$, we set again

$$R_F = \frac{1}{p_g^* + p_b^*}$$

which is equal to R_F^*. Then the bank will only invest in the risky technology, since $B_1 > 0$ by the argument given in the proof of Proposition 4.4. Suppose $D > 0$. Without default, the bank's profit would become $(E+D)\overline{R} - DR_F^*$ in the good state and $(E+D)\underline{R} - DR_F^*$ in the bad state. If $\underline{R} = 0$, the bank defaults in the bad state.

There is no default as long as $DR_F^* \leq (E+D)\underline{R} = y_M^* \underline{R}$ or $D \leq \dfrac{\underline{R}}{R_F^*} y_M^*$. In this case, the return on equity is

$[(E+D)\overline{R} - DR_F^*]/E = [y_M^* \overline{R} - DR_F^*]/E$ in the good state, and

$[(E+D)\underline{R} - DR_F^*]/E = [y_M^* \underline{R} - DR_F^*]/E$ in the bad state.

As before, $q_1 = 1$, whereas the asset with unit returns $a_3 = ([(E+D)\overline{R} - DR_F^*]/E, [(E+D)\underline{R} - DR_F^*]/E)$ has the arbitrage-free unit price

$$q_3 = \frac{1}{E}[(y_M^* \overline{R} - DR_F^*)p_g^* + (y_M^* \underline{R} - DR_F^*)p_b^*] = \frac{1}{E}[y_M^* - D] = 1.$$

At these prices, the household invests y_F^* in FT, makes the amount D of deposits, and purchases $E = y_M^* - D$ units of bank equity. □

C.4.3 Proof of Proposition 4.6

If $\underline{R} = 0$, let us take as a reference point the Arrow-Debreu equilibrium and the corresponding unique equilibrium with financial intermediation and no default. In that equilibrium, bank deposits have the value $D^o = 0$ and equity assumes the value $E^o = W - y_F^* = y_M^*$. If $\underline{R} > 0$, let us take as a reference point the equilibrium with financial intermediation and no default where the bank is on the brink of defaulting in the bad state. In that equilibrium, as shown in the proof of Proposition 4.5, deposits assume the value

$$D^o = \frac{\underline{R}}{R_F^*} y_M^*,$$

and equity assumes the value

$$E^o = (1 - \frac{\underline{R}}{R_F^*}) y_M^*.$$

Moreover, we found in the proof of Proposition 4.4 that the equilibrium bond return R_F^* satisfies $\sigma\overline{R} + (1-\sigma)\underline{R} > R_F^*$.

Next let us fix a bond return (denoted by $\widehat{R}_F$) slightly above R_F^* such that $\sigma\overline{R} + (1-\sigma)\underline{R} > \widehat{R}_F$. Then the analogue of $B_1 > 0$ holds and the bank still chooses $\alpha = 1$. Given the higher bond return $\widehat{R}_F$, entrepreneur e_F will respond by choosing a profit maximizing input denoted by $\widehat{K}_F$, with $\widehat{K}_F < y_F^*$. The resulting profit is denoted by $\widehat{\Pi}_F$ and satisfies $\widehat{\Pi}_F < \Pi_F^*$.

At the reference equilibrium, the demand for equity is E^o when $T = 0$, the return on bonds is R_F^* and a unit of equity pays $\overline{R}(1 + \frac{D^o}{E^o}) - R_F^* \frac{D^o}{E^o}$ in the good state and zero in the bad state. If one replaced R_F^* by $\widehat{R}_F > R_F^*$, Π_F^* by $\widehat{\Pi}_F$, and $T = 0$ by $\widehat{T} = \widehat{R}_F D^o - \underline{R}(E^o + D^o) > 0$, then the household would demand more of the risk-free asset.[1]

Now assume $E \in (0, E^o]$ and $D = W - E - \widehat{K}_F$. Consider the household's portfolio choice when the profit distributed is $\widehat{\Pi}_F$, $T = \widehat{R}_F D - \underline{R}(E + D)$, the return on bonds is $\widehat{R}_F$ and a unit of equity pays $\overline{R}(1 + \frac{D}{E}) - \widehat{R}_F \frac{D}{E}$ in the good state and zero in the bad state. There is a unique optimal $\gamma(E) \in [0, 1]$ so that the household invests $\gamma(E)W$ in bonds and $[1 - \gamma(E)]W$ in equity. By Berge's maximum theorem (or because of (4.23)), $\gamma(E)$ is a continuous function of E. Set $\eta(E) = [1 - \gamma(E)]W$. As reasoned above, $\eta(E^o) < E^o$. If $E \to 0$, then $D \to W - \widehat{K}_F$, $T \to (\widehat{R}_F - \underline{R})(W - \widehat{K}_F)$, and $\overline{R}(1 + \frac{D}{E}) - \widehat{R}_F \frac{D}{E} \to \infty$. Hence there exists $E_o \in (0, E^o)$ with $\eta(E_o) > E_o$.[2] By the intermediate value theorem, there exists $E \in (E_o, E^o)$ with $\eta(E) = E$. At this E and the corresponding value for T, the asset market is cleared—as well as the consumption good market in both states—while the bond return is $\widehat{R}_F$ and FT production is less than at the Arrow-Debreu equilibrium.

