

# Essays on the Regulation and Taxation of Banks

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# Contents

<b>Introduction</b>	<b>1</b>
<b>1 On the Incidence of Bank Levies: Theory and Evidence</b>	<b>5</b>
1.1 Introduction . . . . .	6
1.2 Bank Levies . . . . .	9
1.3 Theoretical Analysis . . . . .	11
1.3.1 Monti-Klein Model with Taxation and Regulation . . . . .	11
1.3.2 A Tax on Bank Liabilities . . . . .	13
1.3.3 Extensions . . . . .	18
1.3.4 Predictions . . . . .	21
1.4 Empirical Evidence . . . . .	22
1.4.1 Estimation Strategy . . . . .	23
1.4.2 Data and Measurement . . . . .	27
1.4.3 Main Results . . . . .	31
1.4.4 Robustness Tests . . . . .	40
1.5 Conclusion . . . . .	48
1.A Appendix . . . . .	52
1.A.1 Proofs and Derivations . . . . .	52
1.A.2 Variables: Construction and Definitions . . . . .	54
1.A.3 Supplementary Figures and Tables . . . . .	55
<b>2 Rewarding Prudence: Risk Taking, Pecuniary Externalities and Optimal Bank Regulation</b>	<b>59</b>
2.1 Introduction . . . . .	60
2.2 The Model . . . . .	63
2.2.1 Bankers . . . . .	65
2.2.2 Corporations . . . . .	66
2.2.3 Investors . . . . .	66

2.2.4	Markets . . . . .	67
2.3	Equilibrium Analysis . . . . .	67
2.3.1	First Best . . . . .	68
2.3.2	Moral Hazard and Risk Shifting . . . . .	70
2.3.3	Market Equilibrium . . . . .	74
2.3.4	Second Best . . . . .	78
2.3.5	Implementation . . . . .	82
2.3.6	Distributional Implications . . . . .	86
2.4	Extensions . . . . .	88
2.4.1	Zero Lower Bound . . . . .	88
2.4.2	Entrepreneurial Moral Hazard and Diversification of Risk . . . . .	92
2.5	Conclusion . . . . .	98
2.A	Appendix . . . . .	102
2.A.1	Proofs and Derivations . . . . .	102
2.A.2	Numerical Example . . . . .	111
<b>3</b>	<b>The Optimal Adjustment of Bank Capital Regulation in a Downturn</b>	<b>113</b>
3.1	Introduction . . . . .	114
3.2	The Model . . . . .	117
3.2.1	Entrepreneurs . . . . .	118
3.2.2	Banks . . . . .	119
3.2.3	Depositors and Investors . . . . .	121
3.2.4	Markets . . . . .	122
3.2.5	State of the Economy . . . . .	122
3.3	Equilibrium Analysis . . . . .	123
3.3.1	Market Equilibrium . . . . .	124
3.3.2	The Regulator's Problem . . . . .	125
3.3.3	Equilibrium Allocation . . . . .	127
3.3.4	Optimal Capital Regulation . . . . .	128
3.3.5	Entrepreneurial Moral Hazard . . . . .	135
3.4	Conclusion . . . . .	137
3.A	Appendix . . . . .	141
<b>4</b>	<b>Banks and Sovereigns: A Model of Mutual Contagion</b>	<b>147</b>
4.1	Introduction . . . . .	148
4.2	Literature . . . . .	150
4.3	The Model . . . . .	152

4.3.1	Banks . . . . .	153
4.3.2	Households . . . . .	158
4.3.3	Government . . . . .	159
4.3.4	Market Clearing . . . . .	163
4.4	Equilibrium Analysis . . . . .	164
4.4.1	Equilibrium Allocation . . . . .	164
4.4.2	Bank and Sovereign Risks . . . . .	167
4.4.3	Deposit Insurance and Sovereign Risk . . . . .	168
4.4.4	Deposit Insurance and Welfare . . . . .	170
4.5	Capital Regulation . . . . .	174
4.5.1	Banks . . . . .	174
4.5.2	Equilibrium . . . . .	177
4.5.3	Comparative Statics . . . . .	178
4.6	Conclusion . . . . .	181
4.A	Appendix . . . . .	185
4.A.1	Proofs and Derivations . . . . .	185
4.A.2	Summary . . . . .	193





# List of Tables

## Chapter 1

1	Bank Levies . . . . .	10
2	Main Scenario: Predictions . . . . .	22
3	Banks Subject to Levy . . . . .	28
4	Baseline Regressions . . . . .	32
5	Main vs. Alternative Scenario . . . . .	34
6	Heterogeneous Responses: Bank Competition . . . . .	35
7	Heterogeneous Responses: Interest Income and Bank Competition . . . . .	36
8	Heterogeneous Responses: Bank Capitalization . . . . .	38
9	Heterogeneous Responses: NIM and Bank Capitalization . . . . .	39
10	Robustness: Different Time Trends . . . . .	42
11	Robustness: Different Time Trends . . . . .	43
12	Robustness: Instruments for Equity and Provisions . . . . .	44
13	Robustness: Austria and Germany . . . . .	45
14	Robustness: Subsample Tests . . . . .	46
15	Robustness: Quantity Effects . . . . .	47
16	Definition of Variables . . . . .	54
17	Sample by Country . . . . .	56
18	Summary Statistics . . . . .	57

## Chapter 2

1	Numerical Example . . . . .	111
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## Chapter 3

1	Probabilities . . . . .	120
2	Adjustment in a Downturn . . . . .	133

3 Numerical Example . . . . . 134

**Chapter 4**

1 Overview: Three Scenarios . . . . . 193

# List of Figures

## Chapter 1

1	Interest Income on Loans . . . . .	29
2	Interest Expenses on Deposits . . . . .	30
3	Net Interest Margin . . . . .	30
4	Heterogeneity: Lending Rate and HHI . . . . .	37
5	Heterogeneity: Lending Rate and Branch Density . . . . .	37
6	Heterogeneity: NIM and Capital Ratio . . . . .	39
7	Euro Area: IIL and Bank Lending Rates . . . . .	55
8	Euro Area: IED and Bank Deposit Rates . . . . .	55

## Chapter 2

1	Model Overview . . . . .	64
2	First Best . . . . .	70
3	Risk Shifting and Feasible Contract . . . . .	72
4	Market Equilibrium . . . . .	77
5	Second Best . . . . .	81
6	Zero Lower Bound . . . . .	91

## Chapter 3

1	Probability Tree . . . . .	119
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## Chapter 4

1	Time Line . . . . .	153
2	Bank Risk and Bond Repayment . . . . .	155
3	Bank's Failure Threshold . . . . .	156

4	Bank's Asset Allocation . . . . .	158
5	Sovereign Default Threshold . . . . .	162
6	Multiple Equilibria . . . . .	165
7	Deposit Insurance and Sovereign Risk . . . . .	170
8	Default Mechanisms and Deposit Insurance . . . . .	170
9	Bank's Failure Threshold . . . . .	175

## Summary

This dissertation combines four essays on the regulation and taxation of banks as well as on the bank-sovereign nexus. The recent financial crisis and the ongoing sovereign debt crises in the Euro area have put these topics on top of the agenda and have led to several reforms of the banking sector. The first chapter analyzes a newly introduced tax on banks, the bank levy. It is imposed on bank liabilities and its aim as a Pigovian tax is the internalization of the (fiscal) cost of banking crises. This chapter focuses on the tax incidence: Theory and the evidence from EU banks lead to the conclusion that the levy increases the interest rates on loans and deposits and the net interest margin such that banks pass part of the burden onto borrowers while depositors benefit from higher interest rates as deposits are exempt. While moderate on average, the pass-through is particularly strong and economically relevant in concentrated banking sectors. The second chapter studies risk shifting of banks and identifies a pecuniary externality, which provides a new rationale for macroprudential regulation. In particular, the externality leads to a constrained-inefficient market outcome even if deposits are correctly priced and the cost of bank failure are internalized. Interestingly, optimal regulation increases banks' profit margins in order to induce more prudent lending and is thus associated with redistribution from savers to banks and corporate firms. The third chapter analyzes the procyclicality of capital requirements that are a key concern in the context of regulatory reform. It provides new insights about how capital requirements should optimally adjust to adverse shocks as to promote financial stability and to fund profitable investments. Finally, the fourth chapter develops a model of the bank-sovereign nexus that captures the spillovers and feedback loops of risk originated in the banking sector. The analysis reveals two main channels that link sovereign to bank risk: deposit insurance and taxation. Eventually, we also explore how the provision of deposit insurance affects sovereign risk and welfare.

## Zusammenfassung

Diese Dissertation besteht aus vier Aufsätzen zur Regulierung und Besteuerung von Banken sowie zur Verflechtung von Bankrisiken und Staatsschulden. Die jüngste Finanzkrise und die andauernden Schuldenkrisen in der Eurozone machen dieses Themengebiet besonders aktuell und führen derzeit zu zahlreichen Reformen des Bankensektors. Das erste Kapitel der Dissertation untersucht die neu eingeführte Bankensteuer. Sie wird auf Verbindlichkeiten erhoben und zielt als Pigousteuer auf die Internalisierung der (fiskalischen) Kosten von Bankenrisiken ab. Im Zentrum der Analyse steht die Steuerinzidenz: Theorie und Evidenz legen nahe, dass diese Steuer den Kredit- und Einlagezins sowie die Zinsmarge erhöht, sodass ein Teil der Steuerlast auf die Schuldner überwältigt wird wogegen Sparer von höheren Zinsen profitieren, da ihre Einlagen nicht der Steuer unterliegen. Im Durchschnitt sind die Effekte moderat, in konzentrierten Märkten aber stark und ökonomisch signifikant. Das zweite Kapitel untersucht das Risk Shifting von Banken und identifiziert eine pekuniäre Externalität, welche makroprudenzielle Regulierung erfordert. Diese Externalität führt selbst dann zu einer ineffizienten Marktallokation, wenn der Einlagezins das Insolvenzrisiko der Bank korrekt widerspiegelt. Optimale Regulierung erhöht die Zinsmarge und stärkt so den Anreiz für eine vorsichtige Kreditvergabe führt aber auch zu Umverteilung von Sparern zu Banken und Unternehmen. Das dritte Kapitel untersucht die Prozyklizität der Eigenkapitalvorschriften von Banken. Die Analyse zeigt deren optimale Anpassung an adverse Schocks, sodass die Finanzstabilität gesichert und die Investitionstätigkeit der Realwirtschaft nicht behindert wird. Schliesslich wird im vierten Kapitel ein Modell der Verflechtung von Bankrisiken und Staatsschulden entwickelt. Es beschreibt die gegenseitige Ansteckung von Banken und Staat, wobei das Risiko von ersteren ausgeht. Zwei Ansteckungsmechanismen sind zentral: Einlagensicherung und Steuereinnahmen. Zudem wird gezeigt, inwieweit die Einlagensicherung das Risiko für den Staat senken und die Gesamtwohlfahrt erhöhen kann.

# Introduction

Since the financial crises, the reform of the banking sector has been on top of the agenda. A large number of policies and initiatives of how to strengthen the crisis resilience of banks, to correct market failures, and to prevent a spillover of financial risks to the economy as a whole have been proposed, some of them are currently being implemented. In general, these proposals relate to three broad areas that constitute the main pillars of banking reform: effective regulation, specific taxes, and - for the Euro area - the banking union. First of all, a consensus - the so-called macroprudential approach - emerged that the goal of bank regulation needs to be more than just preserving the stability of each single financial institution. In particular, regulation should focus more on improving the stability of the entire banking and financial sector and on reducing the risk of systemic crises. Beyond enhanced capital and liquidity requirements, the new regulatory framework Basel III thus includes additional instruments such as the countercyclical capital buffer that addresses the procyclicality of capital regulation and the build-up of systemic risk during a lending boom and the leverage ratio that limits excessive debt. Second, governments incurred large cost during the financial crisis to prevent a collapse of the banking sector. Hence, the idea of a contribution by the financial sector through the taxation of banks emerged. In addition, such taxes may complement prudential regulation. Following a request of the G20, the IMF issued a report<sup>1</sup> on the taxation of the financial sector that evaluates the scope for three new specific taxes: The financial stability contribution or, more generally, the bank levy imposed on liabilities is essentially a Pigovian tax, which aims at internalizing the fiscal cost of banking crises and at compensating taxpayers for the provision of - explicit or implicit - guarantees; the financial activities tax levied on bank profits and remunerations provides a substitute for the value added tax on financial services; and a tax on financial transactions should discourage short-term speculation and reduce the risk of asset bubbles. Recently, several European countries adopted a bank levy. Third, the ongoing Eurozone crisis highlights the importance of the bank-sovereign nexus as the public debt crises in Ireland and Spain were, first of all, a consequence of a preceding banking crisis while the bailouts, for example of Greece, were also motivated by the fear of a banking crisis

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<sup>1</sup>IMF (2010). *Financial Sector Taxation. The IMF's Report to the G20 and Background Material.*

caused by a sovereign default. Such a scenario seems likely because banks were strongly invested in government bonds. The Eurozone crisis was the main rationale for the development of the European banking union that is now being realized. At its core are the joint supervision of multinational and systemically important banks by the ECB and a single resolution funds. The latter provides a common fiscal backstop such that the restructuring and resolution of distressed banks does not immediately put a country into financial difficulties.

This dissertation is a collection of research papers that analyze specific, detailed aspects of bank regulation and taxation. Nevertheless, its chapters cover topics that are related to each of these three banking reform pillars: The first chapter *On the Incidence of Bank Levies: Theory and Evidence* examines the newly introduced bank levy and provides a theoretical and empirical analysis of its incidence. Beyond distributional aspects and concerns about possible adverse side effects on lending and investment, knowing whether those who benefited from government guarantees in the past indeed bear the burden of the levy is of peculiar interest given its objective as a Pigovian tax. The theoretical analysis carves out the main adjustment mechanisms of banks, relates a potential pass-through to the competitive and regulatory environment and yields predictions that are confronted with the data. In line with the main predictions, the evidence from almost 3'000 EU banks suggests that the tax burden is partly passed onto borrowers by higher lending rates and net interest margins but that depositors even benefit from higher interest rates due to the exemption of (insured) deposits from the levy. While the observed increases are moderate on average, they are particularly strong and economically significant in concentrated markets and for poorly capitalized banks. To my knowledge, it is the first paper with cross-country, bank-level evidence about the incidence of the novel tax. This allows for a more robust measurement of banks' exposure to the levy by exploiting the variation across countries and identifies the impact of market characteristics like, for example, bank concentration on the tax incidence.

The second and the third chapters *Rewarding Prudence: Risk Taking, Pecuniary Externalities and Optimal Bank Regulation* and *The Optimal Adjustment of Bank Capital Regulation in a Downturn* address specific issues in the context of the regulatory reform. Both examine optimal bank regulation and are based on a welfare analysis that identifies market failures and characterizes the optimal policy. The second chapter reconsiders the risk-shifting problem and shows that whenever deposits are ultimately scarce because an alternative sector offers investment opportunities, a pecuniary externality leads to excessive leverage and risk taking of all banks. This provides a strong rationale for macroprudential regulation; in particular, this distortion is independent of mispriced deposits and government guarantees that are currently being addressed by taxes and self-insurance (e.g., the single resolution funds and pre-funded deposit insurance that are essential parts of the banking union). Essentially, capital requirements or



deposit rate ceilings can implement a second-best allocation: By keeping the deposit interest rate artificially low and raising the interest margin, the prospect of earning a higher rent if successful makes risk taking more expensive for banks thereby strengthening their incentives for prudent lending. Alternatively, the second best can also be achieved by issuing a particular number of banking licenses thus creating imperfect competition. Consistent with the idea of financial restraint, optimal regulation is thus associated with redistribution from savers to banks and firms with access to direct finance because the returns on deposits and corporate bonds decline. Hence, banks may even benefit from tighter regulation. The third chapter examines the procyclicality of capital regulation and describes how capital requirements, which in the presence of scarce bank capital balance a trade-off between financing productive investments in the real sector and promoting financial stability, optimally adjust to changes in the state of the economy. The main finding is that the adjustment fundamentally differs depending on the type of economic shock. More specifically, adverse financial shocks primarily associated with the loan supply such as a shortage of bank capital require a countercyclical adjustment while real shocks usually associated with the loan demand, for example, a decline of entrepreneurs' productivity imply a procyclical adjustment of capital requirements.

Motivated by the sovereign debt crises in the Euro area, the fourth chapter *Banks and Sovereigns: A Model of Mutual Contagion* eventually develops a model of the bank-sovereign nexus where risk originates in the banking sector. The latter captures a stylized fact of the recent crisis and sets this contribution apart from other approaches in the literature that highlight the role of fiscal or liquidity risks. The analysis identifies two main channels of bank-sovereign contagion, namely, the cost of deposit insurance and an erosion of the tax base. In addition, banks' sovereign bond holdings make them sensitive to the fiscal state and may even lead to adverse feedback loops such that banks are more likely to fail because of a sovereign default. The latter is, in turn, the result of a poor performance of financial assets. The paper also explores to what extent *ex post* bank bailouts may preserve or jeopardize fiscal stability in the sense that they prevent or trigger a sovereign default and whether they are welfare-improving. We find that these features crucially depend on the cost of a disorderly bank liquidation as well as on the possibility of shifting the cost onto foreign bondholders.



## Chapter 1

# On the Incidence of Bank Levies: Theory and Evidence

Michael Kogler<sup>1</sup>

Several European countries have recently introduced levies on bank liabilities to internalize the fiscal costs of banking crises. This paper studies the tax incidence: Building on the Monti-Klein model, we predict that banks shift the burden to borrowers by raising lending rates and that deposit rates may increase as deposits are partly exempt. Bank-level evidence for 23 EU countries in the period 2007-2013 implies a moderate increase in lending and deposit rates and net interest margins. Market characteristics and capital structure influence the magnitude: The lending rate strongly increases in concentrated markets, whereas the pass-through is weak for well-capitalized banks.

**JEL Classification:** G21, G28, H22

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## 1.1 Introduction

Banking crises are expensive: Beyond their impact on the real economy, they often involve large fiscal costs as a substantial amount of public funds is spent on the stabilization of the banking sector. During the recent financial crisis, EU member states, for example, incurred a fiscal cost for bank recapitalization and asset relief (2008-13) of 4.9 percent of GDP (European Commission, 2013). In addition, government guarantees and liquidity assistance were provided that 2009 reached a peak value of 6.9 percent of GDP. There are, however, large differences in those magnitudes across countries: While the fiscal costs were rather moderate in Germany or Austria, the UK incurred costs of recapitalization and guarantees worth 7.4 and 10.1 percent of GDP respectively. In Ireland, they even reached extreme values of 39.9 and 173.8 percent. Therefore, the G-20 asked the IMF to prepare a report that studies the scope for special taxes on banks for a 'fair and substantial contribution by the financial sector'. Subsequently, 15 European countries including Germany, the Netherlands, and the United Kingdom introduced such a bank levy. In the United States, President Obama proposed a 'Financial Crisis Responsibility Fee' but an implementation in the near future seems unlikely. The objective of this tax is to (i) raise revenue to (partly) cover the fiscal cost of banking crises thereby compensating taxpayers for guarantees and bailouts and (ii), as a Pigovian tax, to internalize externalities associated with such guarantees thus reducing bank risk and complementing regulation.

A key aspect of every tax is the incidence. In case of the bank levy, the main question is whether bank owners bear the burden of the levy themselves or whether they can shift it to their customers by raising lending or lowering deposit rates. The incidence allows drawing some conclusions about whether the burden of the levy is indeed borne by those who benefited the most from government guarantees and bailouts. Moreover, there are concerns that higher lending rates and a contraction of the loan supply may hamper firms' access to finance and lower investment thus slowing down economic growth. Slovik and Cournède (2011), for instance, estimate that a one percentage point increase in (long-term) lending rates reduces annual GDP growth by up to 0.4 percentage points in the Euro area. Small, credit-constrained firms are most likely to be affected as they have difficulties to substitute bank loans with other funds. With banking reforms (e.g., Basel III, Banking Union) that tighten regulatory constraints being implemented at the same time, such adverse effects on the real economy could be amplified.

This paper both theoretically and empirically examines the incidence of the newly introduced bank levies. The focus is on a pass-through of the tax to borrowers and depositors, which is motivated by its economic relevance as well as by the empirical finding of Goodspeed and Havrylchyk (2014) that the incidence on wages is generally of minor importance for banks as opposed to manufacturing. Building on the Monti-Klein framework, we develop a model that

characterizes the lending and borrowing decisions of oligopolistic banks and the equilibrium interest rates. We derive several scenarios for the tax incidence thereby carving out potential determinants such as balance sheet composition, bank competition, and capital structure. Subsequently, our predictions are taken to the data: Using a cross-country panel dataset with financial information of 2'987 EU banks for the period 2007-2013, the impact of the bank levy on lending and deposit rates as well as net interest margins is estimated. For that purpose, we exploit the variation between banks in countries adopting and not adopting a levy during the sample period as well as the variation in tax rates.

The main findings are that banks shift part of the tax burden to borrowers by raising the lending rate, while depositors even benefit from a higher interest rate because deposits are partly exempt. However, the average effects are moderate: For example, the lending rate and the net interest margin with average values of 5.85 and 2.48 percent only rise by 0.24 and 0.05 percentage points respectively if a bank is taxed. The magnitude crucially depends on bank competition: In particular, the pass-through to borrowers is strong and economically significant in highly concentrated markets where the lending rate is up to 0.77 percentage points higher. The capital structure also influences the incidence: Well-capitalized banks are less affected by a tax on liabilities such that the pass-through measured by the net interest margin is weaker. The results are robust to different measures of the bank levy and to a broad set of controls and survive several robustness tests that account for specific shocks during the recent crisis.

This paper draws from two strands of the literature on the taxation of banks: First, several theoretical contributions analyze the role of Pigovian taxes in banking: Keen (2011) studies their role in internalizing externalities associated with the collapse and bailout of banks and suggests a tax on bank borrowing with marginal tax rates that sharply increase at low capital ratios. Perotti and Suarez (2011) explore to what extent a Pigovian tax can internalize a bank's contribution to systemic risk associated with short-term funding. Whether such a tax is preferable to quantity-based regulation crucially depends on bank characteristics. Acharya et al. (2016) propose a Pigovian tax in order to internalize the systemic risk externality. The optimal tax relates to the degree of a bank's undercapitalization in case of a systemic crisis, which is a proxy of its contribution to systemic risk. Furthermore, Devereux et al. (2015) both theoretically and empirically examine how banks that become subject to a levy adjust their capital structure and risk taking: They find that banks indeed reduce their leverage but they also increase risk taking measured by the average risk weight. The latter is due to a mechanical effect as more equity increases the maximum risk-weighted assets of a bank, which tends to favor riskier assets instead of a larger size. Schweikhard and Wahrenburg (2013) simulate the hypothetical levy payments during the recent crisis had such a tax already been in place. Compared the funding benefit of systemically important banks, they find that the levies only

internalize part of systemic risk.

A second strand of the literature analyzes the tax incidence on banks and financial markets: On the theoretical side, Caminal (2003) develops a model of banks' behavioral responses to different taxes including the value added and corporate income tax and taxes on loans and deposits. He stresses the importance of the separability of loans and deposits and of market power. Albertazzi and Gambacorta (2010) examine the incidence of the corporate income tax using a variant of the Monti-Klein model. They show that it leads to a higher lending rate but has no impact on the deposit rate and the price of financial services. Bierbrauer (2014) studies the tax incidence on financial markets in a model with fire sales and focuses on the proposed financial transactions tax. On the empirical side, only two papers provide evidence on the incidence of bank levies: Buch et al. (2014) analyze the levy in Germany. Using a difference-in-difference approach that exploits the variation between large banks that are taxed and small banks that are exempt, they find that the levy reduces the loan volume, has no effect on the lending rate, and increases the deposit rate. The latter can be explained by the exemption of customer deposits that induces banks to shift the funding sources towards deposits. For Hungary, Capelle-Blancard and Havrylchuk (2013) find a positive effect of the levy on the lending rate. Especially, the burden is shifted to customers who already have an ongoing borrowing relationship with a bank and thus face high cost of switching to another bank. These two studies provide evidence for a single country and the post-introduction period is quite short such that a more pronounced effect is likely in the long run. The literature on the incidence of the corporate income tax on banks, which usually involves cross-country studies, is more extensive: Demirgüç-Kunt and Huizinga (1999) find evidence that the tax is fully passed onto customers as net interest margins increase one by one with the tax rate. In the same spirit, Demirgüç-Kunt and Huizinga (2001) show that the pre-tax profitability of international banks varies little with domestic tax rates as they can exploit profit shifting opportunities such that their adjustment to the tax is weaker. Furthermore, Albertazzi and Gambacorta (2010) show that corporate income taxes raise the lending rate such that banks can pass up to 90 percent of the burden onto borrowers. Chiorazzo and Milani (2011) estimate that European banks can pass through 45 percent of the tax burden in the short and 80 percent in the long run. Relying on a different measure of the bank's tax burden, Capelle-Blancard and Havrylchuk (2014), however, find no evidence for a pass-through.

The main contribution of this paper is a comprehensive theoretical and empirical analysis of the incidence of the newly introduced bank levies. Such a combination identifies the main adjustment mechanisms of banks to a levy and assesses its quantitative impact. Importantly, the article highlights how the incidence relates to bank competition and capitalization, the latter of which has not been addressed yet. To my knowledge, it is the first paper with cross-

country evidence on the incidence of bank levies. This is common approach when studying the incidence of the corporate income tax and allows for more general insights and a robust measurement of banks' exposure to the levy by exploiting cross-country variation. In addition, the paper uses more recent data with a longer post-introduction period than previous studies. The remainder of this paper is organized as follows: Section 1.2 provides an overview about bank levies in Europe. Section 1.3 outlines the model and derives several predictions about the incidence, which are taken to the data in section 1.4. Eventually, section 1.5 concludes.

## 1.2 Bank Levies

The IMF's report on financial sector taxation published in 2010 examines the scope for special taxes on banks. An essential part is the proposal of a bank levy, the so-called 'financial stability contribution': Its main objectives are (i) a contribution by the banking sector to compensate taxpayers for the costs of guarantees and bailouts and (ii) the internalization of these fiscal costs as to reduce the risk of a future banking crisis and to complement regulation. Externalities may emerge because of implicit government guarantees for large, systemically important banks. This creates a funding benefit - the 'too-big-to-fail' subsidy - which makes a bank's cost less sensitive to its risk profile thereby strengthening risk-taking incentives. This benefit is well documented in the empirical literature, for example, by Flannery and Sorescu (1996), Balasubramnian and Cyree (2011), and Acharya et al. (2016). Importantly, the tax should be related to a bank's contribution to systemic risk and to all potential costs associated with its failure. The IMF (2010) proposes a tax on bank liabilities excluding capital and insured deposits such that the risky part of funds like uninsured deposits and wholesale funding is taxed; the tax base may also include derivatives. The exemption of insured deposits avoids double taxation due to insurance premia. The tax rate should reflect the funding benefit for large, systemically important banks due to implicit guarantees but a lower rate may apply for smaller banks: The IMF (2010, p. 55) estimates a benefit between 10 and 50 basis points with an average of 20 basis points. For the U.S., Acharya et al. (2016) find a benefit of 30 basis points on average (1990-2012) that strongly increases during a crisis. The tax revenue could either accumulate a resolution fund or be used for the general budget.

Since 2009, 15 countries in the European Union have introduced a bank levy.<sup>2</sup> Table 1 summarizes bank levies currently in place in selected countries.<sup>3</sup> Germany, the UK, and the Netherlands closely follow the proposed financial stability contribution, whereas Hungary and France adopt a different design. In general, levies differ in at least four aspects: First, the tax base

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<sup>2</sup>See, OECD (2013) for detailed information. Australia and Greece had already imposed bank levies before; however, their purpose is different and differs from the IMF's proposal.

<sup>3</sup>An extensive summary can be found in Devereux et al. (2015, Appendix) or OECD (2013).

	Tax Base	Tax Rates	Exemptions
<i>Austria</i> 1.1.2011	Total Liabilities	< EUR 20bn: 0.09%* > EUR 20bn: 0.11%	Insured Deposits Allowance: EUR 1bn
<i>Belgium</i> 1.1.2012	Total Liabilities	0.035%	Insured Deposits
<i>Germany</i> 1.1.2011	Total Liabilities Derivatives	< EUR 10bn: 0.02% EUR 10bn-100bn: 0.03% EUR 100bn-200bn: 0.04% EUR 200bn-300bn: 0.05% > EUR 300bn: 0.06% Derivatives: 0.0003%	Customer Deposits Allowance: EUR 200m Cap: 20% of Net Income Minimum charge**: 5%
<i>France</i> 1.1.2011	Min. Regulatory Capital	0.5%	Allowance: EUR 500m
<i>Hungary</i> 27.9.2010	Total Assets	< HUF 50bn: 0.15% > HUF 50bn: 0.53%	Interbank Loans
<i>Netherlands</i> 1.10.2012	Total Liabilities	0.044% (short-term) 0.022% (long-term)	Insured Deposits Allowance: EUR 20bn
<i>Slovakia</i> 1.1.2012	Total Liabilities	0.4%	Insured Deposits, Subordinated Debt
<i>Sweden</i> 30.12.2009	Liabilities and Provisions	0.044%	Subordinated Debt, Selected Securities
<i>UK</i> 1.1.2011	Total Liabilities	0.036% (short-term) 0.071% (long-term)	Insured Deposits, Liquid Assets Allowance: GBP 20bn

Table 1: *Bank Levies: Overview*

This table summarizes bank levies in selected countries, information as of 2014. \*Until 2014: 0.055% (<EUR 20bn), 0.085% (>EUR 20bn), surcharge 25%; \*\*only 5% of the tax liability is payable if a bank has losses; source: Devereux et al. (2015, Appendix).

usually consists of liabilities excluding equity and insured deposits as suggested by the IMF. In Germany, even all customer deposits are exempt but off-balance sheet derivatives are taxed as well. Hungary and France, however, impose a levy on total assets and minimum regulatory capital respectively. Second, the tax rates are flat (e.g., Belgium, Sweden), progressive (e.g., Austria, Germany, Hungary) or differ between short- and long-term liabilities (e.g., Netherlands, UK). In addition, some countries exempt small banks by an allowance or tax them at lower rates because they are unlikely to benefit from implicit guarantees. Third, the tax rates reach from values clearly below the IMF's proposal of (at most) 20 basis points (e.g., Germany, UK, Sweden) to high values of 40 to 50 basis points (e.g., Hungary, Slovakia). Fourth, the bank levy as a Pigovian tax is forward-looking in the sense that its goal is to cover the fiscal costs of future banking crises. However, it is backward-looking and imposed on past balance sheets in Austria (balance sheet 2010) and Hungary (2009). Since banks cannot reduce their



tax burden, adjustments are less likely<sup>4</sup> unless this feature is temporary like in Austria<sup>5</sup> where forward-looking banks may try to lower the future tax burden.

## 1.3 Theoretical Analysis

We study how loans and deposits and, most importantly, the equilibrium interest rates adjust to a bank levy. The theoretical analysis yields predictions of how banks shift the tax burden to customers and characterizes the main determinants of the incidence. For that purpose, we rely on a variant of the Monti-Klein model complemented with regulation and taxation, which is a popular approach in the incidence literature. This static, industrial organization model of banks goes back to Klein (1971) and Monti (1972); both oligopolistic and monopolistic variants exist.<sup>6</sup> It captures the main determinants of banks' lending and borrowing decisions and yields testable predictions that can be taken to the data. At a first stage, the incidence is analyzed using a textbook variant of this model to establish a benchmark. Subsequently, we add risky loans and bank failure following Dermine (1986). This extension captures the risk dimension given that internalizing the fiscal costs of banking crises is the main rationale for bank levies. The Monti-Klein model is not without controversy, however: In the neoclassical tradition, the bank is modeled as a banking firm and the only friction is imperfect competition. It is, nevertheless, an appropriate framework to study the impact of a tax on interest rates.

### 1.3.1 Monti-Klein Model with Taxation and Regulation

Suppose a number of identical banks indexed by  $i = 1, \dots, N$  compete for loans and deposits in a Cournot fashion; they face a downward-sloping inverse loan demand  $r_L = r_L \left( \sum_{i=1}^N l_i \right)$  and an upward-sloping inverse deposit supply  $r_D = r_D \left( \sum_{i=1}^N d_i \right)$ . Each bank is owned and operated by a license holder with no private wealth (henceforth: bank owner). Bank  $i$  supplies credit  $l_i$  and is funded by deposits  $d_i$  and equity  $e_i$ . To raise equity, the owner promises a share  $\phi_i$  of the bank's end-of-period value to outside shareholders, who elastically supply equity at a required return  $\rho$ . The bank can also raise an amount  $m_i$  of funds from other sources at a fixed interest rate  $r$  determined by monetary authorities or on the international capital market. Such non-deposit liabilities may consist of interbank and money market borrowing, bonds or wholesale funding. Whenever  $m_i$  is negative, the bank is a (net) lender on the money market. The option of borrowing or lending at a fixed interest rate makes loans and deposits separable,

<sup>4</sup>This does not rule out pure price adjustments, e.g., raising lending rates or fees, if a bank has market power. Capelle-Blancard and Havrylchuk (2013) find evidence for such behavior in Hungary.

<sup>5</sup>The levy was imposed on the 2010 balance sheet for the years 2011 to 2013; from 2014 on, it is imposed on the previous year balance sheet.

<sup>6</sup>For a detailed discussion of the Monti-Klein model, see, Freixas and Rochet (2008, Ch. 3).

which is a well-known feature of the Monti-Klein model and affects the tax incidence.<sup>7</sup> It persists if the bank incurs administrative cost as long as they additively separable but is not robust to bankruptcy risk as shown by Dermine (1986). Thus, the bank's profit equals

$$\pi_i = (1 + r_L)l_i - (1 + r_D)d_i - (1 + r)m_i \quad (1)$$

and its objective is to maximize the value appropriated by the bank owner:

**PROGRAM 1** *A bank chooses loans  $l_i$ , deposits  $d_i$ , money market funding  $m_i$ , equity  $e_i$ , and the share of outside equityholders  $\phi_i$  to maximize the surplus of its owner*

$$\max_{l_i, d_i, m_i, e_i, \phi_i} (1 - \phi_i)\pi_i \quad (2)$$

*subject to capital requirements*

$$e_i \geq kl_i$$

*the participation constraint of outside equityholders*

$$\frac{\phi_i \pi_i}{e_i} = 1 + \rho$$

*and the funding constraint*

$$l_i + T_i = d_i + m_i + e_i$$

*where  $T_i$  denotes the bank's tax liability.*

The constraints are interpreted as follows: Standard capital regulation requires a fraction  $k \in [0, 1]$  of loans<sup>8</sup> to be financed with equity. In order to attract equity, the bank needs to promise sufficiently large dividends (i.e., value share  $\phi_i$ ) to outside equityholders such that the (gross) return on equity equals their opportunity cost  $1 + \rho$ . This is captured by the participation constraint. Suppose that equity is privately costly and earns an excess return over debt:  $\rho \geq r$ . This typical assumption can be rationalized, for example, by the agency cost of equity or the debt bias of the corporate income tax. Costly equity leads to a binding regulatory constraint, which is restrictive but appropriate in the context of regulatory reforms and higher capital requirements. Eventually, the funding constraint holds at the beginning. The focus on a levy paid upfront illustrates the forward-looking aspect of this tax.<sup>9</sup> Substituting the constraints and the definition of  $\pi_i$  and using  $L = \sum_{i=1}^N l_i$  and  $D = \sum_{i=1}^N d_i$  allows rewriting the bank's

<sup>7</sup>For a more detailed analysis of separability and tax incidence, see, Caminal (2003).

<sup>8</sup>Whenever the bank is a net lender on the money market ( $m_i < 0$ ), its assets consist of loans and money market lending,  $l_i - m_i$ , and the regulatory constraint is  $e_i \geq k(l_i - m_i)$ .

<sup>9</sup>Note this assumption does not affect the results but it allows for a more realistic interpretation in a variant with bank risk (see, section 1.3.3).

problem:

$$\max_{l_i, d_i} [r_L - r(1 - k) - \rho k]l_i + [r - r_D]d_i - (1 + r)T_i \quad (3)$$

The first two terms capture the surplus earned on loans and deposits respectively. The corresponding first-order conditions are:

$$\begin{aligned} r_L + r'_L(L)l_i - [\rho k + r(1 - k) + (1 + r)T_L] &= 0 \\ r - [r_D + r'_D(D)d_i + (1 + r)T_D] &= 0 \end{aligned}$$

$T_L$  and  $T_D$  denote the partial derivatives of the tax with respect to  $l_i$  and  $d_i$ . The problem is separable in loans and deposits (if  $T_{LD} = 0$ ). The first condition characterizes the lending decision and requires that the marginal return of loans and the marginal funding cost (in square brackets) are equalized. The second condition implies that optimal deposits balance the marginal cost of deposits and interbank borrowing. The tax burden is multiplied by  $1 + r$  due to the upfront payment. In the symmetric equilibrium with  $l_i = l = \frac{L}{N}$  and  $d_i = d = \frac{D}{N}$ , the first-order conditions are:

$$\frac{r_L(L) - [\rho k + r(1 - k) + (1 + r)T_L]}{r_L(L)} = \frac{1}{N\varepsilon_L} \quad (4)$$

$$\frac{r - [r_D(D) + (1 + r)T_D]}{r_D(D)} = \frac{1}{N\varepsilon_D} \quad (5)$$

This formulation relies on the interest rate elasticities of loan demand,  $\varepsilon_L = -\frac{1}{r'_L} \frac{r'_L}{L} > 0$ , and deposit supply,  $\varepsilon_D = \frac{1}{r'_D} \frac{r'_D}{D} > 0$ . The Lerner index equals the inverse interest rate elasticity: Banks charge a markup on loans and a markdown on deposits (compared to its non-deposit funding cost) that is inversely related to the elasticity and the number of competitors, that is, to market power. As a result, the lending rate exceeds the cost of capital, and the deposit rate falls short of the interbank rate (i.e.,  $r_L > r > r_D$ ). Finally, the model nests two special cases: For  $N \rightarrow \infty$ , the perfect competition outcome with no markup or markdown is realized. In this case, outside shareholders receive the entire profit as dividends (i.e.,  $\phi_i = 1$ ). For  $N = 1$ , it coincides with the monopoly.

### 1.3.2 A Tax on Bank Liabilities

This section specifies the benchmark model of the bank levy, namely, a tax on liabilities as proposed by IMF (2010) and adopted in most countries that introduced a levy. Hence, we assume that the levy is imposed on the bank's total liabilities consisting of deposits  $d_i$  and money market funding  $m_i$ . In case the latter is negative (i.e., if the bank is a net lender), however, taxable liabilities consist of deposits only. With a uniform tax rate  $\tau$ , the bank's tax

liability is:

$$T_i = \tau[d_i + \max\{m_i, 0\}] \quad (6)$$

We first focus on the case  $m_i \geq 0$ ; substituting the funding constraint and the capital requirements yields  $T_i = \tau^e(1 - k)l_i$  where  $\tau^e \equiv \frac{\tau}{1 - \tau}$  denotes the effective levy rate. Hence, the levy is essentially a function of loans. Substituting the partial derivatives  $T_L = \tau^e(1 - k)$  and  $T_D = 0$  into (4) and (5) yields the symmetric Cournot-Nash equilibrium:

$$\frac{r_L(L) - [\rho k + r(1 - k) + (1 + r)(1 - k)\tau^e]}{r_L(L)} = \frac{1}{N\varepsilon_L} \quad (7)$$

$$\frac{r - r_D(D)}{r_D(D)} = \frac{1}{N\varepsilon_D} \quad (8)$$

Therefore, the levy influences the loan supply and the lending rate by raising the marginal funding cost. In contrast, condition (8) reveals a fixed relation between deposit and money market rate irrespective of the levy such that deposits and the corresponding interest rate are unaffected. The reason is that both liabilities are equally taxed and the cost of deposits relative to money market funding remains unchanged. The sensitivities to the levy follow from differentiating these conditions.<sup>10</sup> As usual in the Monti-Klein model, we assume constant interest rate elasticities  $\varepsilon_L$  and  $\varepsilon_D$ . This establishes:

**PROPOSITION 1** *The bank levy is passed onto borrowers as it lowers the loan supply,  $\frac{\partial L}{\partial \tau} < 0$ , and raises the lending rate:*

$$\frac{\partial r_L}{\partial \tau} = \frac{(1 + r)(1 - k)}{(1 - \tau)^2 \left(1 - \frac{1}{N\varepsilon_L}\right)} > 0 \quad (9)$$

*The pass-through is stronger if the number of competitors is small and the loan demand inelastic and weaker if banks face high capital requirements; it increases in the levy rate. The bank levy is not passed onto depositors as it neither affects deposits nor the deposit rate,  $\frac{\partial D}{\partial \tau} = \frac{\partial r_D}{\partial \tau} = 0$ .*

**Proof:** See Appendix 1.A.1.

The levy increases a bank's marginal funding cost irrespective of the liability structure. Recall that banks supply loans until the marginal return equals the marginal cost of funds and taxes. Since the levy raises the latter, banks reduce loans which leads to a higher lending rate given the downward-sloping demand. Therefore, borrowers bear part of the tax burden as they face a higher funding cost and a smaller loan supply. The extent of the pass-through depends on bank competition and capitalization: First, the number of competitors  $N$  and the elasticity of

<sup>10</sup>Note that we assume that the levy rate is small enough such that the regulatory constraint is still binding [i.e.,  $\rho > r + (1 + r)\tau^e$ ]. Otherwise, banks would substitute equity for non-deposit liabilities in order to reduce the tax burden.

loan demand  $\varepsilon_L$  influence the magnitude of the effect. If there are few competitors and the loan demand is inelastic, the increase in the lending rate is *ceteris paribus* stronger because of market power in the sense that the balance sheet adjustment of one bank has a more pronounced impact on the equilibrium interest rate. Hence, bank concentration and an inelastic loan demand, which may reflect few alternative sources of funding and high switching costs for borrowers, reinforce the increase. Second, the capital structure, which is essentially given by capital regulation in this model, determines the exposure of a bank to a tax on liabilities. Whenever banks face tighter capital requirements, they are less affected by the levy such that the balance sheet adjustments and the increase in the lending rate are smaller. This effect is purely mechanical. Proposition 1 also implies that the lending rate increases more than proportionately, that is,  $\frac{\partial r_L}{\partial \tau} > 1$ , unless banks have an extremely high capital ratio. In contrast, deposits are insensitive to the levy, and depositors do not bear the tax burden because optimal borrowing balances the marginal costs of deposits and alternative funding sources such as money market or interbank funding. As long as both types of liabilities are subject to the levy, the relative marginal costs and the deposit choice are unaffected. In other terms, the levy uniformly imposed on total liabilities does not influence the fixed relation between deposit and money market rate. This is an implication of the separability of loans and deposits. Hence, any changes on the liability side<sup>11</sup> concern non-deposit liabilities with a fixed interest rate. As a result, the tax burden is borne by borrowers, who face higher lending rates, and inside shareholders, who earn a smaller surplus.<sup>12</sup> Money market lenders and outside shareholders, in contrast, do not bear the tax burden because their returns are fixed.

A typical profitability ratio that features prominently in the incidence literature and represents a main outcome variable in our empirical analysis is the net interest margin (NIM): It measures the lending spread and is defined as net interest revenue divided by average interest-bearing assets. In our framework, the NIM is

$$NIM = \frac{r_L l_i - r m_i - r_D d_i}{l_i} = r_L - r(1 + \tau^e)(1 - k) + \frac{(r - r_D)D}{L} \quad (10)$$

where the second equality uses the funding constraint and  $\frac{d_i}{l_i} = \frac{D}{L}$  in the symmetric equilibrium. The NIM depends on both the interest rates and the composition of the balance sheet. The partial derivative of (10) implies:

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<sup>11</sup>There are two counteracting effects: Banks may reduce their funds because of the smaller loan supply or increase them to pay the upfront tax.

<sup>12</sup>Since the bank owner has no private wealth, the return on (inside) equity is not defined. The decrease in their surplus follows from an Envelope argument:  $\frac{\partial(1-\phi_i)\pi_i}{\partial \tau} < 0$ .

**COROLLARY 1** *The bank levy raises the net interest margin:*

$$\frac{\partial NIM}{\partial \tau} = \frac{1-k}{(1-\tau)^2} \left[ \frac{1+r}{1-\frac{1}{N\varepsilon_L}} \left( 1 + \frac{r_D D}{r_L L} \frac{\varepsilon_L}{N\varepsilon_D} \right) - r \right] > 0 \quad (11)$$

*The effects of bank concentration and the capital structure on the pass-through can be of either sign.*

**Proof:** See Appendix 1.A.1.

The response of the net interest margin has three sources as one can see from (10): an increase in the lending rate, a decrease in loans, and a larger proportion of interbank and money market borrowing due to the upfront levy payment. Whereas the first two effects are positive, the third is negative; overall, the response is clearly positive. The sensitivities of the increase to bank competition and capitalization, however, remain ambiguous due to counteracting price and compositional effects.

So far, the focus has been on banks that borrow from the money market (i.e.,  $m_i \geq 0$ ). The equalization of marginal funding cost effectively fixes the deposit rate such that the burden is not passed onto depositors. This typically characterizes the response of loan-rich, deposit-poor banks in the sense that they rely on funds apart from deposits and equity to finance the initial expenditures. However, some banks are net lenders on the money market (i.e.,  $m_i < 0$ ); they have a richer asset structure but their liabilities consist of deposits only. There are two implications: First, the tax liability equals  $T_i = \tau d_i$  with partial derivatives  $T_L = 0$  and  $T_D = \tau$ . Second, capital requirements are charged on total assets now consisting of both customer and money market loans:  $e_i \geq k(l_i - m_i)$ . Hence, the bank's optimization problem is

$$\max_{l_i, d_i} [r_L - r]l_i + \left[ (r - \rho k) \frac{1-\tau}{1-k} - r_D - \tau \right] d_i \quad (12)$$

and the first-order conditions characterizing the symmetric equilibrium are:

$$\frac{r_L(L) - r}{r_L(L)} = \frac{1}{N\varepsilon_L} \quad (13)$$

$$\frac{(r - \rho k) \frac{1-\tau}{1-k} - [r_D(D) + \tau]}{r_D(D)} = \frac{1}{N\varepsilon_D} \quad (14)$$

Obviously, the lending rate is now fixed, and the levy only affects the deposit side. Note that the mark-down on deposits is determined by the effective return, which is the money market rate net of the required return on equity<sup>13</sup>, and the cost consisting of deposit rate and bank levy. Differentiating these two conditions establishes:

<sup>13</sup>An additional unit of deposits creates  $\frac{1-\tau}{1-k}$  units of assets.

**PROPOSITION 2** *Whenever banks are deposit-rich (i.e.,  $m_i < 0$ ), the levy is passed onto depositors as it lowers the deposit supply,  $\frac{\partial D}{\partial \tau} < 0$ , and the deposit rate:*

$$\frac{\partial r_D}{\partial \tau} = -\frac{1 + r - \frac{(\rho-r)k}{1-k}}{1 + \frac{1}{N\varepsilon_D}} < 0 \quad (15)$$

*The pass-through is weaker if the number of competitors is small and the deposit supply inelastic and if banks are strongly capitalized. The bank levy is not passed onto borrowers as it neither affects loans nor the lending rate,  $\frac{\partial L}{\partial \tau} = \frac{\partial r_L}{\partial \tau} = 0$ .*

**Proof:** See Appendix 1.A.1.

Compared to the first scenario, the results are reversed as the tax burden is now passed onto depositors instead of borrowers. Intuitively, banks choose loans and money market lending as to balance the marginal returns of both assets such that the lending rate is fixed. Since it is imposed on liabilities, the levy does not influence the relative returns of customer and money market loans. Deposits, in contrast, are raised until their marginal cost equal the marginal return earned on both assets. As the levy raises the cost, the deposit demand falls and leads to a lower interest rate. Its response is usually weaker than that of the lending rate in the first scenario provided that capital requirements are not too tight. This can be attributed to the relative stickiness of deposits, a phenomenon well documented in the empirical literature, for example, by Hannan and Berger (1991). The sensitivity is even weaker if banks face few competitors and an inelastic loan demand, which is a standard implication of the Monti-Klein model. In case banks are lenders on the money market, the tax burden is thus borne by depositors and by inside shareholders but borrowers and outside shareholders are unaffected. The analysis reveals two scenarios - shifting the burden to borrowers or depositors - depending on the balance sheet composition, that is, whether banks raise too small or too large an amount of deposits compared to loans. This distinction follows from the separability of loans and deposits: If banks did not borrow or lend on the money market, loans and deposits would be connected by the funding constraint such that the levy, by raising the funding cost, would eventually lead to an increase in the lending and a decrease in the deposit rate. As a result, the burden would be shifted to both sides. As soon as banks can also borrow and lend at a given rate on the money market, either the deposit or the lending rate is *de facto* fixed and insensitive to the levy. The prediction that only one side bears the tax burden is rather conservative. Which of these scenarios is realized is mainly an empirical question: Generally, the money and interbank markets clear on a worldwide scale such that there are markets with banks borrowing from others and markets with banks lending to others. Hence, the incidence may differ depending on whether the tax mainly affects deposit-poor or deposit-rich banks.

Since the levy, by construction, targets the risky part of bank funding like uninsured deposits or short-term debt, which may entail a funding benefit due to implicit guarantees, the first scenario with a richer set of liabilities appears more relevant. Most importantly, the main empirical findings are consistent with this scenario, and we find only weak evidence for a pass-through to depositors. One may also argue that deposit rates can hardly decrease in economies at the zero lower bound. For these reasons, a pass-through to borrowers is considered the main scenario, and the subsequent extensions focus on this case.

### 1.3.3 Extensions

We explore the robustness of the main scenario by adding two features: insured deposits that are exempt and risky loans.

#### Differential Tax Treatment of Deposits

Usually, deposits protected by a guarantee scheme are not taxed to avoid double taxation. This extension analyzes how the differential tax treatment of bank liabilities affects the incidence: Suppose there are two distinct markets for insured and uninsured deposits each with an inverse supply  $r_D^I(D^I)$  and  $r_D(D)$  respectively. The interest rates on insured and uninsured deposits differ; it is likely that the latter is *ceteris paribus* higher  $r_D > r_D^I$  at least if  $D \geq D^I$ . Without loss of generality, the deposit insurance premium is normalized to zero. The liabilities of a bank thus consist of insured and uninsured deposits and interbank borrowing; the funding constraint is  $l_i + T_i = d_i + d_i^I + m_i + e_i$ . The bank maximizes its owner's surplus and solves the optimization problem:

$$\max_{l_i, d_i, d_i^I} [r_L - r(1 - k) - \rho k]l_i + [r - r_D]d_i + [r - r_D^I]d_i^I - (1 + r)T_i \quad (16)$$

Profit equals the surplus earned on loans, uninsured and insured deposits minus the levy payment. Since insured deposits are exempt, taxable liabilities include uninsured deposits and money market borrowing giving  $T_i = \tau(m_i + d_i)$ . Using the funding constraint, the tax liability is  $T_i = \tau^e[(1 - k)l_i - d_i^I]$  with partial derivatives  $T_L = \tau^e(1 - k)$ ,  $T_{D^I} = -\tau^e$ , and  $T_D = 0$ . A bank can thus lower its tax burden by substituting insured deposits for money market and interbank funding. The conditions for the symmetric equilibrium are:

$$\frac{r_L(L) - [\rho k + r(1 - k) + (1 + r)(1 - k)\tau^e]}{r_L(L)} = \frac{1}{N\varepsilon_L} \quad (17)$$

$$\frac{r + (1 + r)\tau^e - r_D^I(D^I)}{r_D^I(D^I)} = \frac{1}{N\varepsilon_D^I} \quad (18)$$

$$\frac{r - r_D(D)}{r_D(D)} = \frac{1}{N\varepsilon_D} \quad (19)$$



Compared to the benchmark, the levy also affects insured deposits. The tax advantage creates an additional gain relative to other liabilities. If the elasticities of insured and uninsured deposits are equal, the bank is even willing to offer a higher interest rate on insured deposits.<sup>14</sup> Totally differentiating the first-order conditions yields:

**COROLLARY 2** *The bank levy raises the lending rate and leaves the interest rate on uninsured deposits unchanged as shown in proposition 1. It also increases insured deposits,  $\frac{\partial D^I}{\partial \tau} > 0$ , and the corresponding interest rate:*

$$\frac{\partial r_D^I}{\partial \tau} = \frac{(1+r)}{(1-\tau)^2 \left(1 + \frac{1}{N\varepsilon_D^I}\right)} > 0 \quad (20)$$

*The magnitude positively depends on bank competition but is independent of the capital structure. The bank levy increases the net interest margin provided that the levy rate and number of competitors are not too large and the supply of insured deposit is inelastic.*

**Proof:** Follows from differentiating (17) and (18). *Q.E.D.*

Whereas the impact on borrowers is unchanged, the differential taxation of liabilities establishes a direct link between the levy and insured deposits by making the latter less costly compared to other sources of funding. Since insured deposits are more attractive, banks may substitute them for liabilities that are fully taxed in order to reduce the tax burden. The higher demand for insured deposits, in turn, raises the corresponding interest rate thereby even benefiting depositors. The somewhat ambiguous response of the NIM is due to the higher interest rate on insured deposits; this effect is less pronounced in case of strong market power and low tax rates. Consequently, the main scenario also involves a higher interest rate on deposits that are exempt. Since we cannot distinguish between the interest rates on insured and uninsured deposits in the data and the latter remain insensitive to the levy, a slight increase in the average deposit rate is expected. Nevertheless, this substitution effect should be cautiously interpreted: The above formulation with two distinct markets and interest rates is restrictive and it is difficult for banks to actively influence the exact amount of insured (e.g., deposits below EUR 100'000) and uninsured deposits. Moreover, deposit rates are sticky as discussed above such that its response is less pronounced. The substitution effect of the levy, however, still results in case of a uniform deposit rate and a fixed share of insured deposits.

## Bank Risk

Since internalizing the fiscal costs of bank failure is the main objective of bank levies, we examine the incidence in a model variant with bank risk. To keep the analysis tractable and in line with

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<sup>14</sup>A positive insurance premium paid by banks may offset this effect.

the main scenario, we abstract from imperfect competition for deposits. More precisely, the deposit supply is elastic and characterized by  $r_D = r$  thereby ruling out any adjustment of the deposit rate. Thus, banks are indifferent about the liability structure as borrowing from depositors and money market lenders is equally costly, and the focus is on banks that only attract deposits (i.e.,  $m_i = 0$ ).

We follow Dermine (1986) who extends the Monti-Klein framework by a model of lending risk à la Jaffee and Modigliani (1969): Borrowers invest in risky projects with a stochastic gross return  $A$  distributed according to some continuous, differentiable distribution function  $F(A)$ . Hence, the loan is only repaid if the realized return exceeds the gross lending rate,  $A > 1 + r_L$ . Otherwise, the borrower defaults and the assets are transferred to the bank. Bank failure risk depends on the correlation of loans: As long as they are uncorrelated, the portfolio is perfectly diversified and the bank is safe. If there is some positive correlation, however, the bank may fail whenever too many of its loans perform poorly. As Dermine (1986), we focus on perfectly correlated returns, and the bank fails as soon as its assets fall short of its liabilities. The failure threshold  $A^*$  thus follows from  $A^*l_i = (1 + r)d_i$ , and the corresponding failure probability is  $F(A^*)$ . Since government guarantees are the main rationale for bank levies, we focus on the case where they are indeed present: Hence, depositors consider deposits risk-free and require no risk premium because they are compensated if the bank fails.

Compared to the benchmark, there is a modification of capital requirements: Although our setup with a single asset offers little scope for typical risk weights, one may alternatively define the latter as a function of the bank's own risk profile given by its failure probability:  $\alpha = \alpha[F(A^*)]$ . Hence, capital requirements are  $e_i \geq k\alpha l_i$  where  $\alpha l_i$  denote the risk-weighted assets. Importantly, the risk weight  $\alpha$  may increase in failure risk,  $\alpha'[F(A^*)] \geq 0$ , to ensure that riskier banks have more equity. This captures a potential interaction of the levy with risk-sensitive capital regulation. The bank solves

**PROGRAM 2** *A bank chooses loans  $l_i$ , deposits  $d_i$ , equity  $e_i$ , and the share promised to outside equityholders  $\phi_i$  to maximize the expected surplus of its owner*

$$\max_{l_i, d_i, e_i, \phi_i} (1 - \phi_i) \left[ (1 - F(1 + r_L))(1 + r_L)l_i + \int_{A^*}^{1+r_L} AdF(A)l_i - (1 - F(A^*))(1 + r)d_i \right] \quad (21)$$

*subject to investors' participation constraint  $\phi_i\pi_i \geq (1 + \rho)e_i$ , capital requirements  $e_i \geq k\alpha l_i$ , and the funding constraint  $l_i + T_i = d_i + e_i$ .*

Expected bank profits consist of the revenue from fully repaid loans (if  $A \geq 1 + r_L$ ) and the liquidation value of failed loans (if  $1 + r_L > A \geq A^*$ ) net of deposit repayment. The levy is imposed on deposits such that  $T_i = \tau d_i = \tau^e(1 - k\alpha)l_i$ . Based on the first-order conditions of

this problem, one can derive the lending decision

$$\frac{r_L(L) - \int_{A^*}^{1+r_L} F(A)dA - [\rho k\alpha + r(1 - k\alpha) + (1 + r)\tau^e(1 - k\alpha)]}{r_L(L)} = \frac{1 - F(1 + r_L)}{N\varepsilon_L} \quad (22)$$

which characterizes the symmetric Cournot-Nash equilibrium with  $l_i = l = \frac{L}{N}$ . Again, the Lerner index is inversely related to the interest rate elasticity of loan demand and the number of competitors. Note that the bank's cost include the loan losses if borrowers default, which are captured by the integral. Differentiating condition (22) yields:

**COROLLARY 3** *The bank levy lowers the loan supply,  $\frac{\partial L}{\partial \tau} < 0$ , and raises the lending rate*

$$\frac{\partial r_L}{\partial \tau} = \frac{(1 - k\alpha)(1 + r)[1 - F(A^*) + (1 + \rho)k\alpha']}{(1 - \tau)^2 [1 + (1 + r)(1 + \tau^e)k\alpha'] \left[ (1 - F) \left( 1 - \frac{1}{N\varepsilon_L} \right) + \frac{fr_L}{N\varepsilon_L} \right]} > 0 \quad (23)$$

where  $F = F(1 + r_L)$ ,  $f = f(1 + r_L)$ ,  $\alpha' = \alpha'[F(A^*)]f(A^*) > 0$ . The pass-through is usually stronger in concentrated markets. The levy raises the net interest margin.

**Proof:** See Appendix 1.A.1.

The main finding that banks shift part of the burden to borrowers also results in this extension. The levy raises the lending rate through its impact on the bank's funding cost: First, there is a direct effect as the levy makes borrowing more expensive like in the benchmark model. Second, it also mechanically raises the bank's failure threshold<sup>15</sup> such that the risk weight  $\alpha$  is higher and the funding cost increase as long as equity is expensive. The second effect may arise because of risk-sensitive capital requirements and reinforces the pass-through. However, it vanishes as soon as  $\alpha'[F(A^*)] = 0$ . The magnitude of the pass-through negatively depends on concentration but no clear conclusion about the impact of capital regulation can be drawn.

### 1.3.4 Predictions

The theoretical analysis yields two scenarios for the tax incidence: First, the levy leads to a higher lending rate and net interest margin. The key finding that the tax burden is partly shifted to borrowers persists in two extensions. Banks may also increase deposits in case a differential tax treatment induces them to shift funds from those fully taxed to deposits that are partly or fully exempt. This eventually raises the deposit rate. Since all countries that introduce a levy in the sample except for Sweden at least partly exempt deposits, such an effect seems likely. Moreover, the magnitude of the response depends on two factors: First, a low

<sup>15</sup>This arises because banks borrow more to pay the levy upfront. The effect would also result if the levy had to be paid *ex post* as it would constitute an additional liability at the end of the period.

degree of competition mainly reflected by a concentrated banking sector and small elasticities reinforces the increase in the lending rate but weakens a potential response of the deposit rate. This is a typical finding in the incidence literature as market power determines how the tax burden is shared. Second, banks' capital structure strongly influenced by regulation determines their exposure to the levy. Since the latter is charged on liabilities, a higher capital ratio mechanically reduces the tax burden and the response of the lending rate. The main predictions for this scenario are summarized in table 2. The alternative scenario where the burden is shifted to depositors with no impact on the lending side may emerge whenever the levy is introduced in markets with many deposit-rich banks that lend to other banks or money market borrowers. Since deposit rates are sticky especially in concentrated markets, however, the pass-through to depositors is expected to be rather weak.

	Lending Rate	Deposit Rate	Net Interest Margin
Levy	+	(+)	+
Concentration	↑	(↓)	ambiguous
Capital Ratio	↓	(none)	ambiguous

Table 2: *Main Scenario: Predictions*

This table summarizes the predictions about the levy's impact on interest rates and NIM and indicates whether bank concentration and a high capital ratio reinforce (↑) or weaken (↓) the effect.

Finally, one should be aware of the model's limitations and interpret its predictions cautiously: The model is static such that there is no gradual transition to a new equilibrium. In reality, the levy will mainly affect new loans and deposits as it is difficult to change existing contracts. In addition, Austria initially imposed the levy on past balance sheets such that the tax burden is, in principle, unrelated to a bank's current loans and deposits. In this case, the static model implies that the choices are unaffected thereby ruling out any adjustment. In a dynamic framework, banks could respond to lower their future tax burden. Moreover, capital requirements are binding such that no substitution of equity for debt takes place. This feature conflicts with Devereux et al. (2015), who find evidence that the levy induces banks to lower their leverage.

## 1.4 Empirical Evidence

This section provides empirical evidence about the incidence of bank levies. We conduct reduced-form tests based on the theoretical predictions, which is common in the related literature. We employ a panel dataset from Bankscope with balance sheet data of 2'987 EU banks between 2007 and 2013.<sup>16</sup>

<sup>16</sup>This *de facto* captures the (post-)crisis period 2008-13 as several bank-level variables are lagged.

### 1.4.1 Estimation Strategy

The empirical strategy closely follows Devereux et al. (2015), who use a similar dataset to estimate the impact of levies on banks' capital structure and risk taking.

#### Baseline Model

The baseline model captures the effect of the levy on an average bank. The main econometric specification is

$$y_{ijt} = \alpha_i + \gamma_t + \beta_1 Levy_{ijt} + \varphi X_{ijt} + \epsilon_{ijt} \quad (24)$$

where  $y_{ijt}$  and  $Levy_{ijt}$  are outcome and main explanatory variable respectively.  $\alpha_i$  and  $\gamma_t$  denote bank and time fixed effects and  $\mathbf{X}_{ijt}$  the vector of controls. Bank fixed effects absorb all time-constant heterogeneity, time fixed effects all common shocks.

We estimate the levy's impact on three different outcome variables: the interest income on loans as a share of average loans,  $ILL_{ijt}$ , the interest expenses on customer deposits as a share of average deposits  $IED_{ijt}$ , and the net interest margin,  $NIM_{ijt}$ . The first two variables measure the average interest rates paid by borrowers and to depositors and approximate lending and deposit rate that are not available in the data. For Euro area banks, it can be shown that they are of comparable magnitude and exhibit similar patterns than a broad array of bank interest rates on loans and deposits (see, figures 7 and 8 in Appendix 1.A.3). These two ratios are rather conservative measures for the incidence such that we may underestimate the real magnitude of the pass-through: In particular, they do not allow distinguishing between interest rates associated with old and new loans and deposits. Since the levy was difficult to anticipate, it mainly affects interest rates of new loans and deposits such that the impact on new customers is stronger than observed. In addition, the interest income on loans is affected by defaults such that the impact on good borrowers may in fact be more pronounced.<sup>17</sup> In line with the literature, we also include the net interest margin,  $NIM$ , defined as the ratio of net interest income to average interest-bearing assets; it captures the pass-through to customers by increasing the spread between lending and borrowing rates.

The main explanatory variable  $Levy_{ijt}$  is represented by three proxies that exploit three different sources of variation: First, only some EU countries introduced a bank levy; second, in some countries with a levy, not all banks are taxed due to an allowance (e.g., Germany, Austria, and the UK); third, banks face different marginal tax rates across and in case of a progressive tax schedule also within countries. First, we construct a dummy variable  $Levy1_{jt}$  that indicates whether a bank is located in a country that charges a levy in a certain year or not. This defines

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<sup>17</sup>This holds *a fortiori* if a higher lending rate as a result of the levy increases borrowers' risk taking and defaults in the sense of Stiglitz and Weiss (1981).

the levy at the country-year level and captures its effect on interest rates and margin of an average bank in such a country. However, this variable might be affected by other country-year level variations such as changes in corporate taxation or government interventions in the banking sector that need to be controlled for. Second, four countries exempt small banks by an allowance. Since we have no information about whether a particular bank is taxed or not, we approximate the taxable liabilities<sup>18</sup> of each bank using the information provided by Devereux et al. (2015). We create a dummy variable  $Levy2_{ijt}$  that equals one if both a levy is in place in the country and year and the taxable liabilities of a bank exceed the allowance threshold. Hence, this variable indicates whether a bank is effectively taxed. A similar measure is also applied by Buch et al. (2014). In countries that tax all banks,  $Levy1$  and  $Levy2$  coincide. Eventually, we calculate the marginal tax rate  $Levy3_{ijt}$  for each bank given its taxable liabilities. As suggested by Albertazzi and Gambacorta (2010), we also include the quadratic term  $Levy3^2$  to account for potential non-linearities. Overall, the bank-level proxies are more informative but they rely on rather rough approximations. The country-level levy variable is, in contrast, clearly measured thus providing a robustness check.

Since the bank-level variables  $Levy2$  and  $Levy3$  by construction depend on balance sheet characteristics, they should be considered endogenous. For instance, a withdrawal of funds affects both interest expenses and the exposure to the levy such that the explanatory variable is correlated with the error term. Or, banks with taxable liabilities around the allowance threshold might strategically lower their exposure to avoid the levy. We address this issue by instrumenting the two variables: Following Devereux et al. (2015) who apply a methodology developed by Gruber and Saez (2002) in the context of personal income taxation, we instrument the possibly endogenous variable with a measure that would have prevailed if the balance sheet was exactly the same after the levy was introduced. More precisely, we construct two bank-level instruments, a dummy variable that indicates whether the bank is taxed and the marginal levy rate, based on the balance sheet in the year prior to the levy's introduction.<sup>19</sup> This instrument is clearly exogenous and strongly correlated with the actual levy variable.<sup>20</sup> The first stage regressions are very strong and the usual F-statistic easily exceeds the value of ten.<sup>21</sup>

The vector of controls  $\mathbf{X}_{ijt}$  is motivated by the Monti-Klein model: At the bank level, we include the capital ratio  $Equity_{ijt}$  and the non-interest expenditures divided by total assets as a proxy for the cost structure,  $Cost_{ijt}$ . We also add the interbank rate  $Interbank_{jt}$ , the statutory corporate income tax rate  $CIT_{jt}$  that may affect bank lending due to the debt bias,

<sup>18</sup>For the calculation of the taxable liabilities, refer to Appendix 1.A.2.

<sup>19</sup>The instrument is based on 2010 balance sheets for Germany and the UK, and on 2011 balance sheets for the Netherlands. For Austria, the tax base is the 2010 balance sheet for the full sample period.

<sup>20</sup>The correlation coefficients 0.947 ( $Levy2$ ) and 0.976 ( $Levy3$ ) are significant at the 1% level.