It remains to check whether the bank is actually going to default in the bad state. In

[1] Observe that $c_g > c_b$ and homothetic preferences of the household (together with standard properties) imply that $|MRS|$ is smaller at the consumption bundle $(\hat{c}_g, \hat{c}_b) = (c_g - (\Pi_F - \widehat{\Pi}_F), c_b - (\Pi_F - \widehat{\Pi}_F) - \widehat{T})$ than at (c_g, c_b). To see this, consider normalized gradients of the form $(|MRS|, 1)$. Denote by ∇ the household's normalized gradient at (c_g, c_b) and by $\hat{\nabla}$ its normalized gradient at $(\hat{c}_g, \hat{c}_b)$. If in the reference equilibrium situation, the household replaces one unit of the bond by one unit of equity, then consumption is changed in the direction $v = (\overline{R}(1 + \frac{D^\circ}{E^\circ}) - R_F \frac{D^\circ}{E^\circ} - R_F, -R_F)$ and at equilibrium, portfolio choice is optimal, that is $\nabla \cdot v = 0$. If in the new situation, the household replaces one unit of the bond by one unit of equity, then consumption is changed in the direction $\hat{v} = (\overline{R}(1 + \frac{D^\circ}{E^\circ}) - \hat{R}_F \frac{D^\circ}{E^\circ} - \hat{R}_F, -\hat{R}_F)$. It follows that $0 = \nabla \cdot v > \nabla \cdot \hat{v} > \hat{\nabla} \cdot \hat{v}$. But $\hat{\nabla} \cdot \hat{v} < 0$ means that the household benefits from reducing its equity holding and increasing its bond holding by the same amount.

[2] Observe that $\overline{R}_E + (A_1 - 1)\widehat{R}_F > 0$. Hence, $\eta(E_o) > E_o$ can be rewritten as

$$(A_1 - 1)\widehat{R}_F W - [\widehat{\Pi}_F(1 - A_1) + TA_1] > E_o[\overline{R}_E + (A_1 - 1)\widehat{R}_F].$$

Substituting T, D, $\overline{R}_E$ and simplifying the expression, we obtain

$$(A_1 - 1)[\widehat{R}_F \widehat{K}_F + \widehat{\Pi}_F] + [A_1\underline{R} - \overline{R}](W - \widehat{K}_F) > 0.$$

If $E \to 0$, then $A_1 \to \infty$, which establishes the existence of $E_o \in (0, E^o)$ with $\eta(E_o) > E_o$.

the reference equilibrium, $\underline{R}(E^o + D^o) - R_F D^o = 0$. Let $\Delta = y_F^* - \widehat{K}_F > 0$. Then $\underline{R}(E^o + D^o + \Delta) - \widehat{R}_F(D^o + \Delta) < 0$. Further $E^o + D^o = W - y_F^*$, $E + D = W - \widehat{K}_F$ and $E < E^o$. Hence $E^o + D^o + \Delta = W - \widehat{K}_F = E + D$ and $D^o + \Delta = W - E^o - y_F^* + y_F^* - \widehat{K}_F = W - E^o - \widehat{K}_F < W - E - \widehat{K}_F = D$. It follows that $\underline{R}(E + D) - \widehat{R}_F D < 0$ which means that the bank is going to default in the bad state, indeed.

Since $\widehat{K}_F \neq y_F^*$, the equilibrium allocation is inefficient, by Corollary 4.1. □

C.4.4 Proof of Proposition 4.7

First of all, all equilibria without default continue to be equilibria under the conditions of the proposition. Second, there are equilibria with default that are equivalent to Radner equilibria explored in Proposition 4.3.

Namely, the economy has an Arrow-Debreu equilibrium with quantities p_g^*, p_b^*, c_g^*, c_b^*, y_F^*, y_M^* such that $0 < y_F^* < W$. Consider the following three securities: A bond with price $p_f = 1$ and return $R_F^* = (p_g^* + p_b^*)^{-1}$, risky bank deposits that promise $R_D \in (\underline{R}, \overline{R})$ in both states, but actually pay R_D in the good state and $\underline{R}$ in the bad state, and bank equity that pays $\overline{R} - R_D$ in the good state and nothing in the bad state. Bank deposits have the price $p_d = p_g^* R_D + p_b^* \underline{R}$ and a bank share costs $p_e = p_g^*(\overline{R} - R_D)$. A unit of bank deposit together with one bank share constitutes one unit of asset a_2 at the price $q_2 = 1$. Hence the household obtains its first-best consumption bundle by purchasing y_F^* bonds and providing y_M^* units of capital to the bank, by investing $p_d y_M^*$ in bank deposits and $p_e y_M^*$ in bank equity. Funds of size y_F^* are used by entrepreneur e_F while the bank invests its capital y_M^* in the MT sector and all markets are cleared. In the bad state, the bank has revenue $y_M^* \underline{R}$ which falls short of its promised payment to depositors, $y_M^* R_D$.

It remains to be shown that under the assumptions made, these are the only equilibria with default.

■ *Step 1:*

Let us consider an arbitrary equilibrium with default in the bad state only.[3] The price of the asset a_f for investment in FT yielding return R_F is denoted by p_f. Suppose next that the bank has obtained the amount D of deposits at price p_d and E equity contracts at price p_e and thus $p_d D + p_e E$ units of the investment good. The promised return on deposits is R_D. Suppose that the bank invests a fraction α into MT and $1 - \alpha$ into FT with $0 \leq \alpha \leq 1$.

[3] There exist equilibria in which the bank defaults in both states. The reasoning of the proof can be readily adapted to such cases as well.