<sup>21</sup>Since we specify clustered standard errors but the usual test statistic for weak instruments relies on i.i.d. errors, we use an F-Statistic based on the Kleinbergen-Paap  $rk$  statistic as suggested by Baum et al. (2007).

and a proxy for the number of banks, the Herfindahl-Hirschman index of bank concentration  $HHI_{jt}$ . Additional controls are chosen in line with the incidence literature: In particular, we add bank size measured by the log of total assets squared,  $Assets_{ijt}$ , which due to allowances and progressive tax rates determines a bank's exposure to the levy. Following Chiorazzo and Milani (2011), we rely on the quadratic values to avoid interfering with other variables defined in terms of total assets. Given the finding that the bank levy may increase asset risk, a concern is that observed higher interest rates may primarily reflect risk premia instead of a pass-through. However, the interest income on loans consists of interest received: Since lending to riskier borrowers is also associated with more defaults, the interest income on loans should not be affected *ex post* provided that the risk premia are accurate. Thus, a higher interest income on loans can indeed be interpreted a pass-through. Nevertheless, it is unlikely that both effects exactly offset each other, and a proxy for the risk of the loan portfolio is included: The average regulatory risk weight or the NPL ratio would be appropriate measures but they are available for a small subsample only. We instead rely on the loan loss provisions as a fraction of average loans,  $Provisions_{ijt}$ ; high values point to poor loan quality and high portfolio risk. To account for different macroeconomic conditions that affect loan demand, the real growth rate of GDP,  $Growth_{jt}$ , and inflation,  $Inflation_{jt}$ , are included. Since government interventions in the banking sector during and after the financial crisis partly overlap with the introduction of levies and influence bank behavior, the fiscal costs of bank recapitalization and asset relief as a share of GDP,  $Recap_{jt}$ , are included. All bank-level stock variables are lagged by one period to avoid simultaneity.

Model (24) is estimated using the fixed-effects (OLS or 2SLS) estimator. The main advantage is that this method controls for time-invariant, unobserved heterogeneity. In this context, one might think of the nature of the bank-borrower relationship: In case of a long-standing borrowing relation, the lending rate is *ceteris paribus* lower as monitoring entails a smaller cost but, at the same time, it facilitates shifting the burden because switching to another bank becomes very costly for a borrower (lock-in effect). The bank-borrower relationship, in turn, depends on the bank's general strategy, expertise, and reputation, which is usually constant in the short- and medium-term. Compared to the difference-in-difference methodology applied in the country studies by Buch et al. (2014) and Capelle-Blancard and Havrylchyk (2013), the fixed-effects estimator is more suitable for cross-country data because the levy was introduced at different points in time and different tax rates captured by the measure  $Levy3$  apply. The key identifying assumption is strict exogeneity, which requires that the independent variables - especially the main explanatory variable - are uncorrelated with past, present, and future values of the time-varying errors  $\varepsilon_{ijt}$ . Apart from the possible endogeneity of the bank-level levy variables that is addressed by using instruments, a concern is that banks might have

anticipated the levy and already adjusted their balance sheets in advance in order to lower or even avoid paying this tax. Such an adjustment before the introduction would be part of the error term that is thus correlated with post-introduction values of the levy variable thereby violating strict exogeneity. However, the levy was introduced on short notice and at the same time in many countries (see, section 1.2). For Germany, Buch et al. (2014) argue that there was substantial uncertainty about the levy's design thereby making it difficult for banks to anticipate their precise exposure. Although anticipation is unlikely especially in countries that introduced the levy in 2011 or earlier, we address this concern as a robustness check using a subsample without banks in countries that introduced the levy after 2011. Another concern is that countries strongly affected by the financial crisis were more likely to adopt a bank levy such that increases in lending rates are mainly driven by stronger deleveraging in those countries. Although there is no levy in Ireland and Spain that experienced the worst banking crises in the EU, this concern is taken into account by controlling for the cost of government intervention in the banking sector and by several robustness checks that account for country-specific shocks.

### Heterogeneity in Responses

The theoretical analysis implies that the magnitude of the pass-through differs in the degree of bank competition and the capital structure. We thus extend the baseline specification and add two interaction terms

$$y_{ijt} = \alpha_i + \gamma_t + \beta_1 Levy_{ijt} + \beta_2 Levy_{ijt} * BC_{ijt} + \varphi X_{ijt} + \epsilon_{ijt} \quad (25)$$

$$y_{ijt} = \alpha_i + \gamma_t + \beta_1 Levy_{ijt} + \beta_2 Levy_{ijt} * CAP_{ijt} + \varphi X_{ijt} + \epsilon_{ijt} \quad (26)$$

where  $BC_{ijt}$  and  $CAP_{ijt}$  denote competition and capitalization measures respectively. Regarding competition, theory highlights the importance of the number of competitors and the interest rate elasticity: Thus, we include the Herfindahl-Hirschman index that is a popular measure of bank concentration; it equals the sum of bank market shares squared. We rely on the HHI based on assets of the entire banking industry in a country provided by the ECB. Furthermore, we add the branch density, that is, the number of bank branches per 10'000 inhabitants: On the one hand, this represents an alternative concentration measure, on the other hand, it can be interpreted as a proxy for the switching cost and thus for the corresponding elasticity.<sup>22</sup>

Similarly, to account for the effect of the capital structure on the incidence, we interact the levy variable with the bank's capital ratio (equity/total assets) and its regulatory capital ratio (regulatory capital/risk-weighted assets). All competition and capitalization variables are based

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<sup>22</sup>Another way to account for differences in elasticities is distinguishing between new and outstanding loans as in Capelle-Blancard and Havrylchuk (2013), which would require individual loan data.



on 2009 values, the year before the bank levy was adopted for the first time.<sup>23</sup> They are thus exogenous to any later changes in capital structure and bank concentration induced by the levy.

## 1.4.2 Data and Measurement

We employ an unbalanced panel dataset that includes bank-level information of (at most) 2'987 banks from 23 European countries between 2007 and 2013. All countries that were members of the EU for the full period except for France, Hungary, Slovenia, and Finland, which adopted a conceptually different levy, are included. The sample consists of 18'747 bank-year observations. Four different types of banks are represented: commercial banks (18.6% of all bank-year observations), savings banks (24.1%), cooperative banks (53.5%), and real estate and mortgage banks (3.8%). The sample covers approximately 44 percent of all banks in the 23 countries (see, table 17 in Appendix 1.A.3). German and Italian banks are overrepresented accounting for 55% (18%) of sample versus 28% (11%) of existing banks in 2010. This issue is addressed as a robustness test, and most results do not appear to be driven by the behavior of banks from Germany or Italy.

A list of variables, their definitions and sources is provided in Appendix 1.A.2. The main source is *Bankscope*, a database provided by the Bureau van Dijk that contains information on balance sheets and income statements of banks based on their annual reports. Since taxes are levied on single entity accounts, we rely on unconsolidated financial statements. This removes the problem that multinational banks may face levies in several countries as we have separate data for the parent bank and its foreign subsidiaries.<sup>24</sup> Detailed information about bank levies is taken from Devereux et al. (2015), who provide hand-collected data about the levy's design (tax base, allowance, tax rates) in all countries. Macroeconomic data (real growth and inflation rates) are from Eurostat and bank sector characteristics from the ECB Banking Structures Report. Data on interbank rates are from the OECD financial statistics or from national central banks<sup>25</sup>. Some adjustments of the sample were made: First, observations with closing date between April and September are excluded because they cannot be clearly attributed to a specific year; observations with closing date between January and March are attributed to the previous and observations with closing date between October and December to the current year. Second, all observations in a currency other than Euro are transformed into Euro. Third, inactive banks as well as banks with negative assets or equity are deleted.<sup>26</sup>

<sup>23</sup>The main effect is absorbed by the fixed effect. The contemporaneous effect is captured by the covariates *HHI* and *Equity*; if the branch density is used in (25), we also replace the control variable *HHI*.

<sup>24</sup>Foreign branches subject to a levy are included in the unconsolidated data of the domestic bank.

<sup>25</sup>Information from central banks for Bulgaria, Cyprus, Latvia, Lithuania, Malta, and Romania

<sup>26</sup>This might give rise to the survivorship bias if banks exit because they cannot pass through the levy. However, this is highly unlikely in the short run as most countries introduced the levy not earlier than 2011 and the sample includes just two follow-up periods.

Fourth, some variables are ratios typically expressed in terms of bank assets, loans, or deposits. They may take extreme values if, for example, the assets are very small or misreported. We reduce the influence of such outliers by winsorizing all bank-level ratios and growth rates at the 2.5 and 97.5 level. The main findings also result for different winsorization levels.

The bank-level levy measures<sup>27</sup> are constructed based on the approximation of banks' taxable liabilities in those four countries that exempt small banks or apply a progressive tax rate: Austria, Germany, the Netherlands, and the UK. The taxable liabilities are approximated and usually equal the balance sheet total net of equity and insured deposits; in Germany, all customer deposits are exempt. Insured deposits are, in turn, calculated by multiplying a bank's customer deposits by the coverage ratio (i.e., the volume share of insured in total deposits); this measure is provided by the EU Commission. The bank-level proxy *Levy2* equals one if the current-year taxable liabilities exceed the allowance threshold and a levy is charged. The variable *Levy3* equals the marginal tax rate based on the taxable liabilities; if short- and long-term liabilities are taxed at different rates, a simple average is used. For Austria, the levy variable is determined according to the 2010 balance sheet for the entire period. The Netherlands and the United Kingdom tax the consolidated balance sheet: For the two countries, we thus restrict the sample to banks for which both consolidated and unconsolidated data are available. The variables *Levy2* and *Levy3* are determined based on its consolidated balance sheet but the subsequent analysis of the incidence relies on unconsolidated data.

The summary statistics are provided in table 18 in Appendix 1.A.3 for the full sample (column 1) and for different groups of banks depending on their exposure to the levy (columns 2-5). Total assets of the average bank amount to EUR 5.49bn, 8.7 percent of which are funded by equity. In general, banks located in levy countries are smaller and funded by a lower share of equity (7.83% vs. 10.72%). Banks that are effectively taxed are, however, considerably larger (total assets of EUR 13.38bn vs. EUR 3.4bn) and have a lower capital ratio (7.96% vs. 8.9%). This is due to the fact that small banks are often exempt and that equity is not taxed.

	Banks in Levy Country		Banks Subject to Levy		Total Banks
	Fraction	Banks	Fraction	Banks	
2010	2.68	76	2.68	76	2836
2011	68.29	2017	18.81	542	2911
2012	70.75	2054	19.66	565	2903
2013	68.20	1398	23.09	469	2050

Table 3: *Banks Subject to Levy*

The first two columns refer to banks in a country that charges a bank levy (i.e., *Levy1* = 1); the next two columns refer to banks that are effectively taxed (i.e., *Levy2* = 1).

In general, roughly 70 percent of banks in the sample are located in 11 out of 23 countries

<sup>27</sup>The detailed construction of the tax base is explained in Appendix 1.A.2.

that adopt the bank levy during the observation period (see table 17 in Appendix 1.A.3). The distribution of banks depending on their tax exposure is summarized in table 3: In 2010, the levy was first effective in Sweden<sup>28</sup> and applied to all banks such that 76 out of 2'836 banks in the sample were taxed. In 2011, the share of banks in countries that charge a levy substantially increased to 68 percent as seven countries including Germany and the United Kingdom introduced such a tax. However, only 19 percent of banks faced a positive tax rate as many small banks were exempt. These shares slightly increased in 2012 when three additional countries adopted a levy. On average, a bank that is taxed faces a marginal levy rate of 0.0345 percent; the range is between 0.018 percent in Sweden (2010) and 0.4 percent in Slovakia.

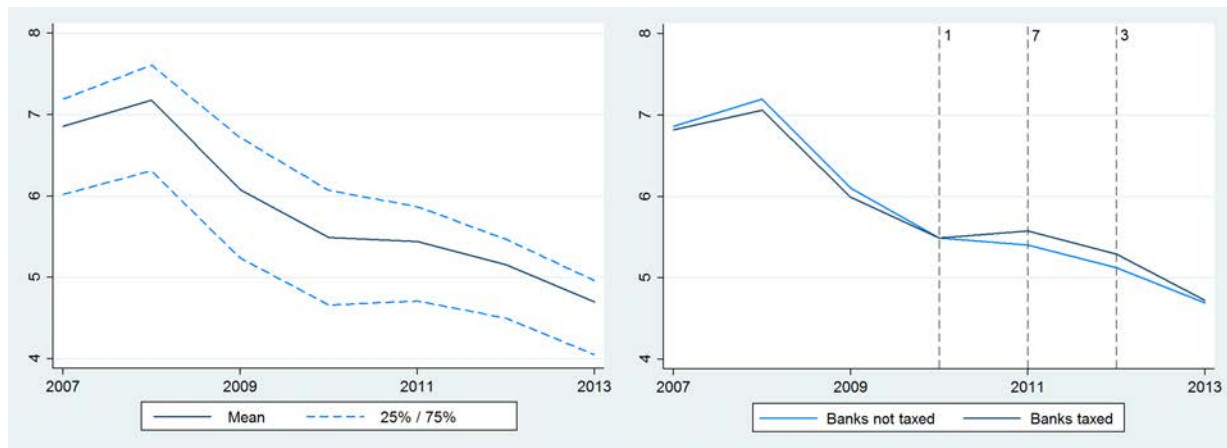
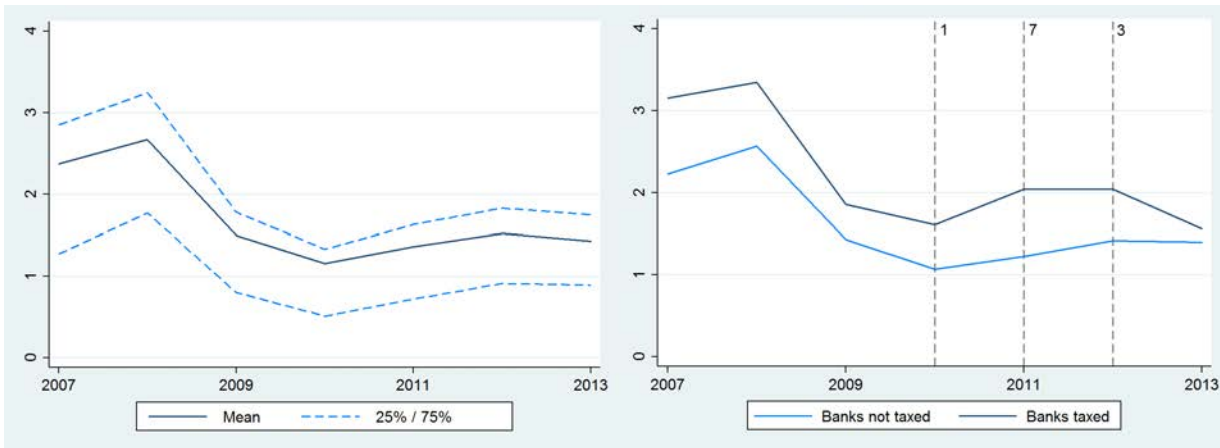


Figure 1: *Interest Income on Loans*

The left panel illustrates the mean interest income on loans as well as the upper and lower quartile. The right panel shows the mean interest income of banks that become subject to a levy (i.e.,  $Levy_2 = 1$ ) during the sample period and for those that do not. The dashed vertical lines indicate the introduction of the levy in 2010 (one country), 2011 (7 countries), and 2012 (3 countries).

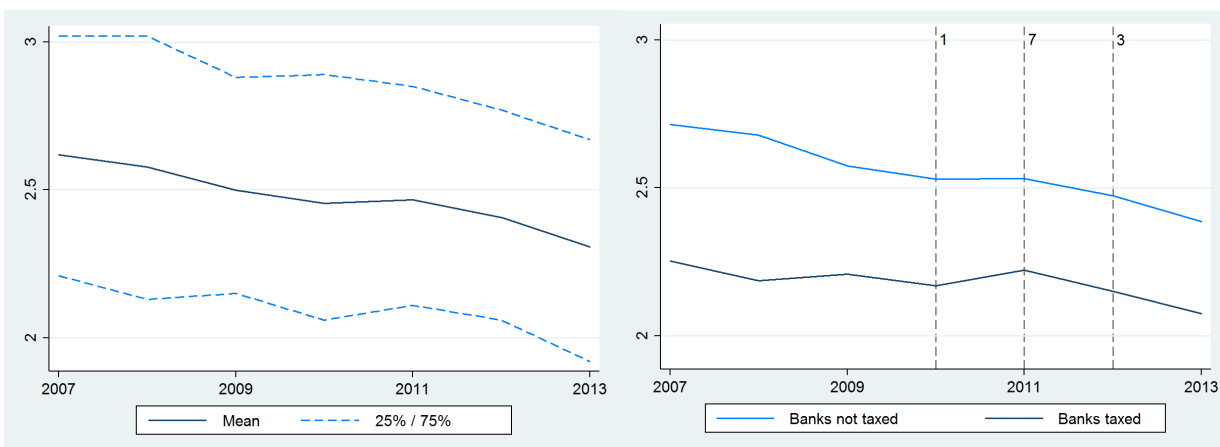
On average, banks earn an interest income on loans of 5.85 percent of loans; those in countries that adopt the levy at one point in time show higher values (6.03%) than those in countries without (5.43%). Figure 1 shows the mean interest income as well as the lower and upper quartile of the distribution (left panel): It steadily decreased from an average value of more than 7 percent in 2008 to less than 5 percent in 2013. This pattern reflects the general decline of interest rates given the expansionary monetary policy and low growth and inflation. The right panel illustrates the mean interest income on loans depending on whether a bank becomes subject to the levy at one point during the observation period or not. Before the levy was adopted for the first time, the interest income of both groups follows a similar pattern. In 2011 when seven countries introduce a levy, the interest income on loans of banks subject to the tax slightly increases, while that of unaffected decreases.

<sup>28</sup>Officially, it was enacted in October 2009 and formally introduced on 30 December such that the first payment was already due in 2009 (see, table 1). Following Devereux et al. (2015), banks are considered unaffected by the levy in 2009 because many had already drawn up their balance sheet when the levy was enacted.

Figure 2: *Interest Expenses on Deposits*

The left panel illustrates the mean interest expenses on customer deposits as well as the upper and lower quartile. The right panel shows the mean interest expenses of banks that become subject to a levy (i.e.,  $Levy2 = 1$ ) during the sample period and for those that do not. The dashed vertical lines indicate the introduction years.

The interest expenses on customer deposits are on average 1.69 percent of deposits; they are higher for banks located in countries adopting a levy (2.19% vs. 1.56%) and for those effectively taxed (2.16% vs. 1.60%). Figure 2 (left panel) shows a decline of interest expenses during the sample period. From 2010 on, they remained rather stable. The right panel illustrates the mean interest expenses depending on the levy exposure. Again, one can observe that in the most relevant introduction year 2011, the interest expenses of affected increase more strongly than those of unaffected banks. Note that data on interest expenses on deposits are available only for a subsample of roughly 1'000 banks where, contrary to the full sample, Italian banks are over- and German underrepresented.

Figure 3: *Net Interest Margin*

The left panel illustrates the mean net interest margin as well as the upper and lower quartile. The right panel shows the mean net interest margin of banks that become subject to a levy (i.e.,  $Levy2 = 1$ ) during the sample period and for those that do not. The dashed vertical lines indicate the introduction years.

The third outcome variable, the net interest margin, reaches an average of 2.48 percent. It is lower for banks in countries that adopt the levy (2.41% vs. 2.64%) and that are effectively

taxed (2.18% vs. 2.56%). Compared to the interest rates, the NIM only slightly declined. The right panel shows the mean net interest margin depending on whether banks become subject to the levy at one point in time or not: For the former, it slightly increases in 2011 when the levy was introduced in seven countries, whereas the NIM of unaffected banks remains constant. Subsequently, the NIM of taxed banks does not decline more strongly.

Overall, the descriptive evidence indicates that the interest rates and margins of banks that became subject to the levy slightly increased around its introduction (especially in 2011). This hints at the positive responses implied by theory.

### 1.4.3 Main Results

This section summarizes the main results, namely, the estimates of the baseline model and of the heterogeneous response models.

#### Baseline Model

Table 4 reports the coefficient estimates of the baseline regression (24). For each of the three outcome variables, we run five regressions, using country- and bank-level levy dummies, *Levy1* and *Levy2*, as well as the marginal tax rate *Levy3*. When relying on the bank-level levy variables, both the OLS and the IV (2SLS) estimates are reported.

First, the interest income on loans increases as soon as a bank is indeed affected by the levy, while the country-level variable *Levy1* remains insignificant: The coefficient of the bank-level dummy *Levy2* is positive and significant, it implies an increase in the average lending rate between 0.2 and 0.24 percentage points. The coefficients of the marginal levy rate, *Levy3*, indicate a positive and non-linear relation: The total effect of introducing a marginal tax rate  $Levy3 = \tau$  is  $\beta_1\tau + \beta'_1\tau^2$ . Taxed banks on average face a marginal levy rate of 0.0345 percent such that the interest income on loans is between 0.19 and 0.31 percentage points higher. In a more extreme case of a 0.06 percent marginal levy rate corresponding to the top levy rate in Germany, the interest income even increases between 0.33 and 0.51 percentage points. Apart from this case, the estimates are rather small given a mean interest income of 5.85 percent.

Moreover, the results suggest that the levy increases the bank's interest expenses on customer deposits. In line with theory, this points to a substitution effect that arises because deposits are largely exempt from the levy such that depositors even benefit. Given mean interest expenses on deposits of 1.69 percent, the effect is not negligible: A bank located in a country with a levy pays a 0.19 percentage points higher interest rate on deposits. For banks effectively taxed (columns 7-8), slightly lower increases are observed. The coefficients for the marginal levy rate, in contrast, remain insignificant. Recall that this outcome variable is only available for a subsample such that the estimates need to be interpreted with some caution.

	Interest Income on Loans				Interest Expenses on Deposits				Net Interest Margin						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Levy1	0.0417 (0.0620)					0.1927** (0.0749)					0.1531*** (0.0210)				
Levy2		0.1957*** (0.0348)	0.2407*** (0.0405)	5.9058*** (1.5166)	9.4214*** (2.0607)		0.1550* (0.0826)	0.1812** (0.0864)	2.6840 (2.0502)	2.8793 (2.5841)		0.0394** (0.0156)	0.0498*** (0.0178)	1.3401* (0.7069)	2.1606** (0.8590)
Levy3				-7.4635 (5.5869)	-15.9897** (6.6287)				-7.3457 (4.9661)	-7.8063 (6.2881)				-2.6055 (1.8162)	-4.5766** (2.1829)
Assets	-0.0099 (0.0095)	-0.0104 (0.0095)	-0.0105 (0.0095)	-0.0102 (0.0094)	-0.0104 (0.0094)	0.0221** (0.0101)	0.0220** (0.0102)	0.0217** (0.0102)	0.0228** (0.0100)	0.0227** (0.0101)	-0.0100** (0.0030)	-0.0099** (0.0029)	-0.0099** (0.0029)	-0.0099** (0.0029)	-0.0099** (0.0029)
Equity	-0.0287* (0.0162)	-0.0297** (0.0151)	-0.0304** (0.0151)	-0.0296** (0.0142)	-0.0305** (0.0142)	0.0163 (0.0104)	0.0171* (0.0103)	0.0167 (0.0103)	0.0187* (0.0103)	0.0187* (0.0103)	0.0180** (0.0051)	0.0232*** (0.0048)	0.0230*** (0.0048)	0.0234*** (0.0048)	0.0231*** (0.0048)
Cost	0.0955** (0.0415)	0.0931** (0.0418)	0.0933** (0.0419)	0.0943** (0.0418)	0.0943** (0.0419)	-0.0769*** (0.0251)	-0.0752*** (0.0250)	-0.0749*** (0.0250)	-0.0763*** (0.0250)	-0.0762*** (0.0250)	0.1434*** (0.0197)	0.1375*** (0.0196)	0.1380*** (0.0195)	0.1374*** (0.0196)	0.1377*** (0.0196)
Provisions	0.0228 (0.0259)	0.0244 (0.0258)	0.0252 (0.0259)	0.0226 (0.0258)	0.0237 (0.0259)	0.1090*** (0.0261)	0.1075*** (0.0261)	0.1078*** (0.0261)	0.1053*** (0.0260)	0.1053*** (0.0261)	-0.0624*** (0.0115)	-0.0678*** (0.0114)	-0.0676*** (0.0114)	-0.0680*** (0.0114)	-0.0676*** (0.0114)
Inflation	-0.0783*** (0.0213)	-0.0739*** (0.0209)	-0.0728*** (0.0209)	-0.0699*** (0.0207)	-0.0656*** (0.0207)	-0.0020 (0.0210)	-0.0015 (0.0212)	-0.0011 (0.0212)	0.0006 (0.0221)	0.0009 (0.0224)	0.0450*** (0.0099)	0.0541*** (0.0099)	0.0544*** (0.0099)	0.0547*** (0.0100)	0.0557*** (0.0100)
Growth	-0.0338** (0.0137)	-0.0401*** (0.0126)	-0.0420*** (0.0126)	-0.0404*** (0.0126)	-0.0446*** (0.0125)	-0.1175*** (0.0124)	-0.1156*** (0.0126)	-0.1168*** (0.0127)	-0.1119*** (0.0123)	-0.1122*** (0.0126)	0.0067 (0.0057)	0.0151*** (0.0051)	0.0148*** (0.0051)	0.0151*** (0.0051)	0.0143*** (0.0051)
Interbank	0.3191*** (0.0378)	0.3105*** (0.0362)	0.3074*** (0.0360)	0.3231*** (0.0360)	0.3246*** (0.0358)	0.2549*** (0.0317)	0.2535*** (0.0325)	0.2520*** (0.0323)	0.2651*** (0.0315)	0.2652*** (0.0313)	0.0596*** (0.0219)	0.0736*** (0.0225)	0.0730*** (0.0224)	0.0764*** (0.0223)	0.0767*** (0.0221)
CIT	-0.0029 (0.0180)	-0.0049 (0.0172)	-0.0062 (0.0172)	-0.0346** (0.0168)	-0.0477*** (0.0163)	0.0769*** (0.0130)	0.0686*** (0.0135)	0.0678*** (0.0136)	0.0652*** (0.0162)	0.0644*** (0.0164)	-0.0163* (0.0095)	-0.0101 (0.0094)	-0.0102 (0.0094)	-0.0150 (0.0097)	-0.0179* (0.0094)
Recap	0.1191*** (0.0261)	0.1155*** (0.0220)	0.1156*** (0.0220)	0.1099*** (0.0213)	0.1086*** (0.0213)	0.0301** (0.0134)	0.0271** (0.0132)	0.0271** (0.0132)	0.0264** (0.0132)	0.0264** (0.0132)	0.0205*** (0.0048)	0.0083** (0.0038)	0.0078** (0.0038)	0.0075** (0.0038)	0.0067** (0.0038)
HHI	13.8475*** (2.7859)	16.0865*** (2.6545)	16.6674*** (2.6924)	17.5240*** (2.6957)	19.2472*** (2.8293)	6.4982** (3.2102)	6.0633* (3.2938)	6.4934* (3.3513)	4.6173 (3.0765)	4.7161 (3.1758)	5.2519*** (1.0958)	4.6352*** (1.0328)	4.7557*** (1.0406)	4.7932*** (1.0914)	5.1130*** (1.1146)
Obs.	13586	13575	13522	13575	13522	4765	4763	4763	4763	4763	15215	15191	15135	15191	15135
No. banks	2550	2549	2524	2549	2524	921	921	921	921	921	2837	2837	2811	2837	2811
R <sup>2</sup>	0.6381	0.6400	0.6398	0.6407	0.6402	0.5869	0.5858	0.5858	0.5855	0.5855	0.1345	0.1268	0.1275	0.1269	0.1274
Method	OLS	OLS	IV	OLS	IV	OLS	OLS	IV	OLS	IV	OLS	OLS	IV	OLS	IV
Bank FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Table 4: *Baseline Regressions*

Dependent variable: interest income on loans/av. loans in (1) - (5); interest expenses on customer deposits/av. customer deposits in (5) - (10); net interest margin in (11) - (15); standard errors clustered at the bank level in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

All estimations are performed in Stata using the `xtivreg2` module.

Eventually, the effects on the net interest margin (NIM) shown in columns (11) - (15) are positive and significant: When using the country-level proxy *Levy1*, one finds that the NIM of banks located in a country that adopts a levy increases by 0.15 percentage points. The coefficient of *Levy2* also implies a positive but smaller increase between 0.04 and 0.05 percentage points. The coefficients for the marginal levy rate have opposite signs pointing to a concave relation: The NIM of banks facing the mean marginal levy rate is between 0.04 and 0.07 percentage points higher; a levy rate of 0.06 percent implies an increase between 0.07 and 0.11 percentage points. Compared to an average NIM of 2.48 percent, the effects imply an increase between two and six percent and their economic significance should not be overstated. The NIM is clearly less sensitive to the bank levy than the interest rates, which may be explained by the higher deposit rate that weakens the increase in the lending spread and by the fact that it also includes interest rates on other assets and liability categories.

Overall, one concludes that the tax burden is indeed passed onto borrowers and raises the lending spread, while depositors may even benefit from higher interest rates. The quantitative effects are moderate especially for the lending rate and the net interest margin. One could partly attribute this to the fact that the outcome variables are averages and thus measure the incidence in a rather conservative way. The estimates are broadly consistent with the literature: The positive effect on deposit rates is in line with Buch et al. (2014). For the Hungarian bank levy, Capelle-Blancard and Havrylchyk (2013) find positive but stronger effects on lending rate and net interest margin: They estimate increases in the interest rate on housing loans between 0.57 and 1.08 percentage points and in the net interest and fee margin of 0.84 percentage points. However, the levy in Hungary is imposed on a broader tax base and involves higher tax rates, and the effect is estimated for borrowers with outstanding loans such that their demand is likely inelastic. Regarding the incidence of the corporate income tax, Albertazzi and Gambacorta (2010) estimate that a 10 percentage points decrease in the tax rate lowers the pre-tax profit as a share of total assets by 9.4 percent, which is stronger than our estimated response of the NIM (the most closely related outcome) of at most six percent. Compared to tighter capital regulation, the levy's impact on the NIM is not stronger than a one percentage point increase in capital requirements, which is associated with a 0.14 percentage points higher lending spread in the Euro area (Slovik and Cournède, 2011).

These findings - the levy increases lending and deposit rate - are fully consistent with the main scenario of the Monti-Klein model. Recall that two scenarios may materialize depending on whether banks are deposit-poor or deposit-rich in the sense that they are (net) borrowers or lenders on the interbank and money markets. We explore this aspect based on banks' loan-to-deposit ratio<sup>29</sup>: High values suggest that a bank is loan-rich and deposit-poor and needs

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<sup>29</sup>Using the bank's funding constraint, one can express the condition for the main scenario,  $m_i > 0$ , in terms

to finance its loans partly by non-deposit liabilities, whereas a low ratio implies that part of a bank's deposits finance substantial asset holdings apart from loans. Hence, the sample is split into two subsamples of banks with a loan-to-deposit ratio above the 70th (103.76%) and below the 30th percentile (71.07%). The results are not very sensitive to these cutoffs; one obtains similar results by splitting the sample at the median, for example. Based on the 2009 distribution, the cutoffs are exogenous to later changes induced by the levy.

	Interest Income on Loans			Interest Expenses on Deposits		
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit-poor banks (Loans/Deposits > 70th percentile)						
Levy1	0.2168*** (0.0662)			0.2927*** (0.1131)		
Levy2		0.1711** (0.0709)			0.3528*** (0.1126)	
Levy3			4.9983 (3.0827)			8.8688*** (2.9911)
Levy3 <sup>2</sup>			-1.4465 (12.4713)			-22.5581*** (7.2546)
Obs.	4541	4478	4478	3026	3025	3025
No. banks	900	874	874	589	589	589
R <sup>2</sup>	0.6628	0.6627	0.6649	0.5975	0.5981	0.5967
Deposit-rich banks (Loans/Deposits < 30th percentile)						
Levy1	-0.0247 (0.1544)			-0.0799 (0.1650)		
Levy2		0.0958 (0.0888)			-0.0728 (0.1978)	
Levy3			4.2737 (4.5410)			-7.9566* (4.5582)
Levy3 <sup>2</sup>			-3.1682 (10.8536)			19.9430* (11.0505)
Obs.	3705	3705	3705	590	590	590
No. banks	685	685	685	117	117	117
R <sup>2</sup>	0.6415	0.6415	0.6419	0.5324	0.5329	0.5338
Method	OLS	IV	IV	OLS	IV	IV
Bank FE, Controls	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES

Table 5: *Main vs. Alternative Scenario*

Dependent variable: interest income on loans/av. loans in (1) - (3); interest expenses on customer deposits/av. customer deposits in (4) - (6); clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 5 reports the coefficients of interest. In line with theory, there are striking differences between deposit-poor and deposit-rich banks: The estimates for the former shown in the upper section imply increases in the average lending and deposit rate. Similar to the results for the full sample, this mirrors the main scenario with differential taxation of deposits. In contrast, there is little evidence for higher lending rates of deposit-rich banks: Instead, they tend to lower the deposit rate although the effect is significant in one specification only. The differential responses depending on the loan-to-deposit ratio can be rationalized by the two scenarios implied by the model. Essentially, the behavior of loan-rich, deposit-poor banks appears to drive the results for the full sample, while the response of deposit-rich banks - shifting the burden to depositors - is at most weak.

of a minimum loan-to-deposit ratio:  $l_i/d_i > (1 - \tau)/(1 - k)$ .



## Heterogeneity in Responses

A key theoretical prediction is that the magnitude of the pass-through depends on bank competition, more precisely, concentration, and capitalization. Table 6 reports the coefficients for regression (25) with interactions term of the levy variable and Herfindahl-Hirschman index and branch density respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Interest Income on Loans						
Levy1	-0.2123** (0.0863)			0.6912*** (0.1506)		
Levy2		0.0030 (0.0680)			0.6836*** (0.1536)	
Levy3			4.8959* (2.7160)			14.8380*** (3.2594)
Levy3 <sup>2</sup>			-30.9939** (13.1133)			-22.5297*** (7.4797)
Levy*BC	8.0159*** (1.5532)	6.4934*** (1.5872)	82.8444 (51.1973)	-0.1492*** (0.0340)	-0.1112*** (0.0331)	-1.4246*** (0.3887)
Obs.	13586	13522	13522	13557	13495	13495
No. banks	2550	2524	2524	2548	2522	2522
R <sup>2</sup>	0.6415	0.6419	0.6402	0.6395	0.6395	0.6383
Interest Expenses on Deposits						
Levy1	0.4025*** (0.1303)			0.3771*** (0.0987)		
Levy2		0.4497** (0.2045)			0.3714*** (0.1097)	
Levy3			24.5843** (11.1169)			9.2633*** (3.1188)
Levy3 <sup>2</sup>			16.0335 (12.9625)			-17.8560*** (6.2641)
Levy*BC	-2.6003* (1.4930)	-3.0091 (2.1282)	-245.7498** (121.8664)	-0.0780*** (0.0210)	-0.0760*** (0.0215)	-1.1786*** (0.3017)
Obs.	4765	4763	4763	4739	4739	4739
No. banks	921	921	921	919	919	919
Net Interest Margin						
Levy1	0.2054*** (0.0246)			-0.0645 (0.0625)		
Levy2		0.0638*** (0.0221)			-0.2743*** (0.0682)	
Levy3			1.5221* (0.8263)			-1.7394 (1.5695)
Levy3 <sup>2</sup>			-6.7927 (5.0575)			1.7174 (2.7814)
Levy*BC	-1.4839*** (0.5300)	-0.3431 (0.5743)	12.0325 (18.7406)	0.0415*** (0.0129)	0.0668*** (0.0148)	0.4839* (0.2535)
Obs.	15215	15135	15135	15186	15108	15108
No. banks	2837	2811	2811	2835	2809	2809
R <sup>2</sup>	0.1359	0.1275	0.1273	0.1330	0.1300	0.1282
BC		HHI		Branch Density		
Method	OLS	IV	IV	OLS	IV	IV
Bank FE, Controls	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES

Table 6: *Heterogeneous Responses: Bank Competition*

The levy variables are interacted with the HHI in (1) - (3) and with the branch density in (4) - (6); clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

The upper section summarizes the results for the interest income on loans: As expected, the interaction terms of the levy and concentration variables are positive and significant in two out of three cases if the HHI is used (columns 1-3) and negative and significant if the branch density is used (columns 4-6). The average lending rate thus increases more strongly in concentrated

banking markets. For a quantitative interpretation, one needs to compute the combined effect, which is  $\beta_1 + \beta_2 * BC$  whenever the levy is represented by a dummy variable and  $\tau * [\beta_1 + \beta_1' * \tau + \beta_2 * BC]$  whenever the marginal tax rate  $Levy3 = \tau$  is applied. Table 7 summarizes the levy's impact on interest income on loans depending on market concentration for three different scenarios: the bank is located in a country that charges a levy (i.e.,  $Levy1 = 1$ , column 1), the bank faces a positive marginal tax rate (i.e.,  $Levy2 = 1$ , column 2), and the bank faces a marginal tax rate of 0.06 percent corresponding to the top marginal tax rate in Germany (i.e.,  $Levy3 = 0.06$ , column 3). Since we explore cross-country heterogeneity, it is appropriate to focus on a simple, country-level distribution of HHI and branch density.<sup>30</sup> Accordingly, we show the effects for banks in countries with bank concentration at the 25th, 50th, and 75th percentile. The effect for the weighted sample median (Germany) is also reported.

			(1)	(2)	(3)
<i>HHI</i>	25th Percentile	UK	0.164***	0.308***	0.416***
	Median	CY	0.661***	0.711***	0.724***
	75th Percentile	SK	0.734***	0.769***	0.769***
	Weighted Median	DE	-0.047	0.137***	0.285**
<i>Branch Density</i>	25th Percentile	SK	0.349***	0.429***	0.613***
	Median	RO	0.220**	0.332***	0.539***
	75th Percentile	AT	-0.059	0.124***	0.379***
	Weighted Median	DE	-0.019	0.154***	0.403**

Table 7: *Heterogeneous Responses: IIL and Bank Competition*

The increase is clearly stronger in concentrated banking markets: Whenever the levy variable is interacted with the HHI, the interest income on loans increases by more than 0.7 percentage points in concentrated markets (Slovakia, HHI=0.127) irrespective of the scenario. The increase of 0.66 to 0.72 percentage points at the median (Cyprus, 0.109) is strong but it is clearly weaker in less concentrated markets like the UK (0.047). For the branch density, one observes more variation across the scenarios as the bank-level have a stronger effect than the country-level variables: The interest income on loans is between 0.35 and 0.61 percentage points higher in countries at the 25th percentile (Slovakia, 2.29 branches/10'000 inhabitants). At the median (Romania, 3.16), one observes an increase between 0.22 and 0.54 percentage points, while the effect is clearly weaker or even insignificant at the 75th percentile (Austria, 5.03). Overall, the pass-through in concentrated markets is economically significant given a mean interest income on loans of 5.85 percent. Evaluating the heterogeneous response model at the weighted sample median (Germany, HHI=0.021, 4.76 branches/10'000 inhabitants), yields estimates broadly consistent with the baseline model.

Figure 4 illustrates the response of a bank that faces a positive marginal tax rate depending on the HHI (scenario 2). The blue points indicate the quartiles as well as the weighted sample

<sup>30</sup>The full sample distribution of the competition measures is less meaningful for a cross-country comparison as fragmented markets are overrepresented due to the large number of German banks.

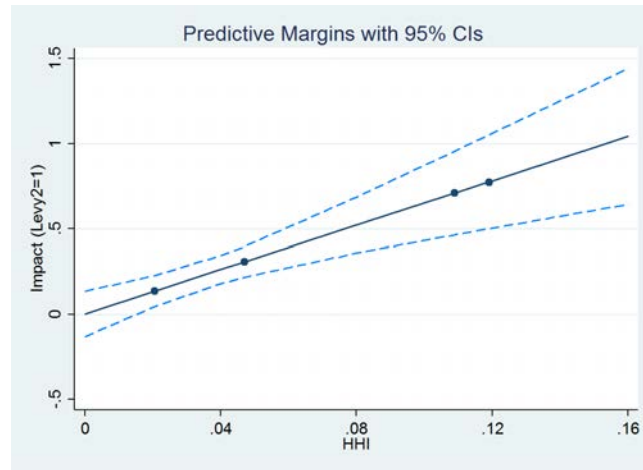


Figure 4: *Heterogeneity: Interest Income on Loans and HHI*

This figure illustrates the effect of a bank being taxed ( $Levy2 = 1$ ) on IIL depending on the HHI. The points indicate unweighted sample median (0.021) and quartiles (0.047, 0.107, 0.127) of the simple HHI distribution.

median. The response of the average lending rate is significant already at a very low degree of bank concentration and rapidly increases in the HHI. Figure 5 shows the increase in the average lending rate of a bank that faces a 0.06 percent marginal tax rate depending on the branch density (scenario 3). The relation is negative as a higher branch density implies a less concentrated market and more alternatives for borrowers. Whenever it exceeds 7.5, the effect becomes insignificant but this only concerns Cyprus. Hence, the evidence supports the prediction that strong bank concentration reinforces the pass-through to borrowers. Depending on the scenario, we find increases up to between 0.6 to 0.75 percentage points in highly concentrated markets that are economically significant and clearly larger than the average effects.

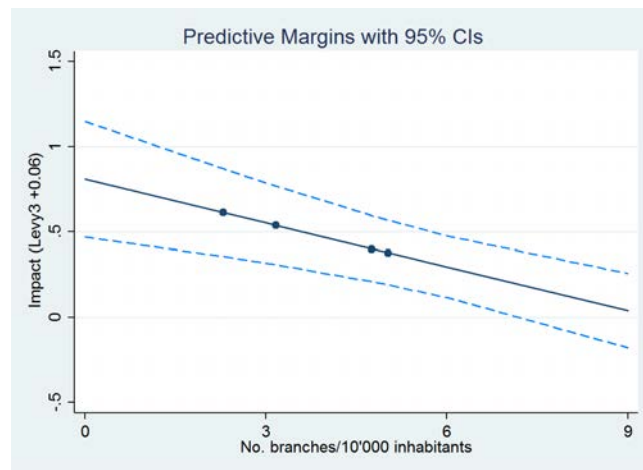


Figure 5: *Heterogeneity: Interest Income on Loans and Branch Density*

This figure illustrates the effect of a 0.06% marginal tax rate on IIL depending on the branch density. The points indicate unweighted sample median (4.76) and quartiles (2.29, 3.16, 5.03) of the simple BD distribution.

The middle section of table 6 reports the estimates for the impact of concentration on the sensitivity of the deposit rate. Interacting the levy with the HHI yields negative and significant

coefficients in two out of three specifications (columns 1-3), which imply that the increase in the average deposit rate is weaker in more concentrated markets. This is in line with the prediction of stickier deposit rates in concentrated markets. The interaction terms with the branch density (columns 4-6), however, show negative and significant coefficients suggesting that the increase is stronger in markets with few branches. This leaves some uncertainty about how competition influences the pass-through to depositors. Eventually, the lower section reports the estimates for the net interest margin. Recall that counteracting price and composition effects do not allow for a clear prediction of how the sensitivity varies with competition. Interacting the levy with the HHI yields only one significant coefficient, whereas those with the branch density are positive and significant. This points to a weaker increase in the NIM in concentrated markets.

	(1)	(2)	(3)	(4)	(5)	(6)
Interest Income on Loans						
Levy1	-0.0446 (0.0910)			0.3933*** (0.1009)		
Levy2		0.0521 (0.0780)			0.3143* (0.1840)	
Levy3			9.6834*** (2.0645)			6.3674*** (2.3500)
Levy3 <sup>2</sup>			-15.3378** (7.0275)			-5.2665 (5.8176)
Levy*CAP	0.0114 (0.0080)	0.0283** (0.0115)	-0.0443 (0.1970)	-0.0211*** (0.0047)	-0.0114 (0.0126)	-3.4737** (1.6877)
Obs.	13296	13283	13283	10262	10254	10254
No. banks	2432	2431	2431	1863	1863	1863
R <sup>2</sup>	0.6427	0.6443	0.6443	0.6858	0.6852	0.6852
Net Interest Margin						
Levy1	0.3243*** (0.0331)			0.3282*** (0.0430)		
Levy2		0.1679*** (0.0337)			0.0809 (0.0750)	
Levy3			3.7437*** (0.8212)			3.1214*** (0.9983)
Levy3 <sup>2</sup>			-4.2270* (2.3072)			-4.4600 (2.7535)
Levy*CAP	-0.0224*** (0.0042)	-0.0170*** (0.0055)	-0.1849** (0.0857)	-0.0054** (0.0022)	-0.0001 (0.0052)	-0.4761 (0.8425)
Obs.	14886	14859	14859	10636	10628	10628
No. banks	2702	2702	2702	1905	1905	1905
R <sup>2</sup>	0.1487	0.1346	0.1331	0.1666	0.1483	0.1481
CAP	Capital Ratio			Regulatory Capital Ratio		
Method	OLS	IV	IV	OLS	IV	IV
Bank FE, Controls	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES

Table 8: *Heterogeneous Responses: Bank Capitalization*

The levy variables are interacted with the capital ratio in (1) - (3) and the regulatory capital ratio in (4) - (6); clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

The second dimension of heterogeneity is the capital structure of banks: Table 8 reports the coefficients of the interaction terms between the levy variable and the 2009 capital (columns 1-3) and regulatory capital ratio (columns 4-6). We focus on the impact of the capital structure on the sensitivities of the interest income on loans and the net interest margin. The deposit side is omitted as, in line with theory, no significant impact of the capital structure is found. The evidence remains somewhat inconclusive about how capitalization affects the increase in

the lending rate: A high regulatory capital ratio has a negative and significant effect in two specifications but the coefficient of the interaction term with the capital ratio is even positive and significant in one case. In contrast, the increase in the net interest margin is clearly less pronounced for well-capitalized banks as all interaction terms are negative and significant. A high regulatory capital ratio also weakens the effect if the levy is measured at the country level.

			(1)	(2)	(3)
<i>Average Effect</i>			0.153***	0.050***	0.110**
<i>Capital Ratio</i>	25th Percentile	5.53%	0.200***	0.074***	0.148***
	Median	7.12%	0.165***	0.047**	0.130***
	75th Percentile	10.0%	0.100***	-0.025	0.098**
	90th Percentile	14.34%	-0.003	-0.076	0.050

Table 9: *Heterogeneous Responses: NIM and Bank Capitalization*

Based on the coefficients, one can compute the marginal effects for three similar scenarios as above, which are summarized in table 9: the bank is located in a country with a bank levy (column 1), is subject to a levy (2), and faces a 0.06 percent marginal tax rate (3). In general, banks with a capital ratio at the 25th percentile of the 2009 capital ratio distribution (5.53%) raise the net interest margin by more than in the baseline estimations. The response of banks with a median capital ratio (7.12%) is roughly similar to the baseline estimates. For banks with a capital ratio of ten percent (75th percentile), the increase in the NIM is less pronounced or insignificant; whenever the capital ratio is 14.34 percent (90th percentile), the effect completely vanishes. For example, if a country adopts a bank levy (column 1), the net interest margin is on average 0.15 percentage points higher. Poorly capitalized banks even raise the NIM by 0.2 percentage points. Banks with a capitalization at the 75th percentile show a 0.1 percentage point increase only but no effect is observed for banks at the 90th percentile.

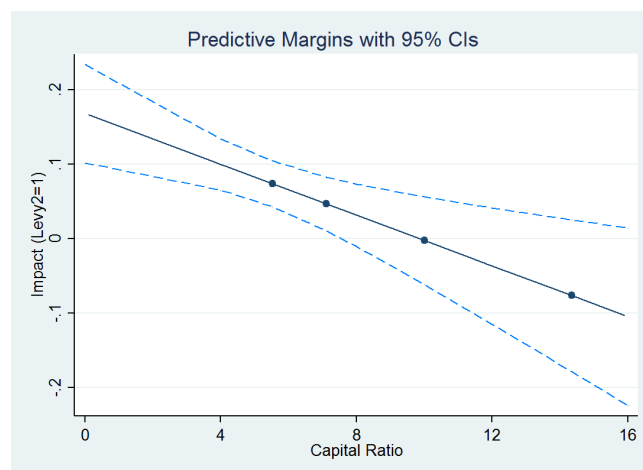


Figure 6: *Heterogeneity: NIM and Capital Ratio*

This figure illustrates the effect of a bank being taxed ( $Levy2 = 1$ ) on the NIM depending on the capital ratio. The points indicate capital ratio at the corresponding percentiles in table 9 (5.53, 7.12, 10, 14.34).

Scenario 2 that describes the response whenever a bank is taxed is illustrated in figure 6: A higher capital ratio weakens the pass-through to customers, which becomes insignificant above a capital ratio of 7.9 percent. The blue points indicate the four quantiles specified in table 9. Hence, well-capitalized banks do not pass the tax burden onto their customers, whereas the pass-through is stronger for those poorly capitalized. The former may in part explain the moderate increase in the NIM on average.

#### 1.4.4 Robustness Tests

The main results are robust in the sense that three different measures of the bank levy are applied and that we control for a broad set of bank- and country-level factors. This section provides additional robustness tests: First, we introduce separate time trends for different groups of banks to capture specific shocks that are likely in the context of financial crisis and regulatory reform. Second, the concern that some covariates are endogenous is addressed using additional instruments. Third, we perform subsample tests and also study the incidence at the country level in Austria and Germany. Finally, we estimate the impact on lending.

##### Specific Shocks

The sample period 2007-13 is characterized by the financial and the Eurozone crisis and by massive government and central bank interventions in the banking sector. In addition, regulatory reforms (Basel III, Banking Union) were enacted or at least prepared during the sample period although the introduction takes place later. A concern is that such shocks may influence the results if they are correlated with interest rates and coincide with the adoption of bank levies. Importantly, the losses and uncertainty during the crisis and the envisaged reforms may lead to deleveraging, which could ultimately drive the increase in the lending rate but does hardly account for the higher deposit rate. Although the baseline specification includes macroeconomic controls and the fiscal costs of the banking crisis as well as time fixed effects that absorb all common shocks, we perform a robustness check that also controls for specific shocks following an approach of Devereux et al. (2015). We estimate several variants of the baseline model (24) with differential time trends, namely, separate time fixed effects for different groups of banks depending on their characteristics and location.

On the one hand, we add bank-specific time trends: First, large and small banks have a different exposure to the crisis and the regulatory reforms; the former are more likely to be systemically important thus benefiting from government guarantees during and facing tighter regulatory constraints after the crisis in the context of 'too-big-to-fail' policies. Evidence, for example, by Acharya et al. (2016) documents a sizable funding advantage due to implicit guarantees. In countries where large banks are more likely to be taxed due to an allowance and progressive

rates, the observed effect might be biased. Hence, we estimate a model with *size-specific time fixed effects* to control for size-specific shocks: For that purpose, a dummy variable for each decile of the total asset distribution in 2009 (i.e., the year before the levy was adopted for the first time) is interacted with the year dummy. Second, poorly capitalized banks may face tighter constraints after the crisis than well-capitalized banks, which leads to stronger cuts in lending and increases in interest rates. At the same time, their tax burden is larger as equity is exempt. Higher lending rates might thus rather reflect the compliance and recapitalization cost. We include *capital ratio-specific time fixed effects* to control for capital-ratio specific shocks by interacting a dummy variable for each decile of the 2009 capital ratio distribution with the time fixed effect. Third, the behavior of banks that suffered from severe losses during the crisis may differ from those less affected. If the former are more likely to be taxed, the observed effects could be driven by downsizing after the crisis. We define a dummy variable for each decile of the distribution of banks' operational profit<sup>31</sup> (as a fraction of total equity) in the crisis year 2008 and interact it with the time dummy to account for *crisis loss-specific* shocks.

On the other hand, the exposure to the financial crisis differs depending on location; Ireland, for example, was severely affected, whereas some eastern European countries like Poland or Slovakia did not experience a banking crisis at all. Whenever countries that were more severely hit - implying a stronger cut in lending and possibly higher lending rates - are more likely to adopt a levy, the estimates can be biased. This concern is addressed in two ways<sup>32</sup>: First, a country's crisis exposure is measured by the fiscal costs for recapitalization and asset relief for the entire sample period (as a share of 2013 GDP), which are provided by the European Commission (2013). Recall that the annual fiscal costs are included as covariates (*Recap*) but they capture the contemporaneous effect only. Hence, we define dummy variables for countries with zero fiscal costs and with fiscal costs below and above the (unweighted) median conditional on having incurred positive costs (Luxembourg: 5.7% of GDP) and thus include *crisis cost-specific time fixed effects*. However, large fiscal outlays may point to substantial government interventions, which mitigate the crisis impact on banks. We thus also measure the exposure by the cumulative output loss 2008-11 (compared to the trend) using the banking crisis database of Laeven and Valencia (2012). Again, we rely on dummy variables for countries with no output loss and an output loss below and above the median (Italy: 32%) that are interacted with the year dummies to include *output loss-specific time fixed effects*. Finally, we add specific time fixed effects depending on whether a country experienced a sovereign debt crisis in the

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<sup>31</sup>The operational profit better captures the crisis impact than net income, which is also affected by taxation. Alternatively, one may rely on net gains or losses from trading, a major source of losses in 2008. However, only some banks report trading activities; for these, the results are roughly similar.

<sup>32</sup>An alternative are country-year fixed effects, which would, however, absorb all country-year variation (including *Levy1*). A significant but smaller increase in IIL and NIM is still observed for the bank-level levy dummy and most marginal tax rates but the increase in IED becomes insignificant.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Interest Income on Loans									
Levy1	0.0427 (0.0622)	-0.0032 (0.0666)	0.0479 (0.0679)						
Levy2				0.3426*** (0.0634)	0.2245*** (0.0447)	0.1958*** (0.0402)			
Levy3							11.2961*** (2.6399)	8.2416*** (2.1274)	6.8717*** (1.9039)
Levy3 <sup>2</sup>							-20.2095*** (7.6190)	-13.5413** (6.8340)	-9.9459 (6.2094)
Obs.	13296	13296	12802	13283	13283	12788	13283	13283	12788
No. banks	2432	2432	2303	2431	2431	2302	2431	2431	2302
R <sup>2</sup>	0.6456	0.6631	0.6635	0.6472	0.6642	0.6646	0.6473	0.6647	0.6653
Interest Expenses on Deposits									
Levy1	0.2266*** (0.0782)	0.2207*** (0.0794)	0.1891** (0.0814)						
Levy2				0.1970** (0.0896)	0.1753** (0.0891)	0.1577* (0.0929)			
Levy3							2.8847 (2.6472)	2.8206 (2.6258)	3.0804 (2.8814)
Levy3 <sup>2</sup>							-7.7767 (6.4579)	-7.8950 (6.4092)	-8.4299 (7.0407)
Obs.	4638	4638	4334	4637	4637	4332	4637	4637	4332
No. banks	870	870	796	870	870	796	870	870	796
R <sup>2</sup>	0.6117	0.6032	0.6197	0.6102	0.6017	0.6185	0.6098	0.6014	0.6183
Net Interest Margin									
Levy1	0.1589*** (0.0210)	0.1066*** (0.0237)	0.1405*** (0.0222)						
Levy2				0.0527** (0.0262)	0.0271 (0.0180)	0.0337* (0.0184)			
Levy3							2.4061** (1.0696)	1.2108 (0.8553)	1.5129 (0.9230)
Levy3 <sup>2</sup>							-5.0943* (2.6811)	-1.6601 (2.1884)	-3.0746 (2.3808)
Obs.	14886	14886	14284	14859	14859	14256	14859	14859	14256
No. banks	2702	2702	2543	2702	2702	2543	2702	2702	2543
R <sup>2</sup>	0.1479	0.2597	0.1743	0.1406	0.2587	0.1678	0.1406	0.2588	0.1682
Method	OLS	OLS	OLS	IV	IV	IV	IV	IV	IV
Bank FE, Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time x Size FE	YES	NO	NO	YES	NO	NO	YES	NO	NO
Time x Cap. Ratio FE	NO	YES	NO	NO	YES	NO	NO	YES	NO
Time x Crisis Loss FE	NO	NO	YES	NO	NO	YES	NO	NO	YES

Table 10: *Robustness: Bank-specific Time Trends*

Baseline regression with size-, capital ratio-, and crisis loss-specific time dummies; clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

sense that they required financial support from EU institutions<sup>33</sup> to control for specific shocks associated with a sovereign debt crisis.

Tables 10 and 11 report the coefficient estimates for the model with bank- and country-specific time trends respectively. In general, the results are robust to the inclusion of specific shocks: When regressing interest income on loans, the coefficients of the bank-level levy variables remain positive and significant. They are also quantitatively similar; with size-specific time fixed effects, the coefficients are even larger. The increases in interest expenses on deposits prevail. However, there are some quantitative differences whenever country-specific time trends are included and the coefficient becomes insignificant in one case. Eventually, the increase in the net interest margin are qualitatively and quantitatively similar. Only for capital ratio-specific time fixed effects, the coefficient is smaller or insignificant. Therefore, the main findings do not appear to

<sup>33</sup>Cyprus, Greece, Ireland, Portugal, and Spain are considered crisis countries.



	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Interest Income on Loans									
Levy1	0.0793 (0.0717)	0.1620*** (0.0541)	0.0897 (0.0777)						
Levy2				0.2505*** (0.0421)	0.2326*** (0.0404)	0.2599*** (0.0434)			
Levy3							11.2823*** (2.1430)	8.5191*** (1.9144)	11.0087*** (2.2580)
Levy3 <sup>2</sup>							-20.1208*** (6.7035)	-12.6955** (6.4131)	-20.1173*** (7.0003)
Obs.	13586	13586	13586	13522	13522	13522	13522	13522	13522
No. banks	2550	2550	2550	2524	2524	2524	2524	2524	2524
R <sup>2</sup>	0.6407	0.6454	0.6402	0.6422	0.6463	0.6419	0.6428	0.6472	0.6422
Interest Expenses on Deposits									
Levy1	0.4210*** (0.0918)	0.0877 (0.0645)	0.4063*** (0.0739)						
Levy2				0.2688*** (0.0908)	0.0673 (0.0770)	0.3965*** (0.0848)			
Levy3							4.2547 (3.2433)	1.0792 (2.0946)	8.4310*** (2.5605)
Levy3 <sup>2</sup>							-9.1632 (8.0540)	-0.8106 (5.0502)	-21.6911*** (6.2491)
Obs.	4765	4765	4765	4763	4763	4763	4763	4763	4763
No. banks	921	921	921	921	921	921	921	921	921
R <sup>2</sup>	0.6010	0.6354	0.6084	0.5968	0.6348	0.6056	0.5965	0.6351	0.6044
Net Interest Margin									
Levy1	0.1578*** (0.0225)	0.1905*** (0.0242)	0.1711*** (0.0226)						
Levy2				0.0501*** (0.0172)	0.0531*** (0.0180)	0.0619*** (0.0177)			
Levy3							2.2562*** (0.8043)	2.0951** (0.8577)	2.7768*** (0.8758)
Levy3 <sup>2</sup>							-4.4140** (2.0865)	-4.2652* (2.1783)	-6.0382*** (2.2066)
Obs.	15215	15215	15215	15135	15135	15135	15135	15135	15135
No. banks	2837	2837	2837	2811	2811	2811	2811	2811	2811
R <sup>2</sup>	0.1430	0.1520	0.1512	0.1362	0.1427	0.1432	0.1362	0.1430	0.1433
Method	OLS	OLS	OLS	IV	IV	IV	IV	IV	IV
Bank FE, Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time x Recap. FE	YES	NO	NO	YES	NO	NO	YES	NO	NO
Time x Output Loss FE	NO	YES	NO	NO	YES	NO	NO	YES	NO
Time x Debt Crisis FE	NO	NO	YES	NO	NO	YES	NO	NO	YES

Table 11: Robustness: Country-specific Time Trends

Baseline regression with recapitalization-, output loss-, and debt crisis-specific time dummies; clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

be driven by shocks to specific groups of banks that are associated with financial and Eurozone crisis and regulatory reforms.

## Instrumental Variables

Given the finding of Devereux et al. (2015) that the bank levy increases the capital ratio and may even encourage risk taking, one might be concerned about the endogeneity of two covariates: *Equity* and *Provisions*. To address this concern, we instrument these two variables with a measure that is independent of the levy. Pre-introduction values of capital ratio and loan loss provisions are obvious candidates but they are already absorbed by the fixed effect. Therefore, for banks located in a country that introduces a levy, we project the capital ratio and loan loss provisions based on the pre-introduction levels using the median growth rate of those two

variables observed in countries that do not adopt a bank levy at all. This projection, which describes how capital ratio and loan loss provisions could have evolved in the absence of a bank levy, provides an instrument for the possibly endogenous covariates. Both instruments are correlated with the endogenous regressors and the F-statistic exceeds the value of ten.

	Interest Income on Loans			Interest Expenses on Deposits			Net Interest Margin		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Levy1	-0.0036 (0.0687)			0.1980*** (0.0758)			0.1731*** (0.0223)		
Levy2		0.2208*** (0.0426)			0.1794** (0.0874)			0.0583*** (0.0184)	
Levy3			8.8241*** (2.0811)			2.8470 (2.6147)			2.3877*** (0.8722)
Levy3 <sup>2</sup>			-14.7630** (6.5422)			-7.6426 (6.3629)			-5.1198** (2.2289)
Equity	-0.0054 (0.0207)	-0.0080 (0.0192)	-0.0099 (0.0175)	0.0201* (0.0110)	0.0210* (0.0110)	0.0228** (0.0110)	0.0159** (0.0064)	0.0226*** (0.0063)	0.0226*** (0.0063)
Provisions	-0.0087 (0.0522)	-0.0045 (0.0534)	-0.0015 (0.0535)	0.0979*** (0.0309)	0.0969*** (0.0308)	0.0974*** (0.0308)	-0.0155 (0.0194)	-0.0095 (0.0196)	-0.0084 (0.0197)
Obs.	13379	13365	13365	4719	4717	4717	14967	14940	14940
No. banks	2467	2466	2466	902	902	902	2740	2740	2740
R <sup>2</sup>	0.6402	0.6419	0.6425	0.5918	0.5906	0.5902	0.1308	0.1199	0.1196
Bank FE, Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES

Table 12: *Robustness: Instruments for Equity and Provisions*

Clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 12 reports the coefficients of the model (24) where in addition to the bank-level levy variables, the variables *Equity* and *Provisions* are instrumented: Most importantly, the estimated sensitivities of interest rates and margins to the levy are qualitatively and quantitatively unchanged compared to the baseline estimates in table 4. The coefficients in the NIM regressions are even slightly larger. Hence, the main finding of higher interest rates and margins is not distorted by the two possibly endogenous covariates. Furthermore, the coefficient estimates of the instrumented covariates *Equity* and *Provisions* are smaller than in the baseline specification. *Equity*, for example, does not significantly affect interest income on loans.

### Single Country Analysis: Austria and Germany

So far, we have presented cross-country evidence. Although the levies are comparable as they are taxes on liabilities, some differences remain especially when using dummy variables. Thus, we study the incidence at the country level in Austria and Germany: In these two countries, the exposure to the levy varies across banks due to an allowance of EUR 300m and EUR 1bn respectively as well as a progressive tax schedule, and a sufficiently large subsample is available. Recall that the Austrian levy is retroactive for the sample period as it is imposed on the 2010 balance sheet such that the levy variables are exogenous and we can rely on OLS. However, the static model implies no adjustment because banks cannot lower the current tax burden. Since the legislator decided and communicated<sup>34</sup> that the tax base will change to the past-

<sup>34</sup>See, § 2 Abs. 2 Stabilitätsabgabegesetz (BGBl I Nr. 111/2010).

year balance sheet from 2014 on, forward-looking banks may, nevertheless, adjust their balance sheets in order to lower the future tax burden. Note that we cannot estimate the sensitivity of the average deposit rate as it is reported only by few banks; in Austria, only the net interest margin is available for a sufficiently large number.

	Austria		Germany			
	NIM		NIM		IIL	
	(1)	(2)	(3)	(4)	(5)	(6)
Levy2	0.1426*** (0.0440)		0.0067 (0.0163)		0.1552*** (0.0422)	
Levy3		8.8129** (3.6404)		3.8439** (1.5772)		9.1632* (5.3141)
Levy3 <sup>2</sup>		-109.7382* (56.9789)		-161.8677*** (46.8277)		-79.4515 (202.8622)
Obs.	995	995	8663	8663	8584	8584
No. banks	206	206	1572	1572	1572	1572
R <sup>2</sup>	0.1965	0.1974	0.2573	0.2582	0.7171	0.7171
Method	OLS	OLS	IV	IV	IV	IV
Bank FE, Controls	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES

Table 13: *Robustness: Austria and Germany*

Dep. Variable: net interest margin (1) - (4), int. income on loans/av. loans (5) - (6); controls only include bank-level variables; clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

The coefficients are shown in table 13: We find that the bank levy has a positive effect on the NIM of Austrian banks (columns 1 and 2), which suggests that they pass the burden onto their customers. More specifically, the levy raises the NIM by almost 0.14 percentage points, which is substantially larger than the baseline, cross-country estimate of 0.05 percentage points. This is likely due to the relatively high Austrian tax rates because at a marginal tax rate of 0.06 percent, the coefficients (column 2) imply a 0.13 percentage points higher NIM, which is only slightly larger than the baseline estimate of 0.11. In contrast, there is little evidence for a significant increase in the NIM of German banks. Even the coefficients in column 4 are not jointly significant and positive for each marginal tax rate applied in Germany. However, the positive effect on interest income on loans (columns 5 and 6) suggests that the burden is partly passed onto borrowers: If a bank is taxed, its interest income increases by almost 0.16 percentage points. The latter is smaller than the baseline effect of 0.24 percentage points and - since the banking market in Germany is competitive - consistent with the heterogeneous response model (25), which implies an increase of roughly 0.15 percentage points. The results for Germany differ from Buch et al. (2014), who find no significant effect. In contrast, our analysis relies on more recent data with a longer post-introduction period.

### Subsample Tests

We perform three additional robustness tests by estimating the baseline regression in subsamples (i) of Euro area banks, (ii) excluding banks from Belgium, the Netherlands and Slovakia,

and (iii) excluding banks from the largest country in the sample (Germany, Italy). The first test provides a routine check in a subsample of more similar banks. The second test addresses an endogeneity concern as these three countries introduced the levy in 2012. Since it had already been in place elsewhere, anticipation seems more likely. However, the relevance of this concern should not be overstated as banks from these countries account for less than two percent of all banks. Eventually, we also check to what extent by the composition of the sample where German banks are overrepresented (see, Appendix 1.A.3) drives the results. One outcome variable, interest expenses on deposits, is only available for subsample where Italian banks are overrepresented such that Italy is excluded instead.

	Interest Income on Loans			Interest Expenses on Deposits			Net Interest Margin		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Euro Area Banks									
Levy1	0.1515*			-0.1249			0.2585***		
	(0.0827)			(0.0966)			(0.0220)		
Levy2		0.1922***			-0.0952			0.0933***	
		(0.0422)			(0.0980)			(0.0160)	
Levy3			6.0665***			-1.7078			3.0260***
			(1.8634)			(2.4105)			(0.6886)
Levy3 <sup>2</sup>			-6.2963			2.2366			-7.1558***
			(6.7773)			(6.0851)			(1.8857)
Obs.	12214	12152	12152	3503	3503	3503	13812	13734	13734
No. banks	2290	2264	2264	679	679	679	2574	2548	2548
R <sup>2</sup>	0.6623	0.6625	0.6637	0.5495	0.5493	0.5498	0.1446	0.1265	0.1262
Banks outside BE, NL, SK									
Levy1	0.0555			0.2295***			0.1713***		
	(0.0597)			(0.0815)			(0.0226)		
Levy2		0.2325***			0.2123 **			0.0524***	
		(0.0410)			(0.0934)			(0.0183)	
Levy3			20.4148***			21.8367***			3.3776***
			(2.7497)			(5.3306)			(1.2856)
Levy3 <sup>2</sup>			-202.9026***			-236.5771***			-22.4493
			(42.3869)			(58.2535)			(25.3580)
Obs.	13526	13462	13462	4711	4709	4709	15026	14946	14946
No. banks	2538	2512	2512	910	910	910	2798	2772	2772
R <sup>2</sup>	0.6445	0.6461	0.6465	0.5887	0.5872	0.5894	0.1406	0.1318	0.1321
Sample Excluding Largest Country*									
Levy1	0.3438***			0.4744***			-0.0089		
	(0.0876)			(0.0711)			(0.0337)		
Levy2		0.3437***			0.4571***			0.0196	
		(0.1000)			(0.0843)			(0.0467)	
Levy3			4.8264*			7.6840***			1.3513
			(2.8978)			(2.6053)			(1.2944)
Levy3 <sup>2</sup>			-7.7731			-16.6538***			-1.4806
			(8.3371)			(6.3816)			(3.2319)
Obs.	4942	4938	4938	1928	1926	1926	6489	6472	6472
No. banks	953	952	952	409	409	409	1239	1239	1239
R <sup>2</sup>	0.6752	0.6752	0.6746	0.6241	0.6180	0.6105	0.3407	0.3427	0.3434
Method	OLS	IV	IV	OLS	IV	IV	OLS	IV	IV
Bank FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES

Table 14: *Robustness: Subsample Tests*

\*German banks excluded in (1) - (3) and (7) - (9), Italian banks in (4) - (6); clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

The results are summarized in table 14: The upper part reports the coefficients for Euro area banks: Regarding the average lending rate and the net interest margin, the effects are even more

pronounced; the estimates also imply a significantly higher interest income on loans whenever the country-level levy variable is used (column 1). However, no increase in the deposit rate is observed in the Euro area. The second part reports the coefficients for a subsample excluding three countries that introduced the bank levy after 2011: Again, the coefficients are of similar sign and magnitude as in the full sample. In case the largest country banks of which are overrepresented in the sample is excluded, the positive impact on interest income and expenses generally prevails such that the higher interest rates do not appear to be driven by the behavior of German or Italian banks. We do not find a significant increase in the net interest margin. This can be attributed to the considerably smaller sample size combined with the relatively small coefficients in the baseline estimations. Overall, the main findings also result in several subsamples; only the positive response of the deposit rate is not observed for Euro area banks.