The realized returns on bank debt and equity are thus as follows:

	Equity	Deposit
good state	R_E	R_D
bad state	0	$\underline{R}_D$

$$\text{where } R_E := \frac{[\alpha\overline{R} + (1-\alpha)\frac{R_F}{p_f}](p_d D + p_e E) - DR_D}{E}$$
$$\text{and } \underline{R}_D := \frac{[\alpha\underline{R} + (1-\alpha)\frac{R_F}{p_f}](p_d D + p_e E)}{D}.$$

The condition that the bank defaults in the bad state and thus the matrix applies is

$$[\alpha\underline{R} + (1-\alpha)\frac{R_F}{p_f}](p_d D + p_e E) - R_D D < 0$$

and consequently,

$$D > \frac{[\alpha\underline{R} + (1-\alpha)\frac{R_F}{p_f}]p_e E}{R_D - [\alpha\underline{R} + (1-\alpha)\frac{R_F}{p_f}]p_d}. \tag{C.4}$$

■ *Step 2:*

We next show that $\frac{R_F}{p_f} < \overline{R}$. Suppose $\frac{R_F}{p_f} \geq \overline{R}$. Then it would be profitable for the bank to invest all resources in FT. Then either there is default in both states or no default at all, contrary to the assumption made. Hence $\frac{R_F}{p_f} < \overline{R}$ must hold.

■ *Step 3:*

Given that $\frac{R_F}{p_f} < \overline{R}$, the bank invests only in MT. That is, $\alpha = 1$. For otherwise, by putting more of its funds into MT, the bank could increase its return on equity in the good state while the return in the bad state would remain zero or become positive.

■ *Step 4:*

Since $\alpha = 1$, by buying μ_1 units of deposit contracts and μ_2 units of equity contracts with

$$\mu_1 = \frac{D}{(p_d D + p_e E)} \text{ and } \mu_2 = \frac{E}{(p_d D + p_e E)},$$

the household can create a new asset $\tilde{a}_2$ with the following characteristics:

Asset	Price in $t = 1$	Return in state g	Return in state b
$\tilde{a}_2$	$\tilde{p}_2$	$\overline{R}$	$\underline{R}$

Note that

$$\tilde{p}_2 = \frac{p_d D}{(p_d D + p_e E)} + \frac{p_e E}{(p_d D + p_e E)} = 1.$$

Asset $\tilde{a}_2$ is identical with asset a_2. Therefore, the household faces the following portfolio choice. It can invest a fraction of its wealth at price 1 into the asset with return $\overline{R}$ and $\underline{R}$ and the remaining part into a safe asset at price p_f with return R_F. Except for potential rescaling the units of the safe asset, this is essentially the same situation as in Section 4.3.6 and we can use Proposition 4.3 which establishes the equivalence of the ensuing equilibrium to the Arrow-Debreu equilibrium. $\square$

D Appendix to Chapter 5

D.1 Proof of Proposition 5.4

■ *Step 1*

We found in the proof of Proposition 5.1 that the equilibrium bond return R_F^* satisfies $R_F^* < \mathbb{E}[\widetilde{R}]$. For $R_F \in (R_F^*, \mathbb{E}[\widetilde{R}]]$, we obtain that $B_2 \geq 0$ and hence banks optimally choose $\alpha = 1$.[1]

■ *Step 2*

If $\underline{R} = 0$, let us take as a reference point the Arrow-Debreu equilibrium and the corresponding unique equilibrium with financial intermediation and no default. In that equilibrium, bank deposits have the value $D^o = 0$ and equity assumes the value $E^o = W - y_F^* = y_M^*$. If $\underline{R} > 0$, let us take as a reference point the equilibrium with financial intermediation and no default where the bank is on the brink of defaulting in the bad state. In that equilibrium, as shown in the proof of Proposition 5.2, deposits assume the value

$$D^o = \frac{\underline{R}}{R_F^*} y_M^*,$$

and equity assumes the value

$$E^o = (1 - \frac{\underline{R}}{R_F^*}) y_M^*.$$

Next let us fix a bond return denoted by $\widehat{R}_F$ such that $R_F^* < \widehat{R}_F < \mathbb{E}[\widetilde{R}]$. Hence, the bank optimally chooses $\alpha = 1$. Given the higher bond return $\widehat{R}_F$, entrepreneur e_F will respond by choosing a profit maximizing input denoted by $\widehat{K}_F$, with $\widehat{K}_F < y_F^*$. The resulting profit is denoted by $\widehat{\Pi}_F$ and satisfies $\widehat{\Pi}_F < \Pi_F^*$.

At the reference equilibrium, the demand for equity is E^o when $T = 0$, the return on bonds is R_F^* and a unit of equity pays $\overline{R}(1 + \frac{D^o}{E^o}) - R_F^* \frac{D^o}{E^o}$ in the good state and zero in the bad state. If one replaced R_F^* by $\widehat{R}_F > R_F^*$, Π_F^* by $\widehat{\Pi}_F$, and $T = 0$ by

[1] We assume that banks choose $\alpha = 1$ if they are indifferent between multiple optimal values, that is, in the case $B_2 = 0$.

$\widehat{T} = \widehat{R}_F D^o - \underline{R}(E^o + D^o) > 0$, then the household would demand more of the risk-free asset.[2]

Now assume $E \in (0, E^o]$ and $D = W - E - \widehat{K_F}$. Consider the household's portfolio choice when the profit distributed is $\widehat{\Pi}_F$, $T = \widehat{R}_F D - \underline{R}(E + D)$, the return on bonds is $\widehat{R}_F$ and a unit of equity pays $\overline{R}(1 + \frac{D}{E}) - \widehat{R}_F \frac{D}{E}$ in the good state and zero in the bad state. There is a unique optimal $\gamma(E) \in [0, 1]$ so that the household invests $\gamma(E)W$ in bonds and $[1 - \gamma(E)]W$ in equity. By Berge's maximum theorem, $\gamma(E)$ is a continuous function of E. Set $\eta(E) = [1 - \gamma(E)]W$. As reasoned above, $\eta(E^o) < E^o$. If $E \to 0$, then $D \to W - \widehat{K_F}$, $T \to (\widehat{R}_F - \underline{R})(W - \widehat{K_F})$, and $\overline{R}(1 + \frac{D}{E}) - \widehat{R}_F \frac{D}{E} \to \infty$. Hence there exists $E_o \in (0, E^o)$ with $\eta(E_o) > E_o$.[3] By the intermediate value theorem, there exists $E \in (E_o, E^o)$ with $\eta(E) = E$. At this E and the corresponding value for T, the asset market is cleared—as well as the consumption good market in both states—while the bond return is $\widehat{R}_F$ and FT production is less than at the Arrow-Debreu equilibrium.

■ *Step 3*

It remains to check whether the bank is actually going to default in the bad state. In the reference equilibrium, $\underline{R}(E^o + D^o) - R_F D^o = 0$. Let $\Delta = y_F^* - \widehat{K_F} > 0$. Then $\underline{R}(E^o + D^o + \Delta) - \widehat{R}_F(D^o + \Delta) < 0$. Further $E^o + D^o = W - y_F^*$, $E + D = W - \widehat{K_F}$ and $E < E^o$. Hence $E^o + D^o + \Delta = W - \widehat{K_F} = E + D$ and $D^o + \Delta = W - E^o - y_F^* + y_F^* - \widehat{K_F} = W - E^o - \widehat{K_F} < W - E - \widehat{K_F} = D$. It follows that $\underline{R}(E + D) - \widehat{R}_F D < 0$ which means that the bank is going to default in the bad state, indeed.

Since $\widehat{K_F} \neq y_F^*$, the equilibrium allocation is inefficient. □

[2] Let us repeat the essential logic also applied in the proof of Proposition 5.3. We observe that $c_g > c_b$ and homothetic preferences of the household (together with standard properties) imply that $|MRS|$ is smaller at the consumption bundle $(\hat{c}_g, \hat{c}_b) = (c_g - (\Pi_F - \widehat{\Pi}_F), c_b - (\Pi_F - \widehat{\Pi}_F) - \widehat{T})$ than at (c_g, c_b). To see this, consider normalized gradients of the form $(|MRS|, 1)$. Denote by ∇ the household's normalized gradient at (c_g, c_b) and by $\hat{\nabla}$ its normalized gradient at $(\hat{c}_g, \hat{c}_b)$. If in the reference equilibrium situation, the household replaces one unit of the bond by one unit of equity, then consumption is changed in the direction $v = (\overline{R}(1 + \frac{D^\circ}{E^\circ}) - R_F \frac{D^\circ}{E^\circ} - R_F, -R_F)$ and at equilibrium, portfolio choice is optimal, that is $\nabla \cdot v = 0$. If in the new situation, the household replaces one unit of the bond by one unit of equity, then consumption is changed in the direction $\hat{v} = (\overline{R}(1 + \frac{D^\circ}{E^\circ}) - \hat{R}_F \frac{D^\circ}{E^\circ} - \hat{R}_F, -\hat{R}_F)$. It follows that $0 = \nabla \cdot v > \nabla \cdot \hat{v} > \hat{\nabla} \cdot \hat{v}$. But $\hat{\nabla} \cdot \hat{v} < 0$ means that the household benefits from reducing its equity holding and increasing its bond holding by the same amount.

[3] Observe that $\overline{R}_E + (A_1 - 1)\widehat{R}_F > 0$. Hence, $\eta(E_o) > E_o$ can be rewritten as

$$(A_1 - 1)\widehat{R}_F W - [\widehat{\Pi}_F(1 - A_1) + TA_1] > E_o[\overline{R}_E + (A_1 - 1)\widehat{R}_F].$$

Substituting T, D, $\overline{R}_E$ and simplifying the expression, we obtain

$$(A_1 - 1)[\widehat{R}_F \widehat{K}_F + \widehat{\Pi}_F] + [A_1 \underline{R} - \overline{R}](W - \widehat{K}_F) > 0.$$

If $E \to 0$, then $A_1 \to \infty$, which establishes the existence of $E_o \in (0, E^o)$ with $\eta(E_o) > E_o$.

D.2 Proof of Proposition 5.5

At the equilibrium $\{\hat{E}, \hat{D}, \hat{K}_F, \hat{K}_M \hat{R}_F\}$, taxes are $\hat{T} = \hat{R}_F\hat{D} - \underline{R}(\hat{E}+\hat{D}) > 0$, and a unit of equity pays $\overline{R}(1 + \frac{\hat{D}}{\hat{E}}) - \hat{R}_F\frac{\hat{D}}{\hat{E}}$ in the good state and zero in the bad state. Suppose we replace in this equilibrium $\hat{R}_F$ with $\hat{\hat{R}}_F > \hat{R}_F$. Then taxes would be $\widetilde{T} = \hat{\hat{R}}_F\hat{D} - \underline{R}(\hat{E} + \hat{D}) > \hat{T}$, entrepreneur e_F would choose a profit maximizing input such that $\hat{\hat{K}}_F < \hat{K}_F$, and the resulting profits $\hat{\hat{\Pi}}_F$ satisfy $\hat{\hat{\Pi}}_F < \hat{\Pi}_F$.