### Quantity Effects: Loan Supply

A particular concern about bank levies is an adverse effect on lending, which may reduce investment and slow down economic growth. Theory implies that the levy reduces the loan supply, which is the very reason for the higher lending rate. We examine its impact on loans by regressing growth rates of a bank's total loans, commercial and corporate loans, and residential mortgages on the three levy proxies and the standard controls. In line with Buch et al. (2014), a profitability measure (return on average assets) is included; this replaces the interbank rate. Using growth rates instead of levels as dependent variables better captures the effect on new loans. In case of mortgage and commercial loans, the sample is smaller due to data availability.

	Loans			Commercial loans			Mortgages		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Levy1	3.5210*** (0.5694)			-6.5976** (3.1410)			5.3491 (3.5478)		
Levy2		-0.8202* (0.4773)			-4.1928** (2.0944)			-3.1567*** (1.0429)	
Levy3			-37.9973* (22.4775)			-133.6962* (77.5227)			-164.0802*** (52.7737)
Levy3 <sup>2</sup>			77.2668 (61.3707)			468.3332** (201.9653)			734.3030*** (131.7840)
Obs.	15189	15110	15110	7063	7013	7013	7009	6966	6966
No. banks	2831	2805	2805	1647	1625	1625	1563	1542	1542
R <sup>2</sup>	0.1573	0.1517	0.1514	0.0301	0.0296	0.0299	0.0314	0.0307	0.0342
Method	OLS	IV	IV	OLS	IV	IV	OLS	IV	IV
Bank FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES

Table 15: *Robustness: Quantity Effects*

Dep. Variable: growth rate of loans (1) - (3), commercial loans (4) - (6), residential mortgages (7) - (9); clustered standard errors in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

The estimation results are summarized in table 15: The levy's impact on total loan growth (columns 1-3) is ambiguous as the bank-level variables suggest a slowdown, whereas the country-

level dummy even implies a higher growth rate. One explanation for these contrasting results is that in countries where small banks are exempt, the latter increase their loan supply and provide a substitute for loans of large banks that are taxed and reduce lending. The evidence is more informative about how the levy affects the growth of two loan categories: First, the levy lowers commercial loan growth (columns 4-6). Whenever a bank is taxed, the growth rate with an average of 7.69 percent falls by 4.19 percentage points; if it faces a marginal levy rate of 0.06 percent, commercial loan growth even falls by 6.33 percentage points. Second, the growth rate of mortgage loans (columns 7-9) is significantly lower whenever the exposure to the levy is measured at the bank level: If a bank is affected, the growth rate with an average of 4.15 percent decreases by 3.16 percentage points. Overall, the bank levy slows down growth of lending, and shifting the tax burden to borrowers is associated with a smaller loan supply.

## 1.5 Conclusion

This paper theoretically and empirically analyzes the question who bears the burden of the newly introduced bank levies. Using a variant of the Monti-Klein model, we develop several scenarios for the tax incidence: The main prediction is that the levy leads to a higher lending rate and net interest margin such that banks pass the tax burden onto borrowers. The magnitude of the pass-through depends on bank competition and capitalization; it is particularly strong for banks that operate in concentrated markets and have a low capital ratio. Since (insured) deposits are usually not taxed, banks may shift funds towards deposits such that depositors earn higher interest rates. These predictions are taken to the data: We employ a cross-country panel dataset with financial information of 2'987 banks from 23 EU countries (2007-13) to estimate the levy's impact on interest rates and net interest margin. The empirical results support the main predictions and imply a positive effect on average lending and deposit rate as well as on the net interest margin: Whenever a bank is taxed, the interest income on loans (as a share of average loans) increases by 0.2 to 0.24, the interest expenses on deposits (as a share of average deposits) by 0.16 to 0.18, and the net interest margin by 0.04 to 0.05 percentage points. Although moderate compared to the corresponding sample means, the effects are not negligible; given that the outcome variables are conservative measures of the incidence, they rather represent a lower bound. In line with theory, the higher interest rates are mainly the result of the behavior of loan-rich, deposit-poor banks. Bank competition and capitalization influence the extent to which to burden is passed onto customers: In highly concentrated markets, the average lending rate of a bank that is taxed is between 0.43 and 0.77 percentage points higher, which is economically significant. There is also evidence that banks with a very high capital ratio do not shift the burden to customers. The main estimates are

robust as we rely on different measures of the bank levy and include a broad set of controls and as they survive several robustness checks.

The main contribution is a comprehensive analysis of the incidence of a novel tax on banks. In particular, we explore the heterogeneous responses of banks depending on market concentration and capital structure and find considerable differences in the tax incidence. To my knowledge, it is the first paper with cross-country evidence about the incidence of bank levies. This approach allows for a more robust measurement of banks' exposure to the levy by exploiting cross-country variation and is a prerequisite for studying how market characteristics that vary mainly across countries affect the incidence. In addition, the post-introduction period is longer than in previous studies such that effects, which materialize with some delay, are better captured. One objective of the bank levy is a 'fair and substantial contribution by the financial sector' to compensate taxpayers for providing guarantees. Of course, this contribution should be made by those who - explicitly or implicitly - benefited from such guarantees. Since we find that the tax burden is at least partly borne by the borrowers, the question arises whether they benefited from government guarantees before the crisis: One could imagine that banks which were protected by such guarantees and enjoyed a funding advantage charged lower interest rates or had more lenient lending standards. In this case, the observed pass-through is unproblematic and part of an effective internalization. However, it is likely that some borrowers who did not benefit from such favorable credit conditions now face higher lending rates as a result of banks' adjustment while others who benefited do not. Some of them might have defaulted in the meantime thus not making any contribution. The issue whether those borrowers who bear the tax burden were indeed the beneficiaries of such guarantees cannot be addressed with our dataset as it requires data about individual loans. This question is thus left for future research.

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## 1.A Appendix

### 1.A.1 Proofs and Derivations

**Proof of Proposition 1:** The partial derivative (9) follows from differentiating (4)

$$\frac{\partial L}{\partial \tau} = \frac{(1+r)(1-k)}{(1-\tau)^2 r'_L(L) \left(1 - \frac{1}{N\varepsilon_L}\right)} < 0$$

together with  $r_L = r_L(L)$  and  $r'_L(L) < 0$ ; the second derivatives yield the signs of the sensitivities with respect of  $N$ ,  $\varepsilon_L$  and  $k$ . *Q.E.D.*

**Proof of Corollary 1:** The partial derivative of the NIM is given by:

$$\frac{\partial NIM}{\partial \tau} = \frac{\partial r_L}{\partial \tau} - \frac{r(1-k)}{(1-\tau)^2} - \frac{(r-r_D)D}{L^2} \frac{\partial L}{\partial \tau}$$

Using  $\frac{\partial r_L}{\partial \tau} > 0$  and  $\frac{\partial L}{\partial \tau} < 0$  from proposition 1 yields corollary 1. *Q.E.D.*

**Proof of Proposition 2:** The partial derivative follows from differentiating (14):

$$\frac{\partial D}{\partial \tau} = -\frac{1+r - \frac{(\rho-r)k}{1-k}}{r'_L(L) \left(1 + \frac{1}{N\varepsilon_D}\right)} < 0$$

Using  $r_D = r_D(D)$  with  $r'_D(D) > 0$  yields (15); the second derivatives yield the signs of the sensitivities with respect of  $N$ ,  $\varepsilon_L$  and  $k$ . *Q.E.D.*

**Proof of Corollary 2:** The sensitivities of the interest rates to the levy follow from (17) - (18). The net interest margin is  $NIM = (r_L l_i - r m_i - r_D d_i - r_d^I d_i^I) / l_i = r_L - r(1 + \tau^e)(1 - k) + [(r - r_D)D + (r(1 + \tau^e) - r_D^I)D^I] / L$ . The partial derivative is:

$$\frac{\partial NIM}{\partial \tau} = \frac{\partial r_L}{\partial \tau} - \frac{r(1-k)}{(1-\tau)^2} - \frac{(r-r_D)D + (r(1+\tau^e) - r_D^I)D^I}{L^2} \frac{\partial L}{\partial \tau} + \frac{\frac{rD^I}{(1-\tau)^2} + (r(1+\tau^e) - r_D^I - r_D^I(D^I)D^I) \frac{\partial D^I}{\partial \tau}}{L}$$

After substituting for the derivatives, one obtains

$$\begin{aligned} \frac{\partial NIM}{\partial \tau} &= \frac{1-k}{(1-\tau)^2} \left[ \frac{(1+r)}{1 - \frac{1}{N\varepsilon_L}} \left( 1 - \frac{(r-r_D)D + (r(1+\tau^e) - r_D^I)D^I}{r'_L(L)L^2} \right) - r \right] \\ &\quad + \frac{1}{(1-\tau)^2 L} \left[ rD^I + \frac{(1+r)(r(1+\tau^e) - r_D^I - r_D^I(D^I)D^I)}{r_D^I \left( 1 + \frac{1}{N\varepsilon_D^I} \right)} \right] \end{aligned}$$

Using the first-order condition w.r.t.  $D^I$  and substituting  $r_D^I = r_D^I/\varepsilon_D^I D^I$  yields

$$\begin{aligned} \frac{\partial NIM}{\partial \tau} = & \frac{1-k}{(1-\tau)^2} \left[ \frac{(1+r)}{1-\frac{1}{N\varepsilon_L}} \left( 1 - \frac{(r-r_D)D + (r(1+\tau^e) - r_D^I)D^I}{r_L'(L)L^2} \right) - r \right] \\ & + \frac{D^I}{(1-\tau)^2 L} \left[ r - \left( \frac{\tau^e \varepsilon_D^I}{r_D^I} + 1 - \frac{1}{N} \right) \frac{1+r}{1+\frac{1}{N\varepsilon_D^I}} \right] \end{aligned}$$

The first term is positive (see, proposition 1) but the sign of the second is ambiguous. By inspection, the negative part is small whenever  $N$ ,  $\varepsilon_D^I$ , and  $\tau$  are small. *Q.E.D.*

**Proof of Corollary 3:** After substituting the constraints into the objective function, one can derive the corresponding first-order condition w.r.t. loans:

$$\begin{aligned} (1+r_L+r_L' l_i) + \int_{A^*}^{1+r_L} AdF(A) - [1-F(A^*)](1+r)(1-k\alpha)(1+\tau^e) \\ -(1+\rho)k\alpha - (1+r_L)f(1+r_L)r_L' l_i + (1+r_L)f(1+r_L)r_L' l_i = 0 \end{aligned}$$

Integration by parts implies

$$1+r_L + [1-F(1+r_L)]r_L' l_i + F(A^*)A^* - \int_{A^*}^{1+r_L} F(A)dA - [1-F(A^*)](1+r)(1-k\alpha)(1+\tau^e) - (1+\rho)k\alpha = 0$$

Substituting  $A^* = (1+r)(1+\tau^e)(1-k\alpha)$  and  $r_L' l_i = -r_L/N\varepsilon_L$  gives (22). Differentiating this condition together with  $\frac{\partial r_L}{\partial \tau} = r_L' \frac{\partial L}{\partial \tau}$  and  $\frac{\partial A^*}{\partial \tau} = (1+r)(1-k\alpha)/[(1-\tau)^2(1+(1+r)(1+\tau^e)k\alpha)']$  yields the sensitivity of the lending rate.

The second partial derivative with respect to the number of competitors  $N$  is:

$$\frac{\partial^2 r_L}{\partial \tau \partial N} = \frac{\partial r_L}{\partial \tau} \frac{\partial r_L}{\partial N} \frac{(1-F(1+r_L)) \left(1 - \frac{1}{N\varepsilon_L}\right) - \frac{f'(1+r_L)r_L^2}{N\varepsilon_L} - \frac{f(1+r_L)^2 r_L^2}{N\varepsilon_L(1-F(1+r_L))}}{r_L \left[ (1-F(1+r_L)) \left(1 - \frac{1}{N\varepsilon_L}\right) + \frac{f(1+r_L)r_L}{N\varepsilon_L} \right]}$$

The sign depends on the numerator: It is positive if  $N$  or  $\varepsilon_L$  are large enough such that the whole expression is negative due to  $\frac{\partial r_L}{\partial N} < 0$ , and bank concentration weakens the pass-through. One cannot draw any conclusion about the sign of  $\frac{\partial^2 r_L}{\partial \tau \partial k}$ , and the impact of the capital ratio remains ambiguous. Eventually, the net interest margin,  $NIM = r_L - rd/l = r_L - r(1+\tau^e)(1-k\alpha)$ , responds according to

$$\begin{aligned} \frac{\partial NIM}{\partial \tau} = & \frac{\partial r_L}{\partial \tau} - \frac{r(1-k\alpha)}{(1-\tau)^2} + r(1+\tau^e)k\alpha' \frac{\partial A^*}{\partial \tau} = \\ & \frac{(1-k\alpha)}{(1-\tau)^2 [1+(1+r)(1+\tau^e)k\alpha']} \left[ \frac{(1+r)[1-F(A^*) + (1+\rho)k\alpha']}{(1-F(1+r_L)) \left(1 - \frac{1}{N\varepsilon_L}\right) + \frac{f(1+r_L)r_L}{N\varepsilon_L}} - r \right] \end{aligned}$$

where  $\alpha' = \alpha'[F(A^*)]f(A^*) \geq 0$ . The expression in square brackets is positive unless the term  $f(1+r_L)r_L/N\varepsilon_L$  becomes very large. *Q.E.D.*

## 1.A.2 Variables: Construction and Definitions

Table 16 describes the variables and the corresponding data sources:

Variable	Description	Source
IIL	Interest income on loans/average loans	Bankscope, code No. 18030
IED	Interest expenses on deposits/average customer deposits	Bankscope, code No. 18035
NIM	Net interest margin	Bankscope, code No. 4018
LGR	Growth rate of loans, commercial loans, mortgages	Author's calculations
Levy1	Levy dummy at country level	Devereux et al. (2015)
Levy2	Levy dummy at bank level	Author's calculations
Levy3	Marginal levy rate (bank level)	Author's calculations
Assets	(Log of) Total assets squared	Bankscope, code No. 2025
BD	Bank branches per 10'000 inhabitants	ECB
CIT	Corporate income tax rate	Devereux et al. (2015)
Cost	Non-interest expenses/total assets	Bankscope, code No. 4021
Equity	Total equity/average assets	Bankscope, code No. 18165
Growth	Growth rate of real GDP	ECB
HHI	Herfindahl-Hirschman index (based on assets)	ECB
Inflation	Inflation rate	ECB
Interbank	Interbank rate (Euro area: 3-months EURIBOR)	OECD, Central Banks
Provisions	Loan loss provisions/average loans	Author's calculations
RCAP	Regulatory capital ratio	Bankscope, code No. 38300
Recap	Fiscal costs of recapitalization and asset relief (% of GDP)	European Commission (2013)

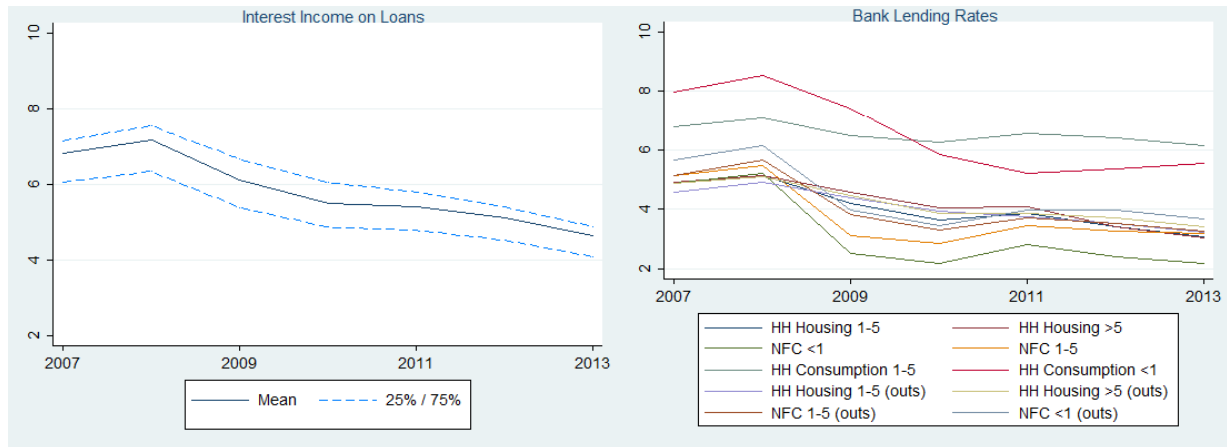
Table 16: *Definition of Variables*

In those four countries that exempt small banks from the levy or apply a progressive tax schedule, the bank-level levy variables *Levy2* and *Levy3* are based on the approximated taxable liabilities, which are constructed according to the information from Devereux et al. (2015, Appendix):

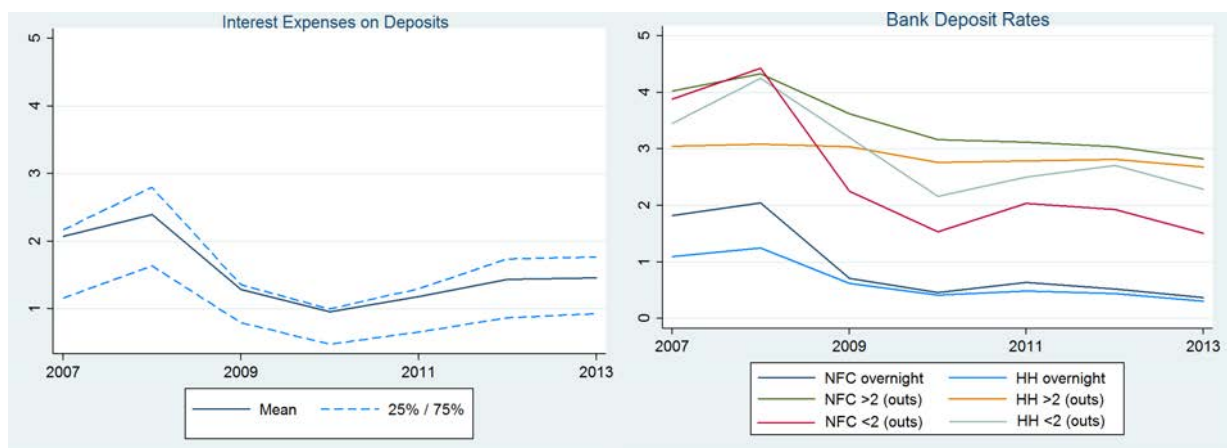
- Austria: Total liabilities (code No. 11750) - Insured deposits
- Germany: Total liabilities (code No. 11750) - Customer deposits (code No. 11550)
- Netherlands: Total liabilities and equity (code No. 11850) - Insured deposits - Regulatory Capital (code No. 30670) or Common Equity (code No. 11800) or Equity (code No. 11840) [Equity measure chosen depending on data availability]
- United Kingdom: Total liabilities and equity (code No. 11850) - Insured deposits - Tier 1 Equity (code No. 30660) or Common Equity (code No. 11800) or Equity (code No. 11840) [Equity measure chosen depending on data availability]

For Austria, the taxable liabilities are based on the 2010 balance sheet, otherwise, the current year balance sheet is used. Insured deposits are computed by multiplying customer deposits (code No. 11550) by the coverage ratio, which is the volume share of insured deposits in a country. Data on the coverage ratio are from the EU Commission.

## 1.A.3 Supplementary Figures and Tables

Figure 7: *Euro Area: Interest Income and Bank Lending Rates*

The left panel shows mean interest income on loans of Eurozone banks and the upper/lower quartile of the distribution. The right panel shows interest rates on new and outstanding loans of households (HH; housing and consumption loans) and non-financial corporations (NFC, volume > EUR 1m) with different maturities (less than 1 year, 1 - 5 years, more than 5 years). Source: ECB MFI Statistics.

Figure 8: *Euro Area: Interest Expenses and Bank Deposit Rates*

The left panel shows mean interest expenses on customer deposits of Eurozone banks and the upper/lower quartile of the distribution. The right panel shows interest rates on overnight deposits and outstanding deposits with different maturities (more or less than 2 years) of households (HH) and non-financial corporations (NFC). Source: ECB MFI Statistics.

	Banks 2010		Sample 2010	
	No.	Share	No.	Share
11 Countries Adopt Levy 2010-13				
Austria	750	11.58	218	7.69
Belgium	48	0.74	29	1.02
Cyprus	127	1.96	8	0.28
Germany	1'819	28.08	1'579	55.68
Latvia	29	0.45	17	0.60
Netherlands	254	3.92	2	0.07
Portugal	133	2.05	20	0.70
Romania	33	0.51	15	0.53
Slovakia	15	0.23	9	0.32
Sweden	148	2.28	76	2.68
United Kingdom	239	3.69	31	1.09
12 Countries do not Adopt Levy 2010-13				
Bulgaria	24	0.37	19	0.67
Czech Republic	36	0.56	19	0.67
Denmark	143	2.21	79	2.79
Estonia	7	0.11	4	0.14
Greece	36	0.56	9	0.32
Ireland	461	7.12	5	0.18
Italy	697	10.76	510	17.90
Lithuania	77	1.19	8	0.28
Luxembourg	118	1.82	50	1.76
Malta	26	0.40	8	0.28
Poland	685	10.57	33	1.16
Spain	255	3.94	88	3.10
TOTAL	6'160		2'836	

Table 17: *Sample by Country*

For each country, this table compares the number of active banks to those in the sample in 2010. Source: ECB Monetary and Financial Statistics, Author's calculations.

	Full Sample					No Levy					With Levy					Banks not taxed					Banks taxed				
	Mean	Std. Dev.	Obs.	Min	Max	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.		
IIL	5.85	1.69	16000	3.01	11.43	5.43	1.94	4717	6.03	1.53	11283	5.85	1.63	12561	5.85	1.87	3438								
IED	1.69	2.26	5605	0.34	6.09	1.56	1.18	4507	2.19	1.42	1098	1.60	1.20	4707	2.16	1.44	898								
NIM	2.48	0.83	18747	0.49	4.73	2.64	1.04	5618	2.41	0.72	13129	2.56	0.79	14767	2.18	0.87	3963								
LGR Loans	4.67	10.29	15546	-15.70	44.58	5.29	12.73	4635	4.41	9.04	10911	4.68	10.14	12235	4.64	10.82	3304								
LGR Commercial	7.68	34.39	7238	-60.00	127.59	5.28	30.03	664	7.93	34.79	6574	7.26	35.68	5466	8.99	30.02	1772								
LGR Mortgage	4.14	14.87	7081	-20.92	65.53	8.93	19.49	118	4.06	14.76	6963	3.95	14.98	5354	4.47	14.51	1727								
Assets	5490	42911	18746	0.32	2246381	7688	35508	5618	4505	45682	13128	3339	22223	14766	13376	82412	3963								
Equity	8.70	4.35	18747	2.92	24.22	10.72	4.72	5618	7.83	3.88	13129	8.90	4.21	14767	7.96	4.77	3963								
Cost	2.65	1.29	18735	0.25	7.25	2.96	1.40	5618	2.53	1.21	13128	2.75	1.23	14756	2.32	1.42	3963								
Provisions	0.59	0.98	17852	-2.03	3.51	0.93	0.98	5244	0.44	0.95	12608	0.61	0.98	14061	0.51	0.97	3785								
Inflation	2.05	1.13	18747	-1.70	12.00	2.35	1.32	5618	1.92	1.00	13129														
Growth	0.65	3.01	18747	-17.70	10.50	-0.45	2.83	5618	1.11	2.96	13129														
CIT	29.21	4.45	18747	10.00	38.90	27.11	4.25	5618	30.11	4.23	13129														
Recap	0.68	1.17	18747	0.00	24.60	0.38	1.43	5618	0.81	1.01	13129														
HHI	0.04	0.03	18747	0.02	0.34	0.05	0.03	5618	0.03	0.02	13129														
BD	4.83	1.22	18717	1.10	12.33	5.43	1.70	5614	4.57	0.82	13103														

Table 18: *Summary Statistics*

In percent; assets in million EUR, the HHI is normalized in the unit interval. The second and third columns show the statistics for banks in countries that do (not) adopt a levy during the sample period (i.e.,  $Levy1 = 1$ ). The fourth and fifth columns show the statistics for banks that are (not) taxed during the sample period (i.e.,  $Levy2 = 1$ ).





## Chapter 2

# Rewarding Prudence: Risk Taking, Pecuniary Externalities and Optimal Bank Regulation

Michael Kogler<sup>1</sup>

This paper reconsiders the risk-shifting problem of banks and presents a novel rationale for macroprudential regulation. Using a model of a two-sector economy with bank moral hazard, we show that a market equilibrium is constrained-inefficient because of a pecuniary externality: Competitive banks fail to internalize that attracting deposits affects the aggregate capital allocation and leads to inferior financing contracts with higher funding costs that exacerbate risk shifting of all other banks. As a result, banks are too large, have too much leverage, and take excessive risks. This distortion is a strong rationale for intervention because it persists even in the absence of classical frictions like mispriced deposit insurance and implicit guarantees. A second best can be implemented by prudential regulation or by issuing a specific number of banking licenses. Optimal regulation increases banks' rent opportunities to reward prudent behavior and to discourage risk taking. However, it is not a Pareto-improvement as it leads to redistribution from depositors to banks and firms with access to the capital market.

**JEL Classification:** D60, D62, G21, G28

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## 2.1 Introduction

The recent financial crisis provides many insights for economists and policymakers. This paper focuses on two of them: First, the importance of interactions and interconnections between banks gave rise to a new regulatory paradigm, macroprudential regulation. Previous frameworks like Basel II were strongly influenced by the predominant microprudential approach and proved to be inadequate given their strong focus on the stability of a single financial institution. Although still somewhat vague, macroprudential regulation has become an important benchmark when shaping the new regulatory framework Basel III. In particular, this approach takes a more systemic perspective and addresses problems like procyclicality, contagion, and pecuniary externalities. Second, the crisis forcefully demonstrated the importance of asymmetric information as banks are opaque operations such that adverse selection and moral hazard are widespread phenomena. This problem has been well recognized in the literature and can be resolved by private contracting: Essentially, bank owners need to invest sufficient equity such that the incentives for prudent lending and diligent monitoring are preserved. However, the private solution may ignore externalities, which, in turn, provides a rationale for regulation. This paper combines the two insights and reconsiders a standard agency problem - risk shifting - that can be addressed by private contracting and a typical form of interaction between banks - competition for scarce deposits. It focuses on risk taking as the management of risks is one of the main functions of banks in the economy. The normative analysis identifies a novel pecuniary externality: Banks fail to internalize that raising deposits exacerbates risk shifting of all other banks through its effect on the capital allocation and deposit interest rate. As a result, banks are too large and have too much leverage, which leads to excessive risk taking. In particular, this distortion is generic in the sense that it exists even in the absence of typical frictions such as incorrectly priced deposit insurance or government guarantees and thus provides a strong rationale for intervention. This aspect becomes even more relevant because attempts are being made to internalize such costs through bank levies or self-insurance of banks<sup>2</sup> in the context of the European Banking Union. Moreover, the paper characterizes optimal regulation, its key mechanisms, and distributional consequences: The essence is to reward prudent banks which relates to the paradigm of financial restraint emphasized by Hellmann et al. (1997, 2000). The regulator creates rent opportunities for banks by limiting leverage and deposit demand, which keeps the funding cost artificially low and raises interest margins. The prospect of earning a rent, in turn, increases the private cost of risk taking and strengthens the incentive for prudent lending. We find that different approaches including capital requirements and imperfect competition may create such rent opportunities thus implementing a constrained-

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<sup>2</sup>Banks contribute to the Single Resolution Funds and to *ex ante* financed deposit insurance.

efficient allocation. The distributional consequences are largely determined by this *modus operandi* which yields new insights about how the costs of bank regulation are shared.

For that purpose, this paper develops a static model of an economy consisting of (i) a banking sector with a risky technology and moral hazard and (ii) a corporate sector with a frictionless technology. In particular, deposits are scarce as the corporate sector offers alternative investment opportunities such that the interest rate reflects the aggregate capital allocation. This modification, which replaces the elastic deposit supply common in many moral hazard models in banking<sup>3</sup>, is crucial because it creates the possibility for a pecuniary externality: When deciding about size and leverage, competitive banks fail to internalize the impact on the capital allocation and thus on financing contracts and risk-shifting incentives of other banks.

This paper builds on three strands of the literature: (i) pecuniary externalities and macroprudential regulation, (ii) moral hazard and risk shifting, and (iii) bank risk taking. First, pecuniary externalities (i.e., price externalities) are the source of second-best inefficiencies in sectors characterized by imperfect information and incomplete markets as shown by Greenwald and Stiglitz (1986). These frictions are particularly relevant in banking, and pecuniary externalities thus provide a rationale for macroprudential regulation. Essentially, atomistic agents do not take into account price reactions that affect incentives, financial or collateral constraints. Gersbach and Rochet (2012) show that the failure of banks to internalize the effect of reallocating capital after an adverse shock on asset prices results in excessive downsizing. Using a double moral hazard model that allows for collusion between banker and borrower, Tressel and Verdier (2014) identify a pecuniary externality associated with the return on bank capital that provides a rationale for macroprudential regulation. Using a quantitative model, Bianchi (2011) points to economically significant welfare gains from correcting pecuniary externalities. Other common mechanisms in finance that involve pecuniary externalities are amplification effects due to financial constraints, for example, Suarez and Sussman (1997), Caballero and Krishnamurthy (2003) and Lorenzoni (2008), and fire sales (i.e., the sale of assets at a dislocated price because of liquidity needs or regulatory requirements), for example, Shleifer and Vishny (1992), Diamond and Rajan (2011) or Korinek (2011).

Second, moral hazard is a typical phenomenon in banking and corporate finance. In contrast to Modigliani and Miller (1958), the capital structure becomes key as it influences choices like risk taking and effort. A classical implication of moral hazard is risk shifting (or asset substitution); seminal contributions include Jensen and Meckling (1976) and Stiglitz and Weiss (1981). Essentially, firms favor riskier activities<sup>4</sup> if they are funded by a large share of debt. Intuitively, owners protected by limited liability can shift the downside risk onto debtholders

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<sup>3</sup>For example, Suarez and Sussman (1997) or Repullo (2013).

<sup>4</sup>Such projects are characterized by a high payoff if successful and a low success probability

and increase their value by engaging in excessively risky activities. This holds *a fortiori* for banks, which are highly levered; it is exacerbated by guarantees and deposit insurance as shown by Merton (1977).<sup>5</sup> The problem is usually addressed by ensuring that a bank has sufficient equity ('skin in the game'); a fully equity funded bank would have first-best risk-taking incentives. Using a model where banks conduct a credit risk analysis, Inderst and Mueller (2008), however, argue that all-equity financed banks can be too conservative leading to underinvestment. Applications of the risk-shifting problem include, for example, Suarez and Sussman (1997) who show that it is the source of endogenous cycles even in the absence of stochastic shocks; Boot and Ratnovski (2012) who study risk shifting associated with the trading activities of a bank that engages both in trading and traditional banking; Repullo (2013) who characterizes how the capital structure mitigates risk shifting focusing on its cyclical adjustment; or Acharya et al. (2013) who examine the optimal capital structure of banks when there is both risk shifting and managerial rent seeking. The empirical relevance of risk shifting by banks is documented, for example, by the Office of the Comptroller of the Currency (1988), Esty (1996) or Landier et al. (2011).

Risk shifting is at the core of the closely related literature on two determinants of risk taking: bank competition and capital regulation. The first branch stresses the role of the charter value (i.e., the present value of future bank profits) as a disciplining device similar to equity, which makes banks more prudent by increasing the private cost of failure. Since intense competition lowers bank profits, the so-called 'charter value hypothesis' emphasized, for example, by Keeley (1990), Matutes and Vives (2000), and Allen and Gale (2000, 2004), postulates a negative relationship between bank competition and financial stability. Moreover, low profits also make it difficult to build up capital that further discourages risk taking. However, this view has been challenged: Boyd and De Nicoló (2005) show that this positive relation is reversed as soon as risk is determined by borrowers who benefit from intense competition among banks. Martinez-Miera and Repullo (2010), however, argue that lower bank profits reduce the buffer to absorb loan losses giving rise to a u-shaped relationship between competition and financial risk. The evidence is mixed: Keeley (1990) and Demirgüç-Kunt and Detragiache (1997, 1998) find that increased bank competition following deregulation reduces charter values resulting in higher bank risk and a higher frequency of banking crises, whereas Jayaratne and Strahan (1998) obtain a negative effect of deregulation on loan losses. Beck et al. (2006, 2007) provide robust evidence that systemic banking crises are less likely in concentrated banking systems. Consistent with this finding, Schaeck et al. (2009) estimate a negative effect of concentration on the probability of and the time to a banking crisis; however, they argue that concentration and competition may capture different features as a stabilizing effect of competition measured

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<sup>5</sup>For bank shareholders, deposit insurance is equivalent to a put option, the value of which increases in risk.

by conduct is found. Capital regulation usually discourages risk taking by increasing the 'skin in the game': Rochet (1992) shows that capital requirements with correct risk weights lead to the choice of a less risky portfolio whenever financial markets are incomplete and banks behave as utility maximizers. However, capital requirements cannot prevent excessive risk taking and should be replaced by fair deposit insurance premia if banks maximize future profits. Hellmann et al. (2000) argue that capital requirements have an ambiguous effect on risk taking as they put equity at risk but also reduce charter values due to costly equity. The latter can be eliminated using deposit rate controls. However, Repullo (2004) shows that this adverse effect vanishes in case of intense competition and low charter values. Freixas et al. (2007) study optimal capital regulation and risk-taking incentives in the context of financial conglomerates the divisions of which differ in their coverage by deposit insurance. They stress the role of market discipline and charter value as substitutes for capital requirements. Besanko and Kanatas (1996) disentangle risk taking and monitoring and stress the adverse dilution effect if outside equity needs to be raised. Eventually, Hakenes and Schnabel (2011) find counteracting effects of tighter capital requirements in a model with both bank and entrepreneurial risk shifting.

This paper combines the three literatures: It is most closely related to Allen and Gale (2000, 2004) and Suarez and Sussman (1997), from which the models of risk taking and moral hazard are borrowed. The key innovation is that banks' risk-taking incentives are sensitive to the aggregate capital allocation, which is fully endogenized using a model of a two-sector economy à la Gersbach and Rochet (2012): This replaces the common assumption in moral hazard models that deposits are elastically supplied, which opens the ground for feedback effects like pecuniary externalities. Whereas positive models of risk taking<sup>6</sup> indeed include such a mechanism using a reduced-form deposit supply, a full-fledged model is necessary for a welfare analysis and for clearly identifying market failures and characterizing optimal regulation.

The remainder of this paper is organized as follows: Section 2.2 outlines the model; and section 2.3 subsequently provides a first-best benchmark, introduces moral hazard, and analyzes both the market equilibrium and the allocation chosen by a social planner subject to the same informational constraints. Eventually, section 2.4 discusses two extensions of the model, and section 2.5 concludes.

## 2.2 The Model

This paper develops a static, partial equilibrium model of an economy with two sectors, banking and corporate sector that produce a homogeneous good but differ in the technologies. There are three types of agents (bankers, corporations, and investors). The technologies satisfy

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<sup>6</sup>For example, Allen and Gale (2000), Boyd and De Nicoló (2005), Hakenes and Schnabel (2011).

**ASSUMPTION 1** *The banking technology includes a continuum of risky investment projects (loans) characterized by constant returns to scale and a binary payoff; the project's success probability  $p$  is decreasing in the return if successful  $R$ . The frictionless technology is risk-free and characterized by the aggregate production function  $F(X)$  with  $F(0) = 0$  and  $F'(X) > 0 > F''(X)$  satisfying the Inada conditions  $\lim_{X \rightarrow 0} F'(X) = \infty$  and  $\lim_{X \rightarrow 1} F'(X) = 0$ .*

The setup with two technologies is borrowed from Gersbach and Rochet (2012) and Lorenzoni (2008). Only bankers have access to the banking technology, which can be justified by specific skills for monitoring or loan collection. Effectively, both technologies are operated by firms or entrepreneurs, which only play a passive role in the baseline model. Those in the banking sector are funded by bank loans, while those in the corporate sector issue corporate bonds and are directly financed by investors. Following Holmström and Tirole (1997), one may interpret the two sectors as small, credit-constrained firms and large corporations respectively. This interpretation of the banking technology is consistent with the fact that small firms are often riskier and more productive (as captured by the linear technology). An alternative interpretation is trading in the spirit of Boot and Ratnovski (2012) since this activity is also risky and subject to moral hazard although banks in our setup would only engage in trading.

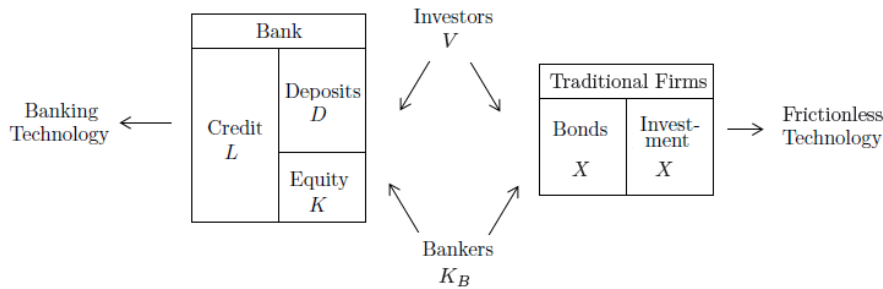


Figure 1: *Model Overview*

The economy is populated by three types of risk-neutral agents: First, a continuum of measure one of identical bankers (owner-managers) is endowed with private wealth<sup>7</sup>  $K_B > 0$  and each of them operates a bank that invests an amount  $L$  in the banking technology.<sup>8</sup> The bank is funded with bank capital (inside equity)  $K \leq K_B$  and deposits  $D$ . The banker is protected by limited liability. Second, a continuum of identical investors, each saving an exogenous amount  $V > 0$ , solve a portfolio choice problem as they can either deposit their savings with the bank or purchase corporate bonds. Third, corporations funded by bonds invest an amount  $X$  and

<sup>7</sup>An equity endowment is standard in corporate finance models with moral hazard, e.g., Holmström and Tirole (1997), and also applied in the banking literature, e.g., Rochet (1992) and Gersbach and Rochet (2012).

<sup>8</sup>Since firms are not modeled explicitly, this is a shortcut for providing credit to firms that invest in such projects.

operate the frictionless technology. The total resources that can be invested in both sectors are normalized to one such that  $V = 1 - K_B$ . If not invested, the endowment perishes. Figure 1 graphically illustrates the model.

The assumption of risk neutrality is necessary to keep the welfare analysis tractable and common in related models such as Gersbach and Rochet (2012) or Tressel and Verdier (2014). However, it is possible to reproduce a market equilibrium with risk-averse depositors and actuarially fair deposit insurance premia or uncorrelated risks across banks. Eventually, the time line is:

1. Bankers choose size and capital structure, raise deposits, and promise a deposit interest rate; corporations issue corporate bonds and invest; investors allocate their savings between deposits and bonds
2. Bankers invest thereby determining the risk-return profile of their loan portfolio
3. All investments mature, the contracts are settled

The sequential structure of the banker's choices may create a hidden action problem and is consistent with related models such as Suarez and Sussman (1997) and Repullo (2013).

### 2.2.1 Bankers

The model builds on Allen and Gale (2000, 2004) to which we add bank capital. Beyond the owner-manager, the notion of the 'banker' may as well include large shareholders whose objectives are aligned with the manager's. Essentially, the banker's key choice is risk taking, that is, determining the risk-return profile of the bank's loan portfolio.

First, the banker opens a bank, injects an amount  $K$  of his private wealth  $K_B$  as inside equity, and raises deposits  $D$  from investors. He invests the remainder  $K_B - K$  in corporate bonds. Then, the amount  $L = D + K$  is invested in the banking technology, which is a shortcut for providing loans to businesses. Each loan yields a binary return  $R$  if successful (henceforth: target return) and zero else. The success probability is characterized by:

**ASSUMPTION 2** *The success probability is a decreasing function of the return if successful:*

$$p'(R) < 0, \quad p''(R) \leq 0$$

*There exist values of  $R$  such that  $p(R)R > 1$ .*

This is essentially the return structure of Allen and Gale (2000), which goes back to Stiglitz and Weiss (1981): High-yield loans are riskier, while safer loans promise smaller returns if successful. Hence, the expected return  $p(R)R$  is an inverse u-shaped function of  $R$ , which exceeds one at least at its maximum. The negative relationship between risk and return gives

rise to the well-recognized risk-shifting problem of debt as soon as  $R$  is unobservable. As Allen and Gale (2000), we assume that the portfolio consists of a continuum of identical loans with perfectly correlated returns but relax this assumption in section 2.4.2. Hence, the bank fails with probability  $1 - p(R)$ . This implies no role for a capital buffer such that the only purpose of bank capital is to alleviate the agency problem. The banker's objective is to maximize expected profits of both investments

$$\pi^B = p(R)(RL - bD) + \gamma(K_B - K) \quad (1)$$

which equals expected revenue  $p(R)RL$  net of deposit repayment ( $b$  denotes the gross deposit rate) plus the (gross) return of corporate bonds. Subsequently, we rely on the capital ratio  $\kappa = \frac{K}{L}$ . The banker determines lending  $L$ , bank capital  $K$ , and the target return  $R$ . He offers a financing contract that specifies a repayment  $b$  if the bank succeeds and zero if it fails.

### 2.2.2 Corporations

The model of the corporate sector builds on Gersbach and Rochet (2012) and Lorenzoni (2008)<sup>9</sup>: The frictionless technology is operated by firms which, due to the absence of risk and agency problems, can access the capital market and directly borrow from investors. More precisely, a continuum of corporations invest an amount  $X$  and produce an output  $F(X)$ . The production function satisfies assumption 1 and the Inada conditions guarantee an interior solution  $X \in [0, 1]$ . For that purpose, they issue corporate bonds<sup>10</sup> that promise a risk-free (gross) return  $\gamma$ . They choose investment in order to maximize profits

$$\pi^C = \max_X F(X) - \gamma X \quad (2)$$

such that the marginal product equals the cost of capital, that is, the bond return  $\gamma$ :

$$F'(X) = \gamma \quad (3)$$

One may also interpret this condition as the participation constraint of corporations.

### 2.2.3 Investors

The model of the investor also follows Gersbach and Rochet (2012): Each investor, for example, a household, has exogenous savings  $V = 1 - K_B$  for end of period consumption. He can either

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<sup>9</sup>However, we disentangle investors and corporations; they rely on a shortcut where each investor owns a firm in the corporate sector.

<sup>10</sup>Every financial claim on the firm can be issued since Modigliani-Miller applies here.



deposit the savings with a bank or purchase corporate bonds. The bank promises a (gross) deposit rate  $b$  if successful [with probability  $p(R)$ ] and zero else; bonds yield a safe return of  $\gamma$ . Hence, investors solve a portfolio choice problem by allocating their savings between deposits  $D$  and bonds  $X = V - D$  as to maximize their expected end-of-period value:

$$\pi^I = \max_D p(R)bD + \gamma(V - D) \quad (4)$$

Investors choose the asset that promises a higher expected return; they invest in both if expected returns are equalized:

$$p(R)b = \gamma \quad (5)$$

Intuitively, investors require a risk-adjusted deposit rate to be compensated for the risk of bank failure. Accordingly, condition (5) is interpreted as a participation constraint.<sup>11</sup>

## 2.2.4 Markets

Two markets exist in this economy: a deposit market where banks raise deposits from investors and a bond market where investors and bankers purchase corporate bonds issued by corporations. In equilibrium, both markets simultaneously clear:

$$D = L - K \quad (6)$$

$$X = V - D + K_B - K \quad (7)$$

Condition (6) can also be interpreted as a bank balance sheet identity. Walras' law implies that the bond market clears as soon as the deposit market clears and vice versa because adding up the two market clearing conditions yields the resource constraint  $X + L = 1$ .

## 2.3 Equilibrium Analysis

This section examines three equilibria: First, a frictionless benchmark without asymmetric information ('first best') is established. Second, the moral hazard (risk-shifting) problem of banks is introduced. Subsequently, we derive and characterize two equilibria with asymmetric information: a market or laissez-faire equilibrium and an allocation chosen by a social planner or regulator subject to the same informational constraints (henceforth: second best). Thereby, the inefficiency of the market equilibrium is shown and the implementation of the second-best allocation as well as its distributional implications are discussed. A numerical example that

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<sup>11</sup>Alternatively, one may think of deposit insurance with a fairly priced insurance premium  $(1 - p)\gamma/p$  that ensures a balanced budget of the deposit insurance fund.

illustrates the equilibria and their properties is provided in table 1 in Appendix 2.A.2.

### 2.3.1 First Best

This section characterizes a benchmark without any informational frictions. In particular, bank risk taking is observable and contractible. A social planner or regulator maximizes social welfare defined as the sum of expected payoffs  $W = \pi^B + \pi^I + \pi^C$  that can be consumed. This coincides with the aggregate, expected output of both sectors. The choice is only subject to an aggregate resource constraint.

**PROGRAM 1** *The regulator maximizes social welfare  $W$  by choosing target return  $R$ , bank lending  $L$ , and investment in the corporate sector  $X$*

$$W = \max_{R,L,X} F(X) + p(R)RL \quad (8)$$

*subject to the aggregate resource constraint (RC)*

$$L + X = 1$$

Solving program 1 yields the first-order conditions

$$p(R) + p'(R)R = 0 \quad (9)$$

$$F'(X) = p(R)R \quad (10)$$

as well as the resource constraint (RC). Target return and success probability are determined independently of the bank's size and capital structure: It maximizes the expected loan return  $p(R)R$  such that the marginal gains of increasing the return equal the marginal cost due to the reduced success probability. Furthermore, corporate investment  $X$  and, by the resource constraint, bank lending  $L$  are determined as to equalize the (expected) marginal returns of both technologies: The left-hand side of (10) captures the marginal return of the frictionless and the right-hand side the constant expected return of the banking technology. Therefore, the marginal gain of additional bank lending equals its opportunity cost, the forgone return from corporate investment.

The bank's capital structure is indeterminate as (10) and (RC) only pin down the resource allocation between the two sectors. Therefore, any capital ratio  $\kappa$  between zero and  $\frac{K_B}{L}$  is consistent with equilibrium. Furthermore, the prices  $\gamma$  and  $b$  are irrelevant for the first-best allocation and only determine the income distribution. Nevertheless, they can be computed:

The corporate bond return follows from the marginal productivity of corporations according to (3) and the deposit rate from investors' participation constraint (5).

Most importantly, condition (10) implies a zero profit margin of banks: The expected deposit rate,  $p(R)b$ , equals the bond return, which follows from the marginal product in the corporate sector  $F'(X)$ . Since the marginal returns are equalized across sectors, it also equals the expected return of bank lending,  $p(R)R$ . In other terms, as  $L$  is not determined at the bank level, each bank expands until the rise of the equilibrium bond return and funding cost drives the profit margin down to zero. Note that a bank only earns a positive profit if partly funded by inside equity (i.e.,  $K > 0$ ). The zero profit margin is a necessary equilibrium condition given a constant returns to scale technology and perfect competition. Combining first-order conditions and resource constraint establishes:

**PROPOSITION 1** *The first-best equilibrium allocation  $\{\tilde{R}, \tilde{L}, \tilde{X}, \tilde{\gamma}, \tilde{b}\}$  is characterized by (3), (5), (9), (10), and (RC). The target return maximizes the expected loan return; expected marginal returns of both technologies are equalized such that the bank's profit margin is zero. The capital structure is indeterminate and a larger supply of bank capital  $K_B$  has no welfare effect. The first best can be decentralized as a competitive market equilibrium.*

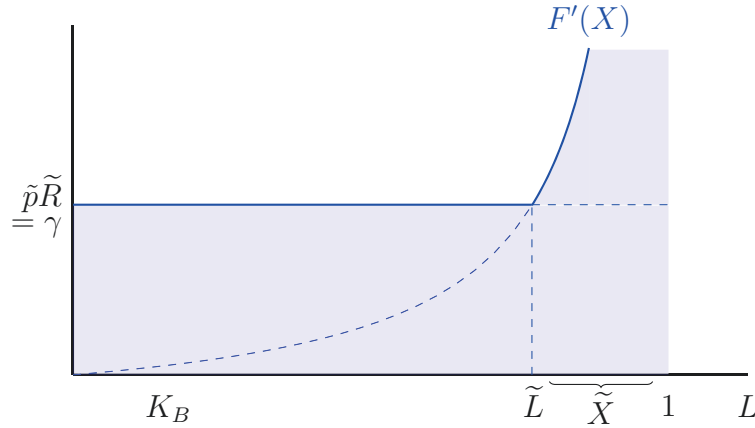
**Proof:** See Appendix 2.A.1.

The neutrality with respect to capital structure and wealth distribution implies that equity has no advantage over debt and that social welfare cannot be increased by *ex ante* redistribution (e.g., from investors to bankers to create additional equity). This is a classical Modigliani-Miller result. Consequently, the bank's capital structure is indeterminate.<sup>12</sup> Furthermore, the first best can be decentralized as a competitive market equilibrium as implied by the first fundamental theorem of welfare economics.

Figure 2 illustrates the first best:  $L$  on the horizontal axis is bank lending, the vertical axis measures the returns. The upward-sloping curve  $F'(X)$  is the marginal return of the frictionless technology<sup>13</sup> and the horizontal curve indicates the first-best expected return of the banking technology  $p(R)R$ , which is constant, determined according to (9). Optimality requires that the marginal returns in both sectors are equalized, and bank lending  $\tilde{L}$  and corporate investment  $\tilde{X}$  are chosen accordingly. The shaded area represents social welfare defined as aggregate output of both sectors:  $W = p(\tilde{R})\tilde{R} + F(\tilde{X})$ . The rectangle to the left of  $\tilde{L}$  is the expected revenue of the banking sector and the area below the  $F'(X)$ -curve to the right of  $\tilde{L}$  is the output of the corporate sector. Note that loan return and deposit rate coincide such that banks earn zero expected profits on their deposit-funded loans and the profit consists of the return on equity.

<sup>12</sup>The allocation only implies  $\tilde{K} \leq \min\{\tilde{L}, K_B\}$  and  $\tilde{D} \leq \min\{\tilde{L}, V\}$ .

<sup>13</sup>This curve intersects the horizontal axis at  $L = 0$  due to the Inada conditions.

Figure 2: *First Best*

This figure illustrates the first-best capital allocation between banking  $L$  and corporate sector  $X$ , which is determined by the equalization of marginal returns. Expected output (shaded area) is shared among the three agents: Investors earn an expected income  $\pi^I$  equal to the entire rectangle below the horizontal line to the right of  $K_B$ , corporate profits  $\pi^C$  are captured by the area between their the  $F'(X)$ - and the  $\gamma$ -curve, and bankers earn expected profits  $\pi^B$  represented by the rectangle below the horizontal line to the left of  $K_B$ .

### 2.3.2 Moral Hazard and Risk Shifting

The agency problem is similar to Suarez and Sussman (1997), who build on the moral hazard part of Stiglitz and Weiss (1981). They focus on entrepreneurial moral hazard but their approach has also been applied to banks, for instance, by Repullo (2013) and Hakenes and Schnabel (2011). In particular, we make the following

**ASSUMPTION 3** *The return if successful  $R$  is private information of the banker.*

In principle, it would be sufficient if no contract based on the *ex post* realized return is court-enforceable.<sup>14</sup> Since the return is not observable or verifiable, moral hazard and limited liability lead to risk shifting: Debt reduces the banker's marginal cost of risk taking thus distorting the choice of the target return. Compared to Suarez and Sussman (1997), we introduce a key innovation: The required return on bank deposits is variable and endogenous and given by investors' opportunity costs (i.e., the bond return).<sup>15</sup> Consequently, the supply of deposits is not perfectly elastic but depends on the aggregate capital allocation. This modification is justified because deposits are, in fact, scarce given that savers can invest in alternative assets. In particular, it is a common feature in positive risk taking models such as Allen and Gale (2000), which include a reduced-form inverse deposit supply. Endogenous opportunity costs are, in turn, the source of a pecuniary externality that is the very reason for market failure. In general, a financing contract that specifies deposit repayment needs to satisfy the participation constraint of investors (5). It requires the deposit rate  $b$  to be fair such that the expected

<sup>14</sup>For a more extensive discussion of this friction, see Freixas et al. (2007).

<sup>15</sup>Another minor change is that the loan return is the choice variable, which determines the success probability, while in Suarez and Sussman (1997), the success probability associated with convex effort cost is chosen.

repayment  $p(R)b$  equals the safe return on corporate bonds  $\gamma$ . This condition holds regardless of an agency problem; it is also fulfilled in the first best. As soon as target return  $R$  and success probability  $p$  are private information of the banker, he cannot commit to a particular risk-return profile that is determined after deposits are attracted. As a result, not all contracts that ensure participation are feasible because the banker chooses the target return  $R$  regardless of the underlying risk-return profile in the contract. Since he can *ex post* deviate, deposits may not be fairly priced anymore and investors are better off purchasing corporate bonds only such that the bank cannot raise deposits in the first place. Only a contract based on a risk-return profile that is privately optimal *ex post* for the banker is feasible. This implies that a contract also satisfies an incentive compatibility constraint (IC):

$$R = \arg \max_R p(R)[R - b(1 - \kappa)]L \quad (11)$$

The target return needs to maximize the banker's expected profit given a deposit rate  $b$ .<sup>16</sup> We subsequently rely on the first-order approach, which is valid given the concavity of the problem. The first-order condition of (IC) is:

$$p(R) + p'(R)[R - b(1 - \kappa)] = 0 \quad (12)$$

Loans  $L$  and equity  $K$  jointly affect risk taking through the capital ratio  $\kappa$ . As in the first best, target return balances marginal gains and costs but the latter is now distorted if the bank is funded by debt. Moral hazard and limited liability give rise to the risk-shifting problem well recognized in the literature and analyzed in related models: Since debt is a flat repayment, it reduces the residual income the banker can appropriate in case of success. Therefore, the banker, who is protected by limited liability and only cares about the 'upside' of his investment, has little to lose if the bank fails such that he prefers more profitable but riskier loans. This can be seen in (12): Debt reduces the bank's profit margin, which can be interpreted as a static counterpart of the charter value<sup>17</sup>, and thus lowers the marginal cost of risk taking. As a result, riskier loans that promise a higher return if successful are less costly from the banker's perspective whenever the bank is funded by debt. Risk shifting occurs even though deposits are fairly priced<sup>18</sup> in equilibrium: Moral hazard and limited liability prevent the banker from committing to a prudent lending strategy such as the first best as long as the bank is partly funded by debt. Essentially, this feature also appears in Jensen and Meckling (1976), where

<sup>16</sup>The banker's income from corporate bonds,  $\gamma(K - K_B)$ , is independent of  $R$  and thus omitted.

<sup>17</sup>As the model is static, discipline is due to the prospect of realizing the profit at the end of the period. Evidence by Keeley (1990) shows that a high charter value discourages risk taking.

<sup>18</sup>Government guarantees or incorrectly priced deposit insurance are not necessary but are likely features of banks that would strengthen this result.

a firm always has an incentive to choose a (potentially) inefficient, risky portfolio although its creditors correctly price the debt, and in Repullo (2013), where risk shifting occurs even though banks pay a risk-adjusted interest rate on uninsured deposits in equilibrium.

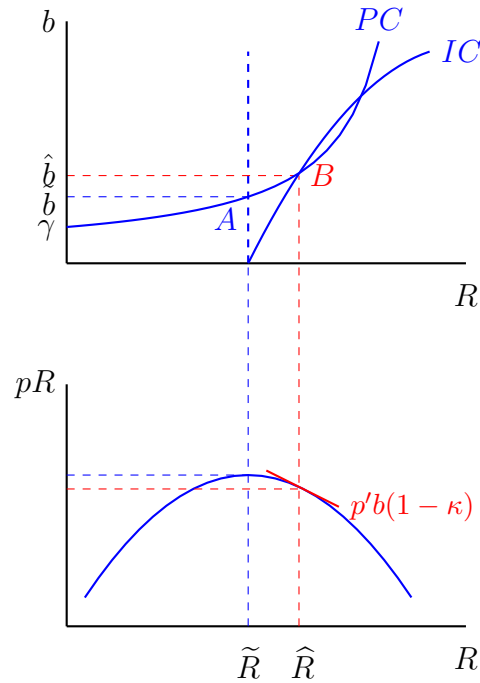


Figure 3: *Risk Shifting and Feasible Contract*

The upper panel shows PC and IC; the lower panel illustrates the expected loan return  $pR$ , which is a concave function of the return if successful  $R$ . In the first best, the IC is eliminated thus getting point A. The second-best financing contract is point B, which involves risk shifting (as  $R > \tilde{R}$ ).

Figure 3 illustrates the feasible financing contract and risk shifting. The IC-curve includes all combinations of  $b$  and  $R$  that are incentive-compatible, the PC-curve all combinations that satisfy the participation constraint. Both curves are upward-sloping, the former since a higher deposit rate exacerbates risk shifting, the latter since investors require a compensation for a higher risk of failure. The set of feasible contracts is thus given by the arc of the IC-curve above the two intersections of IC and PC. Obviously, moving leftwards raises expected bank profits<sup>19</sup> such that point B defines the second-best contract. The dashed, vertical line represents the first-best target return  $\tilde{R}$ , which maximizes expected loan return. Hence, the first-best contract is given by point A. Risk shifting leads to an inefficient portfolio with too high target return and loan risk. Position and shape of both constraints depend on the capital ratio  $\kappa$  and the corporate bond return  $\gamma$ : A higher capital ratio makes the IC-curve steeper and for  $\kappa = 1$ , it coincides with the first-best target return. Consequently, the first best could be replicated if the bank is fully funded by equity, which eliminates risk shifting. A higher bond return  $\gamma$  shifts the PC-curve upwards as for any given risk-return profile, investors require a higher deposit

<sup>19</sup>Higher expected loan return  $pR$  and lower deposit rate  $b$ .

rate. Obviously, the curves might not intersect such that no deposit rate exists that is both fair and incentive-compatible. In such a case, banks cannot attract deposits, and investors allocate their entire savings to the corporate sector. It could occur if banks are poorly capitalized (the IC-curve is rather flat) and if investors require a high return (the PC-curve is shifted upwards). Hence, a feasible contract exists only if  $\kappa \geq \kappa_0$  where  $\kappa_0$  is given by the tangency of the IC- and PC-curve and is an increasing function of  $\gamma$ . Since both capital ratio and bond return are endogenous, however, the equilibrium capital allocation always ensures a feasible financing contract.

Risk taking and deposit rate are thus jointly determined by the constraints (5) and (12) for given a capital structure and required return. They are characterized by:

**LEMMA 1** *Target return and deposit rate decrease in the capital ratio,  $\frac{\partial R}{\partial \kappa} < 0$  and  $\frac{\partial b}{\partial \kappa} < 0$ , and increase in the bond return,  $\frac{\partial R}{\partial \gamma} \geq 0$  and  $\frac{\partial b}{\partial \gamma} > 0$ .*

**Proof:** See Appendix 2.A.1.

A higher capital ratio reduces the bank's debt burden thereby increasing residual income and the marginal cost of risk taking, which alleviates risk shifting. Lower bank risk, in turn, allows reducing the deposit rate. The capital ratio can be raised in two ways: injecting more equity and deleveraging. A higher bond return  $\gamma$  tightens the participation constraint and requires a higher deposit rate which encourages risk taking by lowering its marginal cost. Essentially, a high capital ratio and a low funding cost are substitutes on the 'risk-shifting front' as they both strengthen the incentive for prudent lending. This result is consistent with the finding in the literature that capital ratio and charter value are substitutes [e.g., Repullo (2004), Freixas et al. (2007)]. Importantly, the capital allocation is endogenous in this model such that bank capital increases the banker's 'skin in the game' in two ways: At the bank level, it strengthens incentives by reducing the debt burden. At the industry level, a higher equity share implies a smaller bank leverage, which lowers the demand for deposits such that more resources are allocated to the corporate sector. Hence, the bond return falls and the participation constraint is relaxed creating a positive feedback on each bank as a lower deposit rate discourages risk taking even further. Critically, the second effect is not internalized in a competitive market equilibrium and is the very reason for its inefficiency.

However, given the advantage of equity on the 'risk-shifting front', bankers would prefer an all-equity financed bank, which obviously contrasts with reality. In such models, an interior equity share is ensured by making bank capital scarce or more expensive than deposits.<sup>20</sup> In our framework, banker and investor face similar opportunity costs, namely, the bond return  $\gamma$ .

<sup>20</sup>Equity is scarce, for example, in Suarez and Sussman (1997) where it is effectively given by the deterministic first-stage production or in Gersbach and Rochet (2012). Repullo (2013), Hakenes and Schnabel (2011) assume that equity requires an excess return over debt. Moreover, there are models such as Acharya et al. (2013) with

The fixed supply of bank capital eventually limits the lending capacity thus making a higher capital ratio expensive by deleveraging. Another advantage of focusing on inside equity is that it unambiguously alleviates risk shifting; in case of outside equity, the target return would need to be *ex post* observable for profit sharing and the positive incentive effect would prevail only the absence of dilution effects and shareholder-manager conflicts. More specifically, it only persists if the banker maximizes the joint surplus of all shareholders.

In principle, the financing contract is realized without any intervention as investors only deposit their savings if the offered interest rate is both fair and incentive-compatible. Hence, the agency problem itself provides no rationale for intervention because it is resolved by private contracting. In the spirit of the representation hypothesis of Dewatripont and Tirole (1994), one may, however, argue that implementing this contract is difficult (e.g., lack of sophistication, coordination problems) and expensive (e.g., duplication costs) for investors such that it is preferable if a regulator acts on their behalf.

### 2.3.3 Market Equilibrium

This section derives the competitive market or laissez-faire equilibrium under information asymmetry; all agents are unconstrained by any regulatory requirements.

#### The Banker's Problem

The banker determines lending and capital structure as well as target return and deposit rate (i.e., the financing contract) as to maximize expected profits. His choice is subject to several constraints: In particular, the financing contract has to be feasible and to satisfy incentive compatibility and participation constraint. Furthermore, bank capital is restricted by the banker's endowment, which is captured by a capital availability constraint. Hence, the banker solves:

**PROGRAM 2** *The banker maximizes expected bank profit  $\pi^B$  by choosing target return  $R$ , deposit rate  $b$ , loans  $L$ , and equity  $K$*

$$\pi^B = \max_{R,b,L,K} p(R)[R - b(1 - \kappa)]L + \gamma(K_B - K) \quad (13)$$

*subject to the incentive compatibility constraint (IC)*

$$R = \arg \max_R p(R)[R - b(1 - \kappa)]L$$

---

multiple agency problems, some of which can be resolved by using debt such that the capital structure has an interior solution.



the investors' participation constraint (PC)

$$p(R)b = \gamma$$

and the capital availability constraint (CA)

$$K_B \geq K$$

This optimization problem is similar to Suarez and Sussman (1997) and Repullo (2013); objective function and incentive compatibility constraint only differ in their choice variables as  $b$  and  $\kappa$  are taken as given in the latter. Target return and deposit rate follow from incentive compatibility and participation constraint as discussed above. First, the allocation of the banker's wealth  $K_B$  between equity and bonds is given by

$$\gamma = p(R)b + \frac{\lambda p'(R)b}{L} - \zeta \quad (14)$$

where  $\lambda < 0$  and  $\zeta$  denote the Lagrange multipliers of (IC) and (CA) respectively. If the banker purchases bonds, he earns the bond return  $\gamma$ ; if he invests the wealth in his own bank, he reduces the expected deposit repayment and, on top of that, alleviates risk shifting by increasing the capital ratio such that the expected loan return is higher. This is captured by the term  $\frac{\lambda p'(R)b}{L}$ . Due to this positive incentive effect, equity earns an implicit excess return over bonds and the banker, therefore, injects the entire endowment in his own bank as equity. This can be seen since (14) and (PC) jointly imply  $\zeta > 0$  as long as the incentive compatibility constraint binds (i.e.,  $\lambda < 0$ ). By complementary slackness, the capital availability constraint binds and  $K = K_B$ . Moral hazard is the very reason why the banker is not indifferent between the two assets like in the first best but strictly prefers equity to bonds. If his wealth rises, he is willing to provide even more equity to further alleviate risk shifting, and if it is large enough, he will even prefer full equity funding ( $\kappa = 1$ ), which completely eliminates risk shifting. As soon as the supply of bank capital is scarce, however, the banker trades off portfolio quality against lending. Since  $K = K_B$ , the capital ratio is determined solely by the amount of loans  $L$  and any increase in  $\kappa$  necessarily involves deleveraging. Second, optimal lending is characterized by the first-order condition

$$p(R)(R - b) = \frac{\lambda p'(R)b\kappa}{L} \quad (15)$$

This condition requires that the bankers marginal gains and costs are equalized. In the first best (i.e., if  $\lambda = 0$ ) are no marginal costs at the bank level due to the linear technology and (15) eventually coincides with the zero profit condition (10). In the presence of moral hazard,

however, there exist marginal costs of expanding as *ceteris paribus* the capital ratio declines, which exacerbates risk shifting and reduces the expected loan return. Contrary to the first best, (10), this condition implies that the bank earns a positive profit margin on its externally funded investments because the loan return is larger than the deposit rate,  $R > b$ . Hence, the banker earns an informational rent, which can be interpreted as a static counterpart of charter value, and the opportunity of earning this rent alleviates risk shifting.

### Traditional Firms, Investors, and Market Clearing

The investment decisions of corporations are standard, and equation (3) implies that the bond return equals the marginal product of the frictionless technology,  $F'(X) = \gamma$ . Investors maximize the end-of period value of their savings  $V = 1 - K_B$  by allocating them between deposits and corporate bonds as described in section 2.2.3. Hence, deposits balance (expected) returns from bonds and deposits, which is captured by the participation constraint (PC) in program 2. Eventually, both bond and deposit market clear in equilibrium, and the market clearing conditions (6) and (7) hold.