Observe that $\hat{K}_M > y^*_M > 0$ implies $\hat{c}_g > \hat{c}_b$. This implies that $|MRS|$ is smaller at the consumption bundle $(\widetilde{c}_g, \widetilde{c}_b) = (\hat{c}_g - (\hat{\Pi}_F - \hat{\hat{\Pi}}_F), \hat{c}_b - (\hat{\Pi}_F - \hat{\hat{\Pi}}_F) - (\widetilde{T} - \hat{T}))$ than at $(\hat{c}_g, \hat{c}_b)$ due to homothetic preferences (and standard properties). To see this, consider normalized gradients of the form $(|MRS|, 1)$. Denote by $\hat{\nabla}$ the household's normalized gradient at $(\hat{c}_g, \hat{c}_b)$ and by $\widetilde{\nabla}$ its normalized gradient at $(\widetilde{c}_g, \widetilde{c}_b)$. If in the reference equilibrium situation, the household replaces one unit of the bond by one unit of equity, then consumption is changed in the direction $\hat{v} = (\overline{R}(1 + \frac{\hat{D}}{\hat{E}}) - \hat{R}_F\frac{\hat{D}}{\hat{E}} - \hat{R}_F, -\hat{R}_F)$ and at equilibrium, portfolio choice is optimal, that is $\hat{\nabla} \cdot \hat{v} = 0$. If in the new situation, the household replaces one unit of the bond by one unit of equity, then consumption is changed in the direction $\widetilde{v} = (\overline{R}(1 + \frac{\hat{D}}{\hat{E}}) - \hat{\hat{R}}_F\frac{\hat{D}}{\hat{E}} - \hat{\hat{R}}_F, -\hat{\hat{R}}_F)$. It follows that $0 = \hat{\nabla} \cdot \hat{v} > \hat{\nabla} \cdot \widetilde{v} > \widetilde{\nabla} \cdot \widetilde{v}$. But $\widetilde{\nabla} \cdot \widetilde{v} < 0$ means that the household benefits from reducing its equity holding and increasing its bond holding by the same amount.

Following the reasoning of Proposition 5.4, we can assert that $\hat{\hat{E}} < \hat{E}$ and $\hat{\hat{D}} > \hat{D}$. □

D.3 Proof of Proposition 5.6

Suppose that $\left\{c^o_g, c^o_b, y^o_F, y^o_M, R^o_F\right\}$ is an equilibrium allocation with financial intermediation where $y^o_F < f'^{-1}(\overline{R})$. For entrepreneurs e_F, y^o_F is a profit maximizing choice if and only if $R^o_F > \overline{R}$. Given $R^o_F > \overline{R}$, banks choose $\alpha = 0$ as $B_2 < 0$ and $B_2 < 0$ for all feasible debt-equity ratios. Hence, banks invest their total funds $E + D$ in the frictionless technology. Since households invest their endowment either directly in FT, in bank deposits D, or in bank equity E, total endowment W is channeled to FT. Since $y^o_F < f'^{-1}(\overline{R}) < f'^{-1}(0) = W$, total supply of investment goods to FT exceeds total demand. Hence, $y^o_F < f'^{-1}(\overline{R})$ cannot occur in equilibrium. □

D.4 Proof of Proposition 5.7

■ *Step 1*

Let us first investigate the bank's optimal investment choice. For $R_F > \mathbb{E}[\widetilde{R}]$, we obtain $B_2 < 0$ and the optimal investment choice of the bank depends on the sign of B_2. If $B_2 \geq 0$, the bank optimally invests all of its funds in MT.[4] We can rewrite $B_2 \geq 0$ as a condition on the debt-equity ratio of banks:

$$\frac{D}{E} \geq \varphi_0(R_F),$$
$$\text{with } \varphi_0(R_F) := \frac{R_F - \sigma\overline{R}}{\sigma(\overline{R} - R_F)}$$

as long as the bank's actual debt-equity ratio exceeds $\varphi_o(R_F)$, the bank will invest in MT even though the expected returns are lower than the returns in FT.

■ *Step 2*

Recall from Corollary 5.2 that the highest possible debt-equity ratio of banks that still supports the first-best Arrow Debreu allocation is given by

$$\varphi = \frac{\underline{R}}{R_F^* - \underline{R}}.$$

We observe

$$\varphi_0(R_F) \leq \varphi \text{ for } R_F \in (\mathbb{E}[\widetilde{R}], \overline{R}_F), \tag{D.1}$$
$$\text{where } \overline{R}_F := \frac{\sigma\overline{R}R_F^*}{(R_F^* - (1-\sigma)\underline{R})}.$$

■ *Step 3*

Let $\{E', D', K'_F, K'_M, R'_F\}$ denote an inefficient equilibrium with financial intermediation in the spirit of Proposition 5.4. In this equilibrium, a unit of equity pays $\overline{R}(1+\frac{D'}{E'}) - R'_F\frac{D'}{E'}$ in the good state and zero in the bad state at the equilibrium $\{E', D', K'_F, K'_M, R'_F\}$. Further, taxes are $T' = R'_F D' - \underline{R}(E' + D') > 0$.

Next, let us fix a bond return denoted by R''_F such that $\mathbb{E}[\widetilde{R}] < R''_F < \overline{R}_F$. Suppose we replace R'_F with $R''_F > R'_F$ in the equilibrium $\{E', D', K'_F, K'_M, R'_F\}$. Then taxes would be $\widetilde{T} = R''_F D' - \underline{R}(E' + D') > T'$, entrepreneur e_F would choose a profit maximizing input such that $K''_F < K'_F$, the resulting profits Π''_F satisfy $\Pi''_F < \Pi'_F$, and banks would

[4] We assume that banks choose $\alpha = 1$ if they are indifferent between multiple optimal values, that is, in the case $B_2 = 0$.

still choose $\alpha = 1$.[5] In this new situation, the household would demand more of the risk-free asset.[6]

■ *Step 4*

Now assume $E \in (0, E')$ and $D = W - E - K_F''$. Consider the household's portfolio choice when the profit distributed is Π_F, $T = R_F''D - \underline{R}(E + D)$, the return on bonds is R_F'' and a unit of equity pays $\overline{R}(1 + \frac{D}{E}) - R_F''\frac{D}{E}$ in the good state and zero in the bad state.[7] There is a unique optimal $\gamma(E) \in [0, 1]$ so that the household invests $\gamma(E)W$ in bonds and $[1 - \gamma(E)]W$ in equity. By Berge's maximum theorem, $\gamma(E)$ is a continuous function of E. Set $\eta(E) = [1 - \gamma(E)]W$. As reasoned above, $\eta(E') < E'$. If $E \to 0$, then $D \to W - K_F''$, $T \to (R_F'' - \underline{R})(W - K_F'')$, and $\overline{R}(1 + \frac{D}{E}) - R_F''\frac{D}{E} \to \infty$. Hence there exists $E_o \in (0, E^o)$ with $\eta(E_o) > E_o$.

By the intermediate value theorem, there exists $E \in (E_o, E')$ with $\eta(E) = E$. At this E and the corresponding value for T, the asset market is cleared—as well as the consumption good market in both states—while the bond return is R_F'' and FT production is less than in the Arrow-Debreu equilibrium. □

D.5 Proof of Proposition 5.8

We will determine the sign of each single partial derivative in (5.9). First,

$$\begin{aligned}\frac{\partial c_g(\sigma, p^*)}{\partial \sigma} = &\left[p^* + \left(\frac{p^*}{p_b(p^*)}\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b(p^*)\right]^{-2} \\ &\cdot \left[\frac{1}{\theta}\left(\frac{p^*}{p_b(p^*)}\right)^{\frac{1}{\theta}}\left(\frac{1-\sigma}{\sigma}\right)^{\frac{1-\theta}{\theta}} p_b(p^*)\frac{1}{\sigma^2}\right] \\ &\cdot (W + \Pi_F(p^*)) > 0.\end{aligned}$$

Second,

$$\frac{\partial q(p^*)}{\partial p^*} = \left[\frac{\partial f(y_F)}{\partial y_F} - \overline{R}\right] \cdot \left[\frac{\partial y_F(\,\cdot\,)}{\partial\,\cdot}\frac{\underline{R}(\overline{R} - \underline{R})}{[(\underline{R} - \overline{R})p^* + 1]^2}\right] > 0.$$

[5] From Proposition 5.4 and Corollary 5.2, we know that the debt-equity ratio $\frac{D'}{E'}$ of banks is higher than φ. Hence, $\frac{D'}{E'} > \varphi > \varphi_0(R_F'')$, and we obtain $B_2 > 0$.

[6] Cf. Proposition 5.5.

[7] Observe that banks choose $\alpha = 1$ for all $E \in (0, E')$ and $D = W - E - K_F''$ given R_F''.

Since $\frac{\partial y_F(\,\cdot\,)}{\partial\,\cdot} = f'^{-1\prime}(\,\cdot\,) < 0$ and $\overline{R} > \frac{\partial f(y_F)}{\partial y_F}$. Finally,

$$\begin{aligned}\frac{\partial c_g(\sigma,p^*)}{\partial p^*} &= -\left[p^* + \left(\frac{p^*}{p_b(p^*)}\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b(p^*)\right]^{-2} \\ &\cdot \left[1 + \left[\frac{1}{\theta}\left(\frac{p^*}{p_b(p^*)}\right)^{\frac{1-\theta}{\theta}} - \frac{\overline{R}}{\underline{R}}\frac{\theta-1}{\theta}\left(\frac{p^*}{p_b(p^*)}\right)^{\frac{1}{\theta}}\right]\left(\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}}\right] \\ &\cdot (W + \Pi_F(p^*)) \\ &- \left[p^* + \left(\frac{p^*}{p_b(p^*)}\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b(p^*)\right]^{-1} \\ &\cdot \left[\frac{\overline{R}-\underline{R}}{\underline{R}} f(y_F(p^*)) - \left\{(p^* + p_b(p^*))\frac{\partial f(y_F)}{\partial y_F} - 1\right\}\right. \\ &\left.\frac{\partial y_F(\,\cdot\,)}{\partial\,\cdot}\frac{\underline{R}(\overline{R}-\underline{R})}{[(\underline{R}-\overline{R})p^* + 1]^2}\right].\end{aligned}$$

The term in curly braces is zero due to the first-order condition of firms operating FT. Hence, we can assert that $\frac{\partial c_g(\sigma,p^*(\sigma))}{\partial p^*} < 0$ if $\theta < 1$.