### Equilibrium Allocation

Combining the privately optimal choices of the agents yields the following proposition:

**PROPOSITION 2** *The equilibrium allocation  $\{\widehat{R}, \widehat{L}, \widehat{X}, \widehat{K}, \widehat{D}, \widehat{b}, \widehat{\gamma}\}$  is characterized by (3), (6), (7), (12), (PC), (CA), and*

$$F'(X) = \frac{p(R)R}{1 + \frac{\lambda p'(R)\kappa}{p(R)L}} \quad (16)$$

*The first best can be implemented as a competitive market equilibrium with  $\kappa = 1$  if*

$$K_B \geq 1 - F'^{-1}[p(\widetilde{R})\widetilde{R}] \equiv \overline{K}_B \quad (17)$$

*Otherwise, moral hazard distorts capital allocation and risk taking: Compared to the first best, there is underinvestment in the banking sector (i.e.,  $\widehat{L} < \widetilde{L}$ ) and lending is more profitable but riskier (i.e.,  $\widehat{R} > \widetilde{R}$ ) resulting in a higher probability of bank failure. The banker invests his entire private wealth in the bank (i.e.,  $\widehat{K} = K_B$ ).*

**Proof:** See Appendix 2.A.1.

The central condition is (16), which characterizes the capital allocation. It follows from combining the first-order conditions of corporations and banks, (3) and (15), with (PC). It requires that  $L$  and  $X$  balance the effective marginal returns of the two technologies taking into account risk shifting. In principle, the first best can be replicated as a market equilibrium even

if the target return is not verifiable: This requires an all-equity financed bank (i.e.,  $\kappa = 1$  and  $K = \tilde{L}$ ), which eliminates risk shifting associated with debt such that the first-best financing contract is feasible (point A in figure 3). However, this is only possible if the supply of bank capital  $K_B$  is large enough: Condition (17) requires it to be at least as large as first-best bank lending  $\tilde{L} = 1 - F'^{-1}[p(\tilde{R})\tilde{R}]$ , which depends on characteristics of both technologies. Then, the incentive compatibility constraint is slack (i.e.,  $\lambda = 0$ ) and the conditions (16) and (12) coincide with their first-best counterparts (10) and (9). Nevertheless, full equity funding is not an appropriate description of reality, banks are usually funded by very a small share of equity. Therefore, we subsequently focus on scarce bank capital (i.e.,  $K_B$  is small). Since banks are partly funded by deposits, moral hazard and risk shifting are present such that the incentive compatibility constraint binds ( $\lambda < 0$ ). This reduces the bank's marginal return compared to the first best: First, risk shifting directly lowers the expected return,  $p(R)R$ , as shown above. Second, higher bank lending reduces the capital ratio thereby further weakening the incentive to invest prudently such that portfolio quality deteriorates (see, lemma 1). This effect is captured by the denominator of (16), which is larger than one and drives a wedge between the marginal returns in both sectors. At the same time, it allows the banker to earn an informational rent (i.e., a positive profit margin). Given the distorted return of bank lending, less productive projects in the corporate sector attract funding such that its marginal product decreases,  $F'(\hat{X}) < F'(\tilde{X})$ . Compared to the first best, more resources are allocated to the corporate sector resulting in underinvestment in banks compared to the first best. This arises as scarce bank capital is needed to preserve incentives thereby limiting banks' lending capacity. This is a typical rationing result due to asymmetric information.

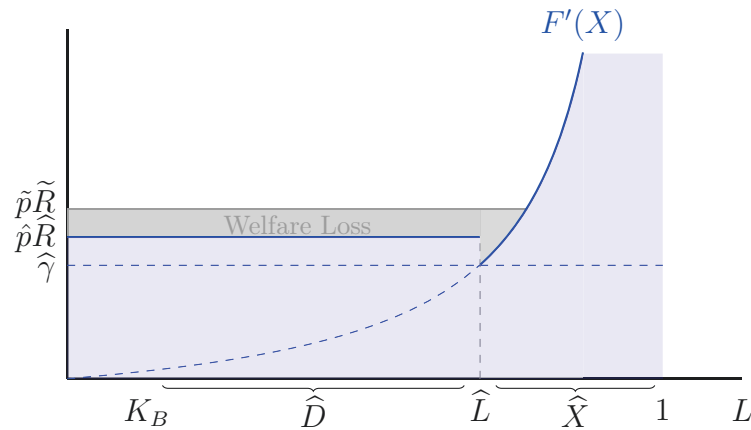


Figure 4: *Market Equilibrium*

This figure illustrates the market allocation with risk shifting, which reduces the return of bank lending  $pR$  compared to the first best. Since expansion of banks has an adverse incentive effect, there is a wedge between the effective returns in both sectors [ $pR > F'(\hat{X})$ ]. The welfare loss due risk shifting and underinvestment corresponds to the gray-shaded area.

In general, moral hazard distorts the banker's risk, lending, and leverage choices resulting in excessive risk taking as well as in underinvestment in the banking sector. Consequently, welfare is lower than in the first best as illustrated in figure 4: The blue-shaded area below the curves is social welfare in the market equilibrium. The distortions of risk (lower expected return) and size (smaller banks) result in a deadweight loss. It consists of a 'quality' loss due to an inefficiently risky loan portfolio as well as a 'quantity' loss due to the reallocation of resources towards the less efficient corporate sector. The former essentially represents the agency costs of debt emphasized by Jensen and Meckling (1976). Moreover, the banker now earns an informational rent as the lending spread is strictly positive [ $p(R)R > \gamma = p(R)b$ ] but the return on equity falls due to risk shifting. Whether overall bank profits increase compared to the first best is thus ambiguous. Corporate profits are higher because of the lower funding cost, whereas investors' expected income decreases as they earn smaller returns.

### 2.3.4 Second Best

Unless the supply of bank capital is large enough to ensure full equity funding, the market equilibrium is constrained-inefficient because of a pecuniary externality: When deciding about size and leverage<sup>21</sup>, banks fail to internalize that attract deposits affects the aggregate capital allocation and changes investors' opportunity costs. As corporate investment declines, the productivity in this sector increases thereby leading to a higher bond return. The latter tightens investors' participation constraints and leads to an inferior financing contract for all banks: The higher deposit rate reduces profit margins and exacerbates the risk-shifting problem of all other banks resulting in inefficiently risky loan portfolios. Of course, a single bank does not influence the deposit rate (because it is infinitesimally small) but the fact that all banks choose their size neglecting the price reaction causes an aggregate externality. Consequently, banks in the market equilibrium are too large and have too much leverage. This distortion is similar in kind to Lorenzoni (2008) and Gersbach and Rochet (2012) but the externality is associated with the deposit rate instead of asset prices. Critically, its presence hinges on the combination of moral hazard with perfect competition<sup>22</sup> and a deposit supply that is not perfectly elastic: Moral hazard makes risk taking sensitive to the deposit rate, perfect competition implies non-internalization due to price taking behavior, and the inelastic supply of deposits links the capital allocation to the deposit rate through variable opportunity costs of investors. In the first best, however, the target return is independent of the deposit rate and the pecuniary externality vanishes. If deposits were supplied elastically as in Suarez and Sussman (1997) and

<sup>21</sup>Since moral hazard establishes a mechanical relation between equity and the banker's wealth endowment, the pecuniary externality effectively distorts the lending choice.

<sup>22</sup>Imperfect competition leads to partial internalization; see, section 2.3.5.

Repullo (2013), raising deposits would not alter the required return and only directly affect risk taking through the capital ratio. Although the reason why bank capital is necessary in this framework is essentially an agency problem of each bank, the pecuniary externality is an aggregate phenomenon therefore giving rise to macroprudential regulation.

This section examines the allocation chosen by a risk-neutral social planner or regulator subject to the same informational constraints. In particular, the regulator cannot restore the first best provided that bank capital is scarce, and the allocation is at most constrained-efficient.

### The Regulator's Problem

Acting as a social planner, the regulator maximizes welfare  $W$ . In contrast to the first best, the regulator cannot observe the target return and needs to design a financing contract that is feasible and preserves the banker's incentives. Therefore, prices are not irrelevant as the contract specifies the deposit rate  $b$ . Obviously, setting  $b = 0$  would eliminate risk shifting and restore the first best. However, forcing investors to deposit their savings at a zero gross rate effectively expropriates them. The choice is thus subject to investors' participation constraint. For notational simplicity, we combine the participation constraints of corporations and investors, (3) and (5), thereby eliminating  $\gamma$ . Therefore, the regulator solves

**PROGRAM 3** *The regulator maximizes welfare  $W$  by choosing target return  $R$ , equity  $K$ , lending  $L$ , corporate investment  $X$ , and the deposit rate  $b$*

$$W = \max_{R,b,L,X,K} F(X) + p(R)RL \quad (18)$$

*subject to the banker's incentive compatibility constraint (IC)*

$$R = \arg \max_R p(R)[R - b(1 - \kappa)]L$$

*the combined participation constraint (CP)*

$$p(R)b = F'(X)$$

*the aggregate resource constraint (RC)*

$$L + X = 1$$

*and the capital availability constraint (CA)*

$$K_B \geq K$$

### Equilibrium Allocation

Solving program 3 yields the following proposition:

**PROPOSITION 3** *The equilibrium allocation  $\{R^*, L^*, X^*, K^*, D^*, b^*, \gamma^*\}$  is characterized by (3), (6), (12), (CP), (RC), (CA), and*

$$F'(X) = \frac{p(R)R}{1 + \frac{\lambda p'(R)\kappa}{p(R)L} \left[ 1 - \frac{(1-\kappa) F''(X)L}{p(R)b \kappa} \right]} \quad (19)$$

*If the supply of bank capital is large enough, banks are fully equity-funded and the second best coincides with the first best. Otherwise, the regulator allocates fewer resources to the banking sector than in the market equilibrium (i.e.,  $L^* < \hat{L}$ ). Banks are better capitalized (i.e.,  $\kappa^* > \hat{\kappa}$ ) and the deposit rate is lower (i.e.,  $b^* < \hat{b}$ ) such that the profit margin increases resulting in the choice of a safer and more efficient loan portfolio (i.e.,  $R^* < \hat{R}$ ). A larger supply of bank capital is welfare-improving as long as  $K_B < \bar{K}_B$ .*

**Proof:** See Appendix 2.A.1.

The central condition is (19) that pins down the second-best capital allocation. It equalizes the social marginal return earned in both sectors taking into account all incentive effects. The social return of bank lending is lower than the private in (16) because of the pecuniary externality. This is captured by the third term in the denominator that represents the response of investors' opportunity costs to higher lending. Hence, the pecuniary externality depends on the shape of the production function, which is intuitive as its curvature indicates the responsiveness of the return to corporate investment. The adverse welfare effect of the pecuniary externality is conditional on moral hazard: As soon as  $\lambda = 0$ , it vanishes because risk taking is independent of the deposit rate, and the mechanism through which a bank's deposit demand affects risk taking of other banks breaks down. In the presence of moral hazard, however, the pecuniary externality reduces the social marginal return of lending as the latter increases deposit demand and eventually raises the deposit rate  $b$  and exacerbates risk shifting of all other banks. If the capital allocation was the same as in the market equilibrium (i.e.,  $X = \hat{X}$  and  $L = \hat{L}$ ), corporate investment would earn an excess return such that more capital is invested in this sector and the marginal product falls due to the concavity of  $F(X)$ . The social marginal return of bank lending increases at the same time due to lower leverage and funding cost. Consequently, the regulator solves the quality-size trade-off more in favor of quality: The reallocation of resources from banks to corporations strengthens the banker's incentive for prudent, more efficient lending directly by increasing the capital ratio and indirectly by lowering the funding cost, which leads to a higher informational rent (profit margin). In other terms, the prospect

of being rewarded by earning a larger rent if successful discourages risk taking as the banker's forgone profit in case of failure is higher.

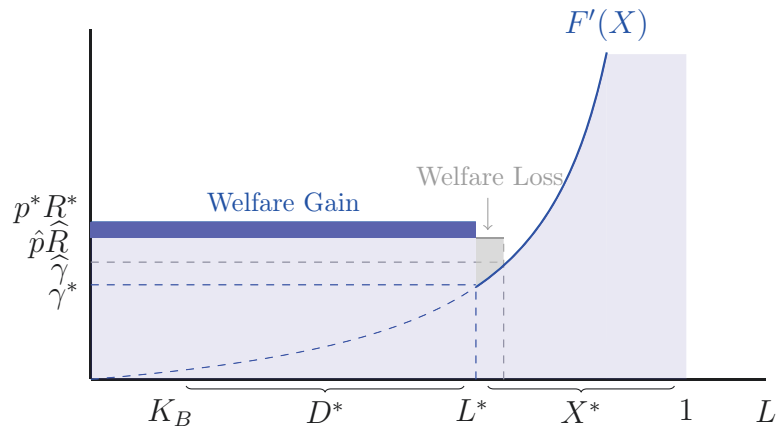


Figure 5: *Second Best*

This figure illustrates the second-best capital allocation. Internalizing the pecuniary externality leads to a smaller banking sector compared to the market equilibrium ( $L^* < \hat{L}$ ). There are both welfare-increasing (better risk-taking incentives, dark-blue-shaded area) and -decreasing effects (more corporate investments that are less productive at the margin, gray-shaded area).

Unless the supply of bank capital is large enough, this allocation is not first-best because moral hazard still distorts the risk and lending choices but it is constrained-efficient. Hence, social welfare is lower than in the first best but there are welfare gains compared to the market equilibrium as illustrated in figure 5: On the one hand, the bank's portfolio is less risky and more efficient resulting in a higher expected loan return ('quality effect'). On the other hand, banks are smaller and more resources are invested in comparatively less productive projects of corporations ('size effect'). However, the positive effect dominates since this allocation is chosen exactly as to maximize social welfare.

Whereas the first best is neutral with regard to the initial wealth distribution, a larger endowment of bankers now translates into a larger supply of bank capital, which improves social welfare as long as the latter is scarce and banks are partly debt-funded. Two effects or a combination of them are possible as illustrated by the numerical example in Appendix 2.A.2: For a given bank size, more equity raises the capital ratio, discourages risk shifting and improves portfolio quality. For a given risk-return profile and capital ratio, it allows for larger banks thereby allocating more resources to the more productive banking sector. Consequently, *ex ante* redistribution from investors to bankers could raise welfare and even restore the first best whenever an amount  $\tilde{L} - K_B$  was redistributed.

### 2.3.5 Implementation

The second best characterized in proposition 3 is flexible in terms of its implementation. Regulation is only necessary if the supply of bank capital is scarce. In this case, there are two ways to implement the second best in a market economy: prudential regulation and imperfect competition. The latter also allows reinterpreting the results in the context of financial liberalization, a policy pursued in many countries during the last three to four decades.

#### Prudential Regulation

A natural approach is prudential regulation. We focus on two standard instruments: minimum capital requirements and deposit rate ceilings.<sup>23</sup> While the former is an essential part of the Basel accords, the latter though rarely in place today was previously an important instrument especially in the U.S. (regulation Q). Since the regulator's choice satisfies incentive compatibility and participation constraint, the second best results as soon as the capital ratio equals  $\kappa = \kappa^*$  or the (risk-adjusted) deposit rate is  $b = b^*$ :

**COROLLARY 1** *The second best can be implemented in a market economy by minimum capital requirements  $\kappa \geq \kappa^*$  or deposit rate ceilings  $b \leq b^*$ .*

**Proof:** See Appendix 2.A.1.

Capital ratio  $\kappa$  and deposit rate  $b$  are mechanically related by the incentive compatibility, participation and resource constraint such that  $b = b^*$  follows as soon as  $\kappa = \kappa^*$  and vice versa provided that bank capital is scarce. The intuition is that regulation internalizes the pecuniary externality associated with bank deposits on others' risk-shifting problem. For that purpose, the regulator needs to prevent the deposit rate from rising too strongly, which can be achieved either by limiting leverage and deposit demand or direct price control. This equivalence result, at first sight, contrasts with Hellmann et al. (2000), who argue that capital requirements are Pareto-inferior compared to deposit rate controls or even counterproductive as (outside) equity is costly reducing charter value. However, our model is static such that future profits and charter value, which may decrease when using costly outside equity, do not affect incentives. In addition, the focus on inside equity eliminates any shareholder-manager conflict, which may weaken the positive incentive effect of bank capital due to a dilution of the banker's stake as shown by Besanko and Kanatas (1996).

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<sup>23</sup>Alternatively, one might think of size restrictions (i.e., an upper bound on lending or deposits) but they are less common.



### Imperfect Competition

Since internalizing the pecuniary externality increases the informational rent to induce prudent lending by keeping the deposit rate artificially low compared to the market, one might think of another approach that achieves a similar outcome: imperfect competition. Suppose that the banking sector is not perfectly competitive and banks compete for deposits in a Cournot fashion, which is common in the literature, for example, in Allen and Gale (2004) or Boyd and De Nicoló (2005). For that purpose, assume that instead of a continuum a finite number  $N \in \mathbb{N}$  of bankers each endowed with private wealth  $K_{Bi} = \frac{K_B}{N}$  exists.<sup>24</sup> The key difference to perfect competition is that each banker takes into account how the required return on deposits is affected by his choices given the optimal choices of all other bankers. As a result, banks are smaller and raise fewer deposits such that the lower deposit rate allows them to earn a rent (i.e., the lending spread increases). Compared to perfect competition, bank  $i$  does not take the bond return in the participation constraint as given anymore. It is replaced by an inverse deposit supply function:

**PROGRAM 4** *The bank maximizes its expected profit  $\pi_i^B$  by choosing target return  $R_i$ , deposit rate  $b_i$ , loans  $L_i$ , and equity  $K_i$*

$$\pi_i^B = \max_{R_i, b_i, L_i, K_i} p(R_i)[R_i - b_i(1 - \kappa_i)]L_i + \gamma(K_{Bi} - K_i) \quad (20)$$

*subject to the incentive compatibility constraint (IC), the capital availability constraint (CA), and the adjusted investors' participation constraint (PC)*

$$p(R_i)b = F' \left[ 1 - \sum_{i=1}^N L_i \right]$$

The term in square brackets equals corporate investment  $X$ . In a symmetric Cournot-Nash equilibrium, the allocation is described by:

**LEMMA 2** *The equilibrium allocation  $\{R', L', X', D', K', b', \gamma'\}$  is characterized by (3), (6), (7), (12), (PC), (CA) and*

$$F'(X) = \frac{p(R)R}{1 + \frac{\lambda p'(R)\kappa}{p(R)L} \left[ 1 - \frac{(1-\kappa)F''(X)L}{p(R)b} \right] - \frac{(1-\kappa)F''(X)L}{p(R)b} \frac{1}{N}} \quad (21)$$

*The banking sector is smaller (i.e.,  $L' < \widehat{L}$ ), the deposit rate and the target return are lower*

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<sup>24</sup>As in Allen and Gale (2004), aggregate bank capital endowment remains bounded if  $N$  increases; otherwise, as  $N \rightarrow \infty$ ,  $K \rightarrow \infty$  and, since banks are partly deposit-funded (i.e.,  $\kappa < 1$ ),  $D \rightarrow \infty$ , which is inconsistent with equilibrium if resources are limited.

(i.e.,  $b' < \hat{b}$  and  $R' < \hat{R}$ ) compared to the perfectly competitive market equilibrium characterized by proposition 2. For  $N \rightarrow \infty$ , these two equilibria coincide.

**Proof:** See Appendix 2.A.1.

Condition (21) characterizes the capital allocation. It differs from perfect competition, (16), because the banker considers the deposit interest rate endogenous and internalizes the feedback effects on the bank's profit: There is the typical direct effect due to lower funding cost (captured by the fourth term in the denominator) as well as an indirect effect due to changes in risk taking (captured by the third term). As a result, the private marginal return of bank lending is smaller than under perfect competition, and bankers reduce lending such that the overall deposit demand falls, which is a typical implication of the Cournot model. This can be seen in (21) as the lower expected return implies an increase in corporate investment and, by the resource constraint, a decrease in bank lending. As implied by lemma 1, the higher capital ratio and the lower opportunity costs of investors mitigate risk shifting. Furthermore, the relationship between the amount of loans  $L$  and the number of banks  $N$  is positive because the denominator in (21) decreases in  $N$  thus raising the private marginal return of banks. Intuitively, the impact of a single bank on deposit rate and profits diminishes as more banks compete: In concentrated markets, the banking sector is small, profits are large and portfolios safe, whereas the competitive banking sector is large, profits are small and portfolios risky. Moreover, if  $N \rightarrow \infty$ , an infinitely large number of very small banks operate, and the impact of a single bank on the deposit rate is negligible; price taking behavior is restored and the perfectly competitive outcome results.

Objective function and first-order condition of banker and regulator differ: The former internalizes an adverse feedback effect on his own profit, the latter the pecuniary externality that distorts risk taking of all other banks. Although both approaches create rent opportunities leading to more prudent lending than under perfect competition, the two outcomes are generally not the same, and the imperfectly competitive market equilibrium is, in principle, inefficient. To illustrate this, we focus on two extreme cases: In a monopsony,  $N = 1$ , the bank fully internalizes the deposit rate's response.<sup>25</sup> Therefore, (21) implies  $L|_{N=1} < L^*$ , and the monopsonistic bank is too small resulting in underinvestment in the banking sector. The intuition is that the banker too strongly reduces lending in order to increase the rent. Thus, the loan portfolio is safer and more efficient than in the second best. The first effect, however, dominates such that the monopsony is inefficient overall. If  $N \rightarrow \infty$ , in contrast, there is no internalization, and the allocation converges to the competitive outcome, which is constrained-inefficient as banks

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<sup>25</sup>If  $N = 1$ , the denominator of (21) is larger than in (19). The marginal return of a monopsonistic bank is smaller than the social marginal return of bank lending implying that banks are smaller.

fail to internalize the pecuniary externalities leading to overinvestment by banks and excessive risk taking. This line of reasoning implies

**COROLLARY 2** *There exists*

$$N^* \approx -\frac{p(R^*)[2p'(R^*) + p''(R^*)(R^* - b^*(1 - \kappa^*))]}{p'(R^*)^2 b^*(1 - \kappa^*)} > 1$$

*such that the second best can be approximately implemented as an imperfectly competitive market equilibrium with  $N^*$  operating banks.*

**Proof:** This follows from equalizing marginal returns of bank lending in both equilibria (21) and (19) and solving for  $N^*$ . As soon as  $L' = L^*$ ,  $X' = X^*$  follows from the resource constraint such that (12) and (PC) jointly imply  $R' = R^*$  and  $b' = b^*$ .  $N^* > 1$  is implied by a property of the feasible contract [see (35) in Appendix 2.A.1]. *Q.E.D.*

Corollary 2 states that for a specific number of banks  $N^*$ , the market mechanism incidentally achieves the second best without any regulatory intervention apart from issuing licenses. This is possible though the objective functions of regulator and oligopsonistic bank differ. Since the degree of internalization of an oligopsonistic bank decreases in the number of banks, whereas the pecuniary externality and the magnitude of the regulator's corrective intervention are constant, there exists a particular value of  $N$  for which both effects are almost the same such that the bank incidentally chooses the efficient lending scale (i.e.,  $L' = L^*$ ). Consequently, the second best can also be implemented simply by issuing  $N^*$  banking licenses. Alternatively, the regulator can issue  $N > N^*$  licenses and, for instance, impose capital requirements. Both strategies yield an equivalent outcome although the latter may appear more realistic.<sup>26</sup>

For  $N < N^*$ , however, prudential regulation cannot achieve constrained efficiency because banks cut back lending too much in order to extract rents.<sup>27</sup> Therefore, financial liberalization, in the sense of increasing the intensity of competition by issuing more licenses, has a positive welfare effect as it reduces market power and allocates more capital to the productive banking technology. At the same time, however, pecuniary externalities become more damaging, which weakens financial stability. If competition is intensified beyond a certain degree (i.e., if  $N > N^*$ ), optimal policy requires accommodation by macroprudential regulation.

This result has implications beyond the equivalence of imperfect competition and optimal regulation: The policy of liberalizing the banking sector (e.g., deregulation of deposit, removal of branching restrictions) and relying on capital requirements as the primary regulatory instrument instead that has been pursued in many countries since the 1970s and 1980s should, in

<sup>26</sup>The reason is that regulation exactly achieves the second best and appears more suitable as it adjusts at the intensive margin, while otherwise some banks must enter or exit the market.

<sup>27</sup>Then, the regulator would need to induce banks to expand.

principle, not have increased risk taking and weakened financial stability since the outcome is independent of the instrument. The fact that the frequency of banking crises, nevertheless, clearly increased<sup>28</sup> indicates that (i) the banking sector might have been too concentrated prior to liberalization (i.e.,  $N < N^*$ ) and the increase in risk is an optimal response as the positive welfare effect of larger banks that employ a superior technology compared to corporations at the margin dominates or (ii) capital requirements imposed after liberalization (e.g., Basel accords) might have been insufficiently low. The latter can be explained by the fact that the predominant microprudential approach likely neglected interactions between banks and aggregate phenomena such as pecuniary externalities.

### 2.3.6 Distributional Implications

In figure 5, one can observe that corporations benefit from regulation, whereas investors lose since the lower demand for deposits drives down deposit rate and bond return; the combined effect for firms and investors is clearly negative. The change of the banker's expected income is characterized by the very same quality-size trade-off as for overall welfare: On the one hand, the interest margin increases due to lower agency and funding costs; on the other hand, banks are smaller. However, the first effect dominates. This is summarized by

**COROLLARY 3** *Optimal bank regulation is not a Pareto improvement since it increases the payoff of bankers and corporations but reduces the payoff of investors.*

**Proof:** The welfare implications for investors and corporations follow from  $\gamma^* < \hat{\gamma}$  and the fact that savings are constant; the banker's gains are necessary for overall welfare to increase compared to the market outcome since the combined effect for firms and investors is negative. *Q.E.D.*

This result is consistent with the idea of financial restraint<sup>29</sup> as the regulator keeps interest rates artificially low thereby creating rents for banks and corporations. Low deposit rates are, however, necessary to alleviate risk shifting and to improve financial stability. This is similar to Hellmann et al. (1997) who essentially argue that the government should create rent opportunities in order to induce efficient actions of banks. Moreover, given the interpretation that the banking technology is operated by (small) entrepreneurs exclusively relying on bank loans (due to agency problems and financial constraints), regulation may have an asymmetric effect on the real sector: While corporations benefit from more attractive funding conditions and invest

<sup>28</sup>See Reinhart and Rogoff (2013).

<sup>29</sup>Hellmann et al. (1997) define financial restraint as a set of policies that aim at creating rents (i.e., excess returns compared to a competitive benchmark) within the private sector (e.g., by setting deposit rate ceilings below their competitive level). This differs from financial repression where the government extracts rents from the private sector.

more, small businesses find it difficult to obtain credit since the lending capacity of banks is constrained.

However, three caveats remain: First, investors' savings are exogenous and constant, which is a reasonable assumption in a static model and keeps the analysis tractable. However, one can expect that investors in fact consume more and save less if the return falls. Consequently, the bond return decreases less strongly than predicted and the distributional effects of bank regulation are less pronounced. Second, the welfare function implies that the regulator places a similar weight on the surplus of all agents. If the relative welfare weight of investors, for example, were larger, allocation and distribution would differ from this benchmark. Third, in reality, banks are reluctant to accept regulatory interventions and are spending large amounts on lobbying against tighter regulation. Given their revealed preference, how can one reconcile it with the view that banks may even benefit from regulation? On the one hand, regulation addresses only one particular distortion in our analysis, namely, a pecuniary externality. In reality, many other inefficiencies exist (e.g., contagion, bankruptcy costs) that justify tighter regulation. Given the trade-off between quality and size discussed above, this may eventually reduce bank profits and only raise the interest margin, which is key for incentives. On the other hand, the focus on inside equity removes any scope for a shareholder-manager conflict on the bank's side: The manager may also earn private benefits proportional to bank size like, for instance, prestige such that the negative size effect is much stronger.

Can the welfare gains be redistributed such that regulation is a Pareto-improvement? The welfare gains of corporations can be redistributed by a lump-sum tax. Taxing bankers, however, requires a tax that does not distort bank risk and that is levied on an observable quantity. Even a lump-sum tax would exacerbate risk shifting by reducing residual income and the marginal cost of risk taking. Although non-distorting, a proportional tax on bank profit would be conditioned upon the unobserved loan return.<sup>30</sup> Consequently, only the welfare gains of corporations can be redistributed. The maximum tax revenue is:

$$T = \pi^C(X^*) - \pi^C(\hat{X}) = [F(X^*) - F(\hat{X}) - \gamma^*(X^* - \hat{X})] + (\hat{\gamma} - \gamma^*)\hat{X} \quad (22)$$

Graphically, it corresponds to the area of  $F(X)$  between  $\gamma^*$  and  $\hat{\gamma}$  in figure 5. The first part captures the gains from expansion, the second the gains due to a lower bond return, the second the surplus of rather unproductive firms that are only activated in the second best. The revenue can be used to compensate investors for the decline of their returns; the surplus of corporations is then similar to the market equilibrium. Imposing even higher taxes on corporate firms would clearly make them worse off.

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<sup>30</sup>However, one might argue that although the regulator does not observe  $R$ , bank behavior could be inferred given capital structure and deposit rate.

Obviously, the maximum revenue falls short of investors' welfare loss  $(\hat{\gamma} - \gamma^*)V$  as  $V \geq X$ . A redistributive tax may thus at most mitigate the adverse consequences for investors but not fully compensate them. Hence, regulation is not an efficiency gain according to the Pareto criterion. The very reason why investors cannot be compensated *ex post* is that asymmetric information makes it impossible to tax the welfare gain of bankers in a non-distorting fashion.

## 2.4 Extensions

This section examines two extensions of the model - a zero lower bound and a loan market and entrepreneurial moral hazard - to derive additional insights and policy implications as well as to evaluate the robustness of the results.

### 2.4.1 Zero Lower Bound

In this model, no endogenous mechanism so far prevents negative returns for investors because they need to allocate their wealth between the two assets as their initial endowment would otherwise perish. Although it is a real model and small negative real returns may occur even if nominal interest rates are nonnegative, the importance of the zero lower bound motivates the following extension: Investors can now consume both at the beginning and at the end of the period;  $Q \leq V$  denotes early consumption.<sup>31</sup> Since they are risk-neutral and do not discount future consumption, investors only save if they at least earn a nonnegative net return on deposits and bonds. As soon as the return is strictly positive, they save the entire wealth and only consume at the end of the period as in the baseline model. The interior solution ( $0 < Q < V$ ) thus results if the return equals one.

An immediate implication is that the bond return and the expected deposit rate never fall below one because investors would otherwise not save at all:

$$p(R)b = \gamma \geq 1$$

Recall that the productivity of corporations equals the bond return such that  $F'(X) = \gamma$ . Whenever early consumption is possible, unproductive projects are not realized. Hence, we define  $\bar{X}$  given by  $F'(\bar{X}) = 1$  as the maximum corporate investment. From the resource constraint, it follows that if  $L > 1 - \bar{X} \equiv \bar{L}$ , corporate investment is below the maximum and the bond return larger than one. Thus, investors save and only consume at the end of the period. If, in contrast,  $L < \bar{L}$ , corporate investment equals  $\bar{X}$ , the bond return is one, and investors consume  $Q = V - D - \bar{X} = \bar{L} - L > 0$  at the beginning of the period. When deciding

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<sup>31</sup>An alternative interpretation of early consumption is storage, which yields a safe return of one.

whether to deposit one unit of wealth with the bank, investors compare the offered deposit rate to the opportunity costs:  $\max\{\gamma, 1\} = \max\{F'(X), 1\}$ . In case the bond return is larger than one, they do not consume early and save the entire wealth such that they only agree to an expected interest rate equal to the bond return. If they consume part of their wealth early, however, investors only fund profitable corporations (i.e.,  $\gamma = 1$ ) and require an expected equal to the value of forgone consumption, which is one. Hence, deposits are supplied elastically.

The first best is characterized by  $p(\tilde{R})\tilde{R} = F'(\tilde{X}) > 1$  due to assumption 2, which implies a positive return for investors. Consequently, they save their entire wealth and do not consume early. As long as bank capital is scarce, moral hazard leads to underinvestment by banks such that more resources are allocated to less profitable projects in the corporate sector. As the returns decline, the economy may endogenously hit the zero lower bound. In this case, a corner solution emerges with early consumption and a bond return of one.

In the market equilibrium, the banker's optimization problem and first-order conditions are unchanged.<sup>32</sup> However, investors' opportunity costs are restricted by the lower bound. Combining the banker's first-order condition (15) and the modified participation constraint yields:

$$\max\{F'(X), 1\} = \frac{p(R)R}{1 + \frac{\lambda p'(R)\kappa}{p(R)L}} \quad (23)$$

In equilibrium, the private marginal returns are equalized across sectors: If the solution of the standard model (see proposition 2) is  $\hat{L} > \bar{L}$  such that the economy is above the zero lower bound,  $F'(\hat{X}) > 1$ , it also follows from (23) and the market equilibrium is unaffected by the possibility of early consumption. Whenever the standard model has a solution  $\hat{L} \leq \bar{L}$  and  $F'(\hat{X}) < 1$ , investors will consume part of their wealth early and only fund profitable corporate investments such that  $X = \bar{X}$ . Since their returns are equal to one, deposits are elastically supplied as long as banks offer an expected interest rate of one. As a result,  $L \leq \bar{L}$  and  $Q = \bar{L} - L \geq 0$ . Since the private marginal return of lending equals one, banks are smaller than they would be in the absence of early consumption when they enjoyed a lower funding cost.

Unlike in the baseline model, the regulator now also decides about intertemporal consumption and faces a different (combined) participation constraint as investors' opportunity costs are given by  $\max\{F'(X), 1\}$ . Social welfare consists of the combined output of both sectors, which agents consume at the end of the period, and early consumption. The regulator solves:

**PROGRAM 5** *The regulator maximizes welfare  $W$  by choosing target return  $R$ , equity  $K$ ,*

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<sup>32</sup>This explains why the banker would never consume early even if this was possible: According to (15), he chooses bank size such that  $p(R)R \geq p(R)b \geq 1$ .

lending  $L$ , corporate investment  $X$ , early consumption  $Q$ , and the deposit rate  $b$

$$W = \max_{R,b,L,X,Q,K} Q + F(X) + p(R)RL \quad (24)$$

subject to the banker's incentive compatibility constraint (IC), the capital availability constraint (CA), the combined participation constraint (CP)

$$p(R)b = \max\{F'(X), 1\}$$

the aggregate resource constraint (RC)

$$L + X + Q = 1$$

Comparing the solution of this optimization problem to the market equilibrium and the second best in the baseline model summarized in propositions 2 and 3 leads to:

**PROPOSITION 4** *Whenever investors can consume early, one needs to distinguish between three different cases:*

- *If  $L^* > \bar{L}$  and  $F'(X^*) > 1$  emerge in the baseline model, the second best is unchanged and involves no early consumption.*
- *If  $L^* < \bar{L}$  and  $F'(X^*) < 1$  emerge in the baseline model, the second best is determined by (3), (6), (12), (CP), (RC), (CA), and*

$$1 = \frac{p(R)R}{1 + \frac{\lambda p'(R)\kappa}{p(R)L}} \quad (25)$$

*Bank lending is  $L^\circ \leq \bar{L}$  and corporate investment is  $X^\circ = \bar{X}$ , part of the wealth is consumed early  $Q^\circ = \bar{L} - L^\circ \geq 0$ . The second best coincides with the market equilibrium.*

- *If both  $L^* < \bar{L}$  and  $F'(X^*) < 1$  and  $\hat{L} > \bar{L}$  and  $F'(\hat{X}) > 1$  are solutions of the baseline model, the second best is determined by (3), (6), (12), (25) (CP), (RC), and (CA). Bank lending is  $L^\circ = \bar{L}$  and corporate investment is  $X^\circ = \bar{X}$ , no wealth is consumed early. The second best differs from the market equilibrium.*

$L^*$  and  $\hat{L}$  denote lending in the baseline second best and market equilibrium respectively.