Combining the results derived above, we obtain

$$\frac{dc_g(\sigma,p^*(\sigma))}{d\sigma} < 0. \tag{D.2}$$

□

D.6 Proof of Proposition 5.9

We will determine the sign of each single partial derivative in (5.12). First,

$$\frac{\partial c_g(\theta,p^*(\theta))}{\partial\theta} = \frac{p_b(p^*)\left(\frac{p^*(1-\sigma)}{p_b(p^*)\sigma}\right)^{\frac{1}{\theta}}\log\frac{p^*(1-\sigma)}{p_b(p^*)\sigma}}{\theta^2\left(p_b(p^*)\left(\frac{p^*(1-\sigma)}{p_b(p^*)\sigma}\right)^{\frac{1}{\theta}} + p^*\right)^2} < 0,$$

as $p^*(1-\sigma) < p_b(p^*)\sigma$.[8] Second,

$$\frac{\partial q(p^*(\theta))}{\partial p^*} = \left[\frac{\partial y_F(\,\cdot\,)}{\partial\,\cdot}\frac{\underline{R}(\overline{R}-\underline{R})}{[(\underline{R}-\overline{R})p^*+1]^2}\right]\left[\frac{\partial f(y_F)}{\partial y_F} - \overline{R}\right] > 0.$$

[8] Remember that $c_g^* > c_b^*$ and, hence, $\left(\frac{p_b^*}{p_g^*}\cdot\frac{\sigma}{1-\sigma}\right)^{\frac{1}{\theta}} p_g^* + p_b^* > \left(\frac{p_g^*}{p_b^*}\cdot\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b^* + p_g^*$.

Since $\frac{\partial y_F(\cdot)}{\partial \cdot} = f'^{-1'}(\cdot) < 0$ and $\overline{R} > \frac{\partial f(y_F)}{\partial y_F}$. And, third,

$$\frac{\partial z_g(\theta, p^*(\theta))}{\partial p^*} = \frac{\partial c_g(\theta, p^*(\theta))}{\partial p^*} - \frac{\partial q(p^*(\theta))}{\partial p^*}.$$

We have determined the second term already, so let us analyze the first term:

$$\begin{aligned}\frac{\partial c_g(\theta, p^*(\theta))}{\partial p^*} &= -\left[p^* + \left(\frac{p^*}{p_b(p^*)}\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b(p^*)\right]^{-2} \\ \cdot \Bigg[1 + \Bigg[\frac{1}{\theta}\left(\frac{p^*}{p_b(p^*)}\right)^{\frac{1-\theta}{\theta}} &- \frac{\overline{R}}{\underline{R}}\frac{\theta-1}{\theta}\left(\frac{p^*}{p_b(p^*)}\right)^{\frac{1}{\theta}}\Bigg]\left(\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}}\Bigg] \\ &\cdot (W + \Pi_F(p^*)) \\ &- \left[p^* + \left(\frac{p^*}{p_b(p^*)}\frac{1-\sigma}{\sigma}\right)^{\frac{1}{\theta}} p_b(p^*)\right]^{-1} \\ \cdot \Bigg[\frac{\overline{R}-\underline{R}}{\underline{R}} f(y_F(p^*)) &- \left\{(p^* + p_b(p^*))\frac{\partial f(y_F)}{\partial y_F} - 1\right\} \\ &\frac{\partial y_F(\cdot)}{\partial \cdot}\frac{\underline{R}(\overline{R}-\underline{R})}{[(\underline{R}-\overline{R})p^* + 1]^2}\Bigg].\end{aligned}$$

The term in curly braces is zero due to the first-order condition of firms operating FT. We can assert that $\frac{\partial c_g(\overline{R}, p^*(\overline{R}))}{\partial p^*} < 0$ if $\theta < 1$.

Hence, we obtain

$$\frac{dc_g(\theta, p^*(\theta))}{d\theta} < 0. \tag{D.3}$$

□

D.7 Proof of Proposition 5.14

Let p_g^* and p_b^* be the Arrow-Debreu equilibrium prices. We set

$$R_F = \frac{1}{p_g^* + p_b^*}.$$

Since

$$f'(y_F^*) = \frac{1}{p_g^* + p_b^*},$$

it follows that $R_F = R_F^* = \mathbb{E}[\widetilde{R}]$.

■ *Firms*

The two problems

$$\max_{K_F} (p_g^* + p_b^*) \cdot f(K_F) - K_F \text{ and}$$

$$\max_{K_F} f(K_F) - R_F^* K_F$$

have the same solution y_F^*. In the first problem, the firm maximizes the present value of profits whereas in the second problem, it maximizes the future value. Again, $\Pi_M = 0$ and $y_M^* = W - y_F^*$ is an optimal choice.

■ *Households*

For the household, investing in FT amounts to buying bonds with return $a_1 = (R_F^*, R_F^*)$ at price $q_1 = 1$. Given $D = 0$, buying equity in the bank amounts to buying shares in the risky asset with returns $a_2 = (\overline{R}, \underline{R})$ at price $q_2 = 1$. The market clearing asset prices in the corresponding Radner equilibrium are

$q_1 = R_F^*(p_g^* + p_b^*) = 1$ because of $R_F^* = 1/(p_g^* + p_b^*)$ and

$q_2 = \overline{R}p_g^* + \underline{R}p_b^* = 1$ because of (5.4).

Hence for the household, investing y_F^* in FT and y_M^* in equity is an optimal choice and yields the same consumption bundle as in the Arrow-Debreu case, provided $D = 0$ and $\alpha = 1$.

■ *Banks*

We observe that $B_1 = 0$. Further, $D = 0$ implies $B_2 \leq 0$. Hence, $\alpha = 1$ is an optimal choice for banks. □

D.8 Proof of Proposition 5.15

For y_F^* to solve $\max f(K_F) - R_F K_F$, we set again

$$R_F = \frac{1}{p_g^* + p_b^*},$$

which is equal to $R_F^* = \mathbb{E}[\widetilde{R}]$. Since $B_1 = 0$, the optimal choice of banks depends on the sign of B_2. Observe that for all $D \in [0, y_M^* \cdot \underline{R}/R_F^*]$, we obtain $B_2 \leq 0$. Hence, $\alpha = 1$ remains an optimal choice for banks.

Suppose $D > 0$. Without default, the bank's profit would become $(E+D)\overline{R} - DR_F^*$ in the good state and $(E + D)\underline{R} - DR_F^*$ in the bad state. The bank defaults in the bad state if $\underline{R} = 0$. Hence, the equilibrium described in Proposition 5.14 is the unique efficient equilibrium in the case with $\underline{R} = 0$.

Otherwise, there is no default as long as $DR_F^* \leq (E+D)\underline{R} = y_M^* \underline{R}$ or $D \leq \dfrac{\underline{R}}{R_F^*} y_M^*$. In this case, the return on equity is

$[(E+D)\overline{R} - DR_F^*]/E = \overline{R} - (\overline{R} - \underline{R})(1-\sigma)\frac{D}{E}$ in the good state;

$[(E+D)\underline{R} - DR_F^*]/E = \overline{R} + (\overline{R} - \underline{R})\sigma\frac{D}{E}$ in the bad state.

The expected return on bank equity is given by $\mathbb{E}[\widetilde{R}] = R_F^*$.[9] Therefore, it is an optimal choice for households to purchase $E = y_M^* - D$ units of bank equity, make the amount D of deposits, and invest y_F^* directly in FT. □

D.9 Proof of Proposition 5.16

Let us fix a bond return $\widehat{R}_F$ with $\widehat{R}_F > R_F^*$ and $\widehat{R}_F < \overline{R}$. Entrepreneur e_F optimally chooses $K_F < y_F^*$ such that $\widehat{R}_F = f'(K_F)$.

Perfect competition in the banking sector and a no-arbitrage condition implies $R_D = \widehat{R}_F$. Given $\widehat{R}_F > R_F^*$, we obtain $B_1 < 0$. If $B_2 < 0$, banks would only invest in FT. This cannot be an equilibrium due to the Inada conditions. Hence, let us assume that $B_2 \geq 0$. This implies $\alpha = 1$, that is, banks invest in MT only.

Given banks choose $\alpha = 1$, risk-neutrality and the Inada conditions require that

$$\widehat{R}_F = \sigma \overline{R}_E + (1-\sigma)\underline{R}_E$$

in any equilibrium. Since we are interested in equilibria where banks default in the bad state, we can rewrite this as a condition on banks' debt-equity ratio

$$\begin{aligned}\widehat{R}_F &= \sigma \frac{\overline{R}(E+D) - \widehat{R}_F D}{E} \\ \frac{D}{E} &= \frac{\widehat{R}_F - \sigma\overline{R}}{\sigma(\overline{R} - \widehat{R}_F)} > 0. \end{aligned} \tag{D.4}$$

In this case, households are indifferent in holding risky bank equity that pays out

$$\sigma \frac{\overline{R}(E+D) - \widehat{R}_F D}{E}$$

in the good state and zero in the bad state, and in holding safe assets with return $\widehat{R}_F$ in both states.

Condition (D.4) implies $B_2 = 0$. Hence, $\alpha = 1$ is an optimal choice for banks and we were right in assuming they invest in MT only. Further, note that banks will indeed

[9] In other words, the arbitrage-free asset price of bank equity is one, and we can apply the same Radner-type argument used in the proof of Proposition 5.14.

default in the bad state.[10]

Hence, there exists a continuum of inefficient equilibria with $K_F < y_F^*$ and $y_M = E + D = W - K_F$. Return on safe assets is $\widehat{R}_F = f'(K_F)$. It is an optimal choice for households to invest $K_F < y_F^*$ directly in FT,

$$D = \frac{\widehat{R}_F - \sigma\overline{R}}{(1-\sigma)\widehat{R}_F}(W - K_F)$$

in deposits and

$$E = \frac{\sigma(\overline{R} - \widehat{R}_F)}{(1-\sigma)\widehat{R}_F}(W - K_F)$$

in bank equity. Banks' debt-equity ratio is given by (D.4), and it is optimal to invest all their funds in MT. Banks default in the bad state.

Finally, let us denote by $\widehat{c}_g$ and $\widehat{c}_b$ consumption of households in the good and in the bad state, respectively. We can readily assert that

$$\sigma\widehat{c}_g + (1-\sigma)\widehat{c}_b < \sigma c_g^* + (1-\sigma)c_b^*.$$

Since households are risk neutral, we conclude that the equilibrium allocation is inefficient. □

[10] To see this, observe that banks default in the bad state if their debt-equity ratio exceeds $\frac{\underline{R}}{\widehat{R}_F - \underline{R}}$, which is lower than the debt-equity ratio given in (D.4) because of $\widehat{R}_F > R_F^*$.

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