**Proof:** See Appendix 2.A.1

If banks are large enough such that corporate productivity is high enough and investors' net returns are strictly positive, the results of the standard model persist, and the possibility of early



consumption is irrelevant because saving maximizes lifetime consumption. Whenever banks are small, however, many resources are left to corporations which are rather unproductive at the margin such that investors face a negative return. Thus, they consume part of their wealth at the beginning of the period such that capital becomes scarcer, which eventually raises bond return and deposit rate. Compared to the baseline model, the second best differs as the economy is now at the zero lower bound and characterized by  $L^\circ \leq \bar{L}$ ,  $X^\circ = \bar{X}$ ,  $Q^\circ = \bar{L} - L^\circ \geq 0$ . Since the social return of bank lending is generally non-increasing in  $L$ , banks are smaller due to the higher funding cost. In particular, the second best and the market outcome are similar as the main conditions, (23) and (25), coincide. This is due to the fact that investors face constant opportunity costs of supplying deposits such that the deposit rate is independent of the capital allocation and the pecuniary externality vanishes. However, this feature is not necessary: A boundary case is possible where investors earn positive returns in the market equilibrium but regulation, by lowering bank size, brings interest rates down to one. The second best thus differs from the market equilibrium. Intuitively, this may occur if the pecuniary externality is strong and the regulatory intervention is sizable.

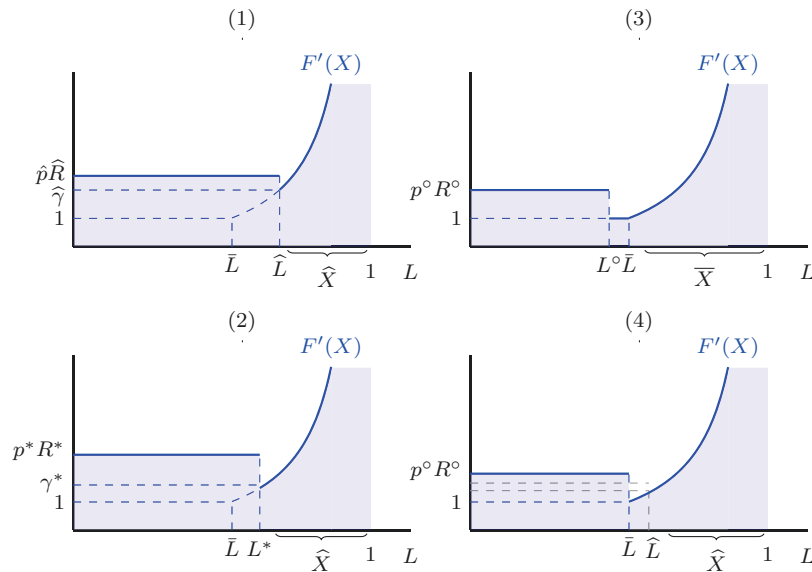


Figure 6: Zero Lower Bound

Panels (1) and (2) illustrate market equilibrium and second best in an economy above the zero lower bound (first case in proposition 4). Panel (3) shows the capital allocation of an economy at the zero lower bound (second case) and panel (4) the boundary case.

Figure 6 illustrates the impact of the zero lower bound: Panels (1) and (2) show market equilibrium and second best with banks large enough such that investors earn positive net returns. Hence, the entire wealth is saved, and the standard model is replicated such that the allocations coincide with their counterparts. One observes that internalizing the pecuniary externality leads to smaller banks, which mitigates risk shifting. The effect of the zero lower bound is illustrated in panel (3): Investors consume part of their wealth at the beginning,

$Q = \bar{L} - L^\circ > 0$ , which fixes the bond return and the deposit rate at one. Hence, the market outcome is second-best. Eventually, panel (4) illustrates the boundary case with second-best lending  $L^\circ = \bar{L}$ . In the market equilibrium, however, banks are larger ( $\hat{L} > \bar{L}$ ) and investors earn a positive return.

The key insight is that if investors consume part of their wealth early, the banks' funding cost is, in fact, constant. Raising deposits - at least marginally - does not tighten participation constraints such that risk shifting of all other banks is unaffected and the pecuniary externality disappears. This line of reasoning implies:

**COROLLARY 4** *If investors can consume early, the pecuniary externality is welfare-reducing as long as bank lending in the market equilibrium is large enough,  $L > \bar{L}$ .*

**Proof:** Immediately follows from proposition 4: The market equilibrium is not second-best in the first and the third case, which both involve a market allocation with  $L > \bar{L}$ . *Q.E.D.*

As soon as  $L \leq \bar{L}$  (second case), investors partly consume their wealth such that the required return on deposits is constant. At the zero lower bound, no pecuniary externality exists, and the market outcome is constrained-efficient. These findings suggest that as soon as investors have the possibility to protect themselves against negative net returns, the pecuniary externality is a relevant, welfare-reducing phenomenon only under some conditions that emerge endogenously. In particular, the economy needs to be above the zero lower bound in the sense that investors earn positive returns and supply deposits not perfectly elastically. This requires that either the underinvestment problem of moral hazard is not too severe or the frictionless technology is productive. The former ensures that banks attract a large deposit volume such that no resources would be wasted in unprofitable projects in the corporate sector. The latter makes sure that enough productive corporations exist such that this sector has the capacity to absorb a large amount of resources.<sup>33</sup> At the zero lower bound, other frictions like failure externalities like, for example, in Repullo (2013) may still motivate intervention. Risk taking is only discouraged by a high capital ratio, whereas creating rents through a low deposit rate is not possible. In other words, capital ratio and the bank's funding cost are disconnected as the latter are constant and independent of the aggregate capital allocation. Thus, investors earn a fixed return and do not suffer from adverse distributional side effects of regulation.

## 2.4.2 Entrepreneurial Moral Hazard and Diversification of Risk

This section adds entrepreneurs and an endogenous loan market, which replaces the shortcut that banks directly invest. Most importantly, entrepreneurs determine target return and loan

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<sup>33</sup>There is a certain tension between these two characteristics as bank size is endogenous and generally decreases in the productivity of the frictionless technology.

risk reflecting the fact that they ultimately decide about investment and that banks cannot perfectly monitor their activities. This extension is motivated by a recent discussion in the literature: Boyd and De Nicoló (2005) show that the negative relationship between bank competition and financial stability that figured prominently in the literature is reversed as soon as borrowers determine risk. Intuitively, loan market competition drives down lending rates and mitigates risk shifting by borrowers. However, such a setup limits the role of banks in risk taking. Therefore, we closely follow the stylized model of Hakenes and Schnabel (2011) that includes both bank and entrepreneurial risk shifting: Whereas a borrower chooses the project's risk-return profile, the banker decides about the diversification of the loan portfolio. Bank risk is thus jointly determined by entrepreneurs and banker. The aim is to explore the role of pecuniary externalities when there is both bank and entrepreneurial moral hazard. In particular, it is *a priori* unclear whether banks are too large or too small in a market equilibrium.

### Risk Taking and Moral Hazard Reconsidered

The main modification is joint risk taking by entrepreneurs and bankers. Loan risk and portfolio diversification are unobservable, which may lead to risk shifting of both agents as they trade off marginal gain and cost of a higher project return and a better diversified portfolio respectively. Entrepreneurs are modeled as follows: There is a continuum of measure one of risk-neutral, potential entrepreneurs with access to a unit-size project characterized by the banking technology (assumption 1): It yields a return  $R$  with probability  $p(R)$  and zero else; the success probability decreases in the return. Entrepreneurs have no private wealth but can borrow from banks at a (gross) lending rate  $r$ . Each entrepreneur faces an opportunity cost  $\theta$  (e.g., forgone labor income, value of leisure) and maximizes the expected surplus:

$$\pi^E = \max_R p(R)(R - r) - \theta \quad (26)$$

The choice is characterized by the first-order condition

$$p(R) + p'(R)(R - r) = 0 \quad (27)$$

Obviously, there is entrepreneurial risk shifting: A high lending rate reduces the marginal cost of investing in a more profitable but riskier project and encourages risk taking. The loan demand is modeled as in Martinez-Miera and Repullo (2010): Entrepreneurs face heterogeneous opportunity costs uniformly distributed on the unit interval,  $\theta \sim U[0, 1]$ . Only entrepreneurs who expect a positive surplus  $\pi^E$  invest:

$$\theta \leq p(R)(R - r) \equiv \bar{\theta}(r)$$

Loan demand equals the fraction of investing entrepreneurs that decreases in the lending rate  $\bar{\theta}'(r) < 0$ . The fraction  $1 - \bar{\theta}$  does invest as the outside option is more attractive.

The banker's model is complemented with portfolio diversification such that banks play an active even though loan risk is determined by borrowers. This captures another key feature of banks, namely, the diversification of risks. Essentially, it is related to a bank's business model: Some banks specialize and provide loans to borrowers with correlated risks such as regional banks or banks primarily lending to a specific sector or type of borrower (e.g., mortgage banks). Others diversify and have a portfolio with weakly correlated returns such as universal or international banks. Following Hakenes and Schnabel (2011), we focus on the two extreme cases of perfect correlation and diversification<sup>34</sup>: Loans are either perfectly correlated with probability  $z$  or perfectly uncorrelated with probability  $1 - z$ . Hence, either the loan portfolio as a whole and thus the bank succeeds with probability  $p(R)$  and fails otherwise or a fraction  $p(R)$  of loans is repaid with certainty. The probability of bank failure is  $z(1 - p(R))$ . The bank is risk-free if its portfolio is perfectly diversified. The banker chooses the probability  $z$ , which is associated with a u-shaped utility cost  $C(z)$  proportional to loans and satisfying  $C(z) \geq 0$ ,  $C'(z_0) = 0$ ,  $C''(z) > 0$  where  $z_0 \in [0, 1]$  reflects the 'natural correlation' and any deviation from this level is costly. One can thus interpret  $C(z)$  as diversification costs for  $z < z_0$  and as specialization costs for  $z > z_0$ .

The contract specifies deposit repayment to investors. As in the baseline model, it satisfies investors' participation constraint, which requires deposits to be fairly priced:

$$[1 - z(1 - p(R))]b = \gamma \quad (28)$$

Since both loan risk and portfolio diversification are unobservable, the contract is feasible if both actions are privately optimal *ex post*. Loan risk (i.e., project return  $R$ ) is determined by entrepreneurs according to (27). The banker, in turn, decides about portfolio correlation (i.e., their business model) after funding is obtained and aims at maximizing expected profit. This is captured by the incentive compatibility constraint:

$$z = \arg \max_z [p(R)r - [1 - z(1 - p(R))]b(1 - \kappa) - C(z)] L \quad (29)$$

The corresponding first-order condition is:

$$(1 - p(R))b(1 - \kappa) = C'(z) \quad (30)$$

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<sup>34</sup>Portfolio correlation is either modeled using a numerical approach [e.g., Martinez-Miera and Repullo (2010)] or ruled out by assuming perfect correlation [e.g., Holmström and Tirole (1997), Repullo (2013), and Gersbach and Rochet (2012)].

Moral hazard leads to overspecialization ( $z > z_0$ ) as soon as the bank is funded by debt. Intuitively, specializing lowers the expected value of the debt burden, whereas expected loan return is unaffected. Hence, the banker is even willing to incur specialization costs. Overspecialization is stronger in case leverage, deposit rate, and loan risk are high. Consequently, entrepreneurial and bank risk taking are determined by three conditions (27), (30), and (28). They are characterized by the following lemma:

**LEMMA 3** *Target return satisfies  $\frac{\partial R}{\partial r} > 0$ ; portfolio diversification and deposit rate satisfy  $\frac{\partial z}{\partial \kappa} < 0$ ,  $\frac{\partial z}{\partial \gamma} \geq 0$ , and  $\frac{\partial z}{\partial r} > 0$  as well as  $\frac{\partial b}{\partial \kappa} < 0$ ,  $\frac{\partial b}{\partial \gamma} \geq 0$ , and  $\frac{\partial b}{\partial r} > 0$ .*

**Proof:** See Appendix 2.A.1.

In contrast to the standard model, loan risk only depends on the lending rate, which balances loan demand and supply. The finding that portfolio diversification increases in the capital ratio but decreases in the bond return is standard. The effect of the lending rate stems from the entrepreneur's risk-shifting response, which raises the gains of specializing. Consequently, higher lending rates raise both loan risk and portfolio correlation.

### Equilibrium Allocation

We first briefly characterize the competitive market equilibrium that largely resembles the baseline model.<sup>35</sup> However, there is one key difference: The project return is now determined by entrepreneurs according to (27). Therefore, bankers only consider their own risk-shifting (i.e., overspecialization) problem when choosing bank size and capital structure. Accordingly, loan risk (project return  $R$ ) and portfolio correlation follow from the incentive compatibility constraints of entrepreneur (27) and banker (30). The choices of investors, who allocate their savings between deposits and corporate bonds, and corporations, which invest if sufficiently productive, are similar to the baseline model. In equilibrium, bond, deposit, and loan market simultaneously clear; the latter requires  $L = \bar{\theta}(r)$ . The equilibrium is characterized by:

**LEMMA 4** *In the market equilibrium, the capital allocation is determined by*

$$F'(X) = \frac{p(R)R - C(z) - L}{1 - \frac{\lambda_1(1-p(R))\kappa}{[1-z(1-p(R))]L}} \quad (31)$$

where  $\lambda_1$  is the Lagrange multiplier of the banker's incentive compatibility constraint (30).

**Proof:** See Appendix 2.A.1.

This condition requires the private marginal returns in both sectors to be equalized taking

<sup>35</sup>A more extensive derivation of the market equilibrium can be found in Appendix 2.A.1.

into account bank risk shifting. Note that entrepreneurs' opportunity costs lower the marginal return earned by banks compared to the standard model.<sup>36</sup>

The regulator's objective is to maximize social welfare, the expected surplus of all four agents:  $W = \pi^B + \pi^E + \pi^F + \pi^I$ . In contrast to the standard model, two counteracting pecuniary externalities exist: Banks fail to internalize that (i) raising deposits tightens investors' participation constraint increasing the deposit rate that leads to overspecialization of all other banks and (ii) their loan supply lowers the lending rate thus alleviating entrepreneurial risk shifting. The externalities are intertwined because an increase in lending requires a similar increase in deposits (unless the bank is fully equity funded). Since the regulator observes neither entrepreneurial nor bank risk taking, he designs a loan and a deposit contract that are feasible and satisfy the incentive compatibility constraints. However, the regulator cannot freely choose lending and deposit rate because participation of investors, corporations, and entrepreneurs needs to be ensured. This requires (expected) returns on deposits and bonds to be equalized [i.e.,  $(1 - z(1 - p(R)))b = F'(X)$  when using the combined formulation] and the loan volume to be consistent with the mass of entrepreneurs willing to invest [i.e.,  $\bar{\theta}(r) = L$ ]. The regulator solves the following problem:

**PROGRAM 6** *The regulator maximizes social welfare  $W$  by choosing project return  $R$ , diversification  $z$ , bank lending  $L$ , corporate investment  $X$ , equity  $K$ , and deposit and lending rates  $b$  and  $r$ :*

$$W = \max_{R,z,b,r,L,X,K} F(X) + [p(R)R - C(z)]L - \int_0^L \theta d\theta \quad (32)$$

*subject to incentive compatibility constraints of banker ( $IC^B$ )*

$$z = \arg \max_z [p(R)r - [1 - z(1 - p(R))]b(1 - \kappa) - C(z)] L$$

*and entrepreneur ( $IC^E$ )*

$$R = \arg \max_R p(R)(R - r)$$

*the combined participation constraint ( $CP$ )*

$$[1 - z(1 - p(R))]b = F'(X)$$

*and entrepreneurs' loan demand ( $LD$ )*

$$p(R - r) = L$$

*the aggregate resource constraint ( $RC$ ) and the capital availability constraint ( $CA$ ).*

Solving program 6 yields the second best summarized in

<sup>36</sup>This effect is captured by the numerator which uses  $r = R - \bar{\theta}/p$ .

**PROPOSITION 5** *The equilibrium allocation  $\{R', z', L', X', K', D', r', b', \gamma'\}$  is characterized by (3), (7), (27), (30), (CP), (LD), (RC), (CA), and*

$$F'(X) = \frac{p(R)R - C(z) - L}{1 - \frac{\lambda_1(1-p(R))\kappa}{(1-PD)L} \left[ 1 - \frac{(1-\kappa)}{(1-PD)b} \frac{F''(X)L}{\kappa} \right] - \frac{\lambda_2 p'(R)}{(1-PD)p(R)b}} \quad (33)$$

where  $\lambda_1 < 0$  and  $\lambda_2 < 0$  are the Lagrange multipliers of  $(IC^B)$  and  $(IC^E)$  and  $PD = z(1 - p(R))$  is a shortcut for the probability of bank failure. The pecuniary externalities are negative overall if in equilibrium:

$$-\frac{\lambda_1(1-p(R))b}{\varepsilon_D} + \frac{\lambda_2 p'(R)r}{\varepsilon_L} > 0 \quad (34)$$

$\varepsilon_D > 0$  and  $\varepsilon_L < 0$  are the interest rate elasticities of deposit supply and loan demand.

**Proof:** See Appendix 2.A.1.

The key condition is (33); it implies that the capital allocation equalizes social marginal returns of both sectors taking into account all incentive effects. In contrast to the private return, which is a critical determinant of the market outcome in (31), the social return includes the two counteracting pecuniary externalities as explained above. They are captured by the third and fourth term of the denominator of (33): The externality associated with the deposit rate is negative and lowers the social return compared to the private; the externality associated with the lending rate is positive and has an opposite effect. Consequently, if there is only bank moral hazard (i.e.,  $\lambda_2 = 0$  and  $R$  is first-best), raising deposits exacerbates risk shifting and leads to inefficient overspecialization.<sup>37</sup> If there is only entrepreneurial moral hazard (i.e.,  $\lambda_1 = 0$  and  $z$  is first-best) such as in Boyd and De Nicoló (2005), a large loan supply discourages risk shifting and is welfare-improving. In a framework characterized by both entrepreneurial and bank moral hazard, it is *a priori* ambiguous whether bank lending is associated with a positive or negative externality overall. This ambiguity is consistent with the positive findings of Hakenes and Schnabel (2011), who study the effect of capital requirements on risk taking.

Whether the pecuniary externalities are positive or negative has far-reaching consequences: In one case, banks are generically too large and have too much leverage, in the other case, they are too small. Thus, the regulator's response fundamentally differs. Which of the two pecuniary externalities eventually prevails is shown in (34): Intuitively, it depends on (i) the elasticities of loan demand and deposit supply<sup>38</sup> (i.e., inelastic supply and demand are associated with large price effects) and (ii) the severity of the agency problems of banker and entrepreneur (captured by the Lagrange multipliers). Hence, the overall welfare effect of the pecuniary externalities is

<sup>37</sup>This essentially reproduces the result of the baseline model with a different risk variable.

<sup>38</sup>The elasticity of deposit supply is expressed in terms of opportunity costs (safe bond return  $\gamma$ ) in order to disentangle scarcity and risk, which are reflected by the deposit rate. The elasticity is positive as higher bond returns discourage corporate investment and investors supply more deposits.

negative if loan demand is rather elastic and entrepreneurial moral hazard of minor importance compared to deposit supply and bank moral hazard respectively. In this case, the analysis leads to similar conclusions, namely, the need for smaller banks funded by a larger share of equity. The key insight is a more complex relationship between bank lending and capital structure and risk taking if there is entrepreneurial moral hazard as well: Pecuniary externalities associated with loans and deposits influence different interest rates with counteracting effects. Therefore, it is *a priori* unclear whether banks are generically too large and have too much leverage or not. Unless loan demand is very inelastic and the entrepreneur's agency problem severe, however, the results of proposition 3 are unchanged, and internalizing the pecuniary externalities reduces bank size and leverage.

## 2.5 Conclusion

This paper studies moral hazard and bank risk taking and examines to what extent this provides a rationale for macroprudential regulation. It develops a static model of banking with an endogenous allocation of capital between two sectors of the economy: a banking sector where risk taking is subject to moral hazard and a corporate sector with a frictionless technology and no risk. The innovation is that this approach enables us to identify a welfare-reducing pecuniary externality, which results from the combination of moral hazard and competition for deposits that are ultimately scarce. We characterize optimal bank regulation, which aims at internalizing the externality, and shed light on its distributional consequences. The analysis yields six key insights: (i) In the presence of moral hazard, debt distorts risk taking and leads to the well-known risk-shifting problem. Discipline can be provided by equity and low funding cost that both raise the banker's 'skin in the game' and increase the private cost of risk taking. (ii) The market outcome is constrained-inefficient because of a pecuniary externality: Banks fail to internalize that through its impact on the aggregate allocation attracting deposits eventually increases the deposit rate and leads to excessive risk taking of all banks. As a result, banks are inefficiently large, have too much leverage, earn low profits, and take excessive risk. This distortion provides a strong rationale for macroprudential regulation as it does not require the presence of typical frictions such as contagion, guarantees, and incorrectly priced deposit insurance. (iii) The pecuniary externality can be internalized by prudential regulation, for example capital requirements, or by issuing a specific number of banking licenses thereby creating imperfect competition. In this case, banks do not directly internalize the pecuniary externality but strategic interaction incidentally achieves the second best. Accordingly, if the banking sector is more concentrated, liberalization may improve efficiency; if it is more competitive, restraining competition has a positive welfare effect. (iv) Irrespective of the instrument, optimal regulation



rewards prudent banks by keeping the funding cost artificially low and increasing their informational rent if successful; this discourages risk taking because the forgone profit in case of failure is larger. (v) Optimal regulation is not a Pareto-improvement as the necessary reallocation of capital to the corporate sector implies a decline of investors' returns that favors banks and firms in the corporate sector. Redistributive *ex post* taxation cannot fully offset this effect without distorting incentives. (vi) If investors can protect themselves against negative net returns, the pecuniary externality is only welfare-reducing as long as the economy is above the zero lower bound. This requires a large banking sector or a relatively productive frictionless technology. Otherwise, the deposit supply is perfectly elastic and the pecuniary externality vanishes. If borrowers determine loan risk and the banker chooses portfolio diversification as in Hakenes and Schnabel (2011), two counteracting pecuniary externalities associated with lending and deposit rate exist. Whether they are welfare-reducing overall crucially depends on the severity of banker's and borrower's risk-shifting problems and on the elasticities of loan demand and deposit supply.

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## 2.A Appendix

### 2.A.1 Proofs and Derivations

**Proof of Proposition 1** The independence of  $R$  from capital structure and size immediately follows from (9). The zero profit margin is implied by (10) and  $F'(X) = p(R)b$  by (3) and (5). The neutrality of the allocation w.r.t. the wealth distribution follows from (10), which shows that the bank's size  $L$  only depends on technological characteristics. The independence of social welfare from the supply of bank capital can be shown by an Envelope argument:  $\frac{\partial W}{\partial K_B} = 0$ . Eventually, one needs to show that this allocation can be implemented as a market equilibrium: The banker chooses  $R$ ,  $b$ ,  $L$ , and  $K$  to maximize expected profit

$$\pi^B = \max_{R,b,L,K} p(R)[R - b(1 - \kappa)]L + \gamma(K_B - K)$$

subject to the investors' participation constraint (5) and the capital availability constraint  $K \leq K_B$ . The corresponding first-order conditions are (5), (9), and

$$\begin{aligned} p(R)b &= p(R)R \\ p(R)b &= \gamma + \zeta \end{aligned}$$

where  $\zeta$  denotes the Lagrange multiplier of the capital availability constraint. The bank expands until it earns zero expected profit (i.e.,  $b = R$ ); the participation constraint pins down the risk-adjusted deposit rate  $b = \frac{\gamma}{p(R)}$ . Therefore,  $\zeta = 0$  and  $K_B \geq K$ . Traditional firms only invest if sufficiently productive such that  $F'(X) = \gamma$  as implied by (3). Furthermore, bond and deposit markets clear, and (6) and (7) hold. Combining these results yields (10) such that the competitive market equilibrium coincides with the first-best allocation. *Q.E.D*

**Proof of Lemma 1** Target return and deposit rate are jointly determined by the constraints (5) and (12). One may derive the Jacobian matrix:

$$J = \begin{bmatrix} 2p'(R) + p''(R)[R - b(1 - \kappa)] & -p'(R)(1 - \kappa) \\ p'(R)b & p(R) \end{bmatrix}$$

The Jacobian determinant is:

$$\nabla = [2p'(R) + p''(R)(R - b(1 - \kappa))]p + p'(R)^2b(1 - \kappa) < 0 \quad (35)$$

The negative sign can be shown graphically: In figure 3, the IC- is steeper than the PC-curve

in the intersection point, which is necessary as the former is a concave and the latter a convex function. The slopes can be related to the Jacobian. Thus, whenever a feasible contract exists (i.e.,  $\kappa < \kappa_0$ ), property (35) holds. Using Cramer's rule, we obtain the sensitivities:

$$\begin{aligned} \frac{\partial R}{\partial \kappa} &= -\frac{p'(R)p(R)b}{\nabla} < 0 & \frac{\partial R}{\partial \gamma} &= \frac{p'(R)(1-\kappa)}{\nabla} \geq 0 \\ \frac{\partial b}{\partial \kappa} &= \frac{p'(R)^2 b}{\nabla} < 0 & \frac{\partial b}{\partial \gamma} &= \frac{2p'(R) + p''(R)(R - b(1-\kappa))}{\nabla} > 0 \end{aligned}$$

*Q.E.D.*

**Proof of Proposition 2** Replacing (IC) by the first-order condition (12), one obtains a Lagrangian with three constraints and the multipliers  $\lambda$ ,  $\mu$ , and  $\zeta$ :

$$\mathcal{L} = p(R)[R - b(1-\kappa)]L + \gamma(K_B - K) + \lambda[p(R) + p'(R)(R - b(1-\kappa))] + \mu[p(R)b - \gamma] + \zeta[K_B - K]$$

The first-order conditions are

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial L} &= p(R)(R - b) - \frac{\lambda p'(R)bK}{L^2} = 0 \\ \frac{\partial \mathcal{L}}{\partial b} &= -p(R)(1-\kappa)L - \lambda p'(R)(1-\kappa) + \mu p(R) = 0 \\ \frac{\partial \mathcal{L}}{\partial R} &= \lambda[2p'(R) + p''(R)(R - b(1-\kappa))] + \mu p'(R)b = 0 \\ \frac{\partial \mathcal{L}}{\partial K} &= p(R)b - \gamma + \frac{\lambda p'(R)b}{L} - \zeta = 0 \end{aligned}$$

as well as the constraints (12), (PC), and (CA) and complementary slackness  $\zeta(K_B - K) = 0$ . The first condition equals (15); together with (PC) and (3) it yields (16). Solving the first-order conditions using (PC) yields the Lagrange multipliers:

$$\begin{aligned} \lambda &= -\frac{p'(R)p(R)b(1-\kappa)L}{[2p' + p''(R - b(1-\kappa))]p + p'^2 b(1-\kappa)} \\ \mu &= \frac{[2p' + p''(R - b(1-\kappa))]p(1-\kappa)L}{[2p' + p''(R - b(1-\kappa))]p + p'^2 b(1-\kappa)} \\ \zeta &= \frac{\lambda p'(R)b}{L} \end{aligned}$$

Note that  $\lambda \leq 0$ ,  $\mu \geq 0$ , and  $\zeta \geq 0$  due to property (35); if  $L$  reaches its upper bound consistent with a feasible financing contract (i.e.,  $\kappa = \kappa_0$ ),  $\lambda$  diverges to infinity.<sup>39</sup> From the first-order condition (15), one can conclude that the banker never expands beyond  $L = \frac{K_B}{\kappa_0}$  because the marginal cost is prohibitively high. Thus, a feasible financing contract exists in equilibrium. Complementary slackness requires

$$\zeta(K_B - K) = 0$$

<sup>39</sup>This is due to (35) which then holds with equality.

When substituting for  $\lambda$ , it follows that  $\zeta$  is an implicit function of the capital ratio  $\kappa = \frac{K}{L}$ , with  $\zeta = 0$  if  $\kappa = 1$  and  $\zeta > 0$  else. Therefore, only two solutions are consistent with complementary slackness:

$$K = \{K_B, L\}$$

If  $K = L$ ,  $\lambda = 0$  and the first-order conditions (16) and (10) coincide. Thus, the first best summarized in proposition 1 is restored. This can only be true if  $L \leq K_B$ . Using the resource constraint, this implies  $\exists X \geq 1 - K_B : F'(X) = p(\widehat{R})\widehat{R}$  where  $R$  is given by condition the f.o.c. of the incentive compatibility constraint (9). Inverting this function and using  $L = 1 - X$  yields condition (17). If  $K = K_B$ ,  $\lambda < 0$  such that the first-order condition (16) differs from (10) in the first best. It follows that  $F'(X) = p(R)b < p(R)R$ , which implies a positive lending spread. The banker always chooses lending  $L$  as to ensure a feasible financing contract.<sup>40</sup> In addition,  $\widehat{R} \geq \widetilde{R}$  immediately follows from (12). Comparing (16) to (10) implies  $F'(\widehat{X}) < p(\widetilde{R})\widetilde{R} = F'(\widetilde{X})$ . Since  $F(X)$  is concave, it follows that  $\widehat{X} > \widetilde{X}$  and from the market clearing conditions (6) and (7)  $\widehat{L} < \widetilde{L}$ . Eventually, the deadweight loss,  $\Delta W = \widehat{W} - \widetilde{W}$ , is:

$$\Delta W = p(\widetilde{R})\widetilde{R}\widetilde{L} - p(\widehat{R})\widehat{R}\widehat{L} + F(\widetilde{X}) - F(\widehat{X})$$

Expanding by  $p(\widetilde{R})\widetilde{R}\widehat{L}$  and using  $p(\widetilde{R})\widetilde{R} = F'(\widetilde{X})$  as well as  $L = 1 - X$ , one obtains:

$$\Delta W = [p(\widetilde{R})\widetilde{R} - p(\widehat{R})\widehat{R}]\widehat{L} + F'(\widetilde{X})[\widehat{X} - \widetilde{X}] + F(\widetilde{X}) - F(\widehat{X})$$

The first term in square brackets, measuring the quality deterioration due to higher portfolio risk, is unambiguously positive. The second and third term reflect the distortion of the bank's size resulting in a smaller banking sector (captured by the second term, positive) but in larger investment in the corporate sector (captured by the third term, negative). The concavity of  $F(X)$  ensures that the combined size effect is positive overall such that there is a positive deadweight loss because of moral hazard. *Q.E.D.*

**Proof of Proposition 3** Replacing (IC) by the first-order condition (12), one can rewrite program 3 as a Lagrangian with four constraints and the multipliers  $\lambda$ ,  $\mu$ ,  $\eta$ , and  $\zeta$ :

$$\begin{aligned} \mathcal{L} = & F(X) + p(R)RL + \lambda[p(R) + p'(R)(R - b(1 - \kappa))] \\ & + \mu[p(R)b - F'(X)] + \eta[1 - L - X] + \zeta[K_B - K] \end{aligned}$$

The first-order conditions are

$$\frac{\partial \mathcal{L}}{\partial L} = p(R)R - \frac{\lambda p'(R)bK}{L^2} - \eta = 0$$

<sup>40</sup>If  $L$  exceeds the upper bound, the Lagrange multiplier is infinitely large such that the marginal return of bank lending drops to zero and is inconsistent with (16).

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial X} &= F'(X) - \mu F''(X) - \eta = 0 \\
\frac{\partial \mathcal{L}}{\partial b} &= -\lambda p'(R)(1 - \kappa) + \mu p(R) = 0 \\
\frac{\partial \mathcal{L}}{\partial R} &= [p + p'(R)R]L + \lambda[2p' + p''(R)(R - b(1 - \kappa))] + \mu p'(R)b = 0 \\
\frac{\partial \mathcal{L}}{\partial K} &= \frac{\lambda p'(R)b}{L} - \zeta = 0
\end{aligned}$$

as well as the constraints (12), (CP), (RC), and (CA). From these conditions one obtains the Lagrange multipliers:

$$\begin{aligned}
\eta &= F'(X) - \mu F''(X) > 0 \\
\lambda &= -\frac{p'(R)p(R)b(1 - \kappa)L}{[2p' + p''(R - b(1 - \kappa))]p + p'^2b(1 - \kappa)} < 0 \\
\mu &= -\frac{p'^2b(1 - \kappa)^2L}{[2p' + p''(R - b(1 - \kappa))]p + p'^2b(1 - \kappa)} > 0 \\
\zeta &= \frac{\lambda p'(R)b}{L} \geq 0
\end{aligned}$$

The signs again follow from property (35), which implies that the denominator is negative. Note that the Lagrange multipliers of (IC) and (CA) are the same functions as in the market equilibrium. Combining the first-order conditions w.r.t.  $L$  and  $X$  and substituting for  $\eta$  and  $\mu$  yields condition (19). In addition, deposits  $D$  and bond return  $\gamma$  follow from (3) and (7). Complementary slackness again implies  $K = \{K_B, L\}$ . If  $K_B \geq G[p(\tilde{R})\tilde{R}]$ , the regulator replicates the first best. If this condition is not met, bankers' wealth is completely invested as inside equity ( $K^* = K_B$ ). The right-hand side denominator in (19) is then strictly larger than in (16) due to the presence of the third, positive term, which implies that social are smaller than private marginal returns of banking. As a result, the capital allocation differs between the two equilibria,  $L^* \neq \hat{L}$ . We show  $L^* < \hat{L}$  by contradiction: From  $L^* > \hat{L}$ , it follows that  $X^* < \hat{X}$  and  $F'(X^*) > F'(\hat{X})$ . Using the first-order conditions (16) and (19) yields

$$\frac{1 + \hat{\varphi}}{1 + \varphi^* \left[ 1 - \frac{1 - \kappa^*}{F'(X^*)} \frac{F''(X^*)L^*}{\kappa^*} \right]} > \frac{p(\hat{R})\hat{R}}{p(R^*)R^*} \quad (36)$$

where  $\varphi = \frac{\lambda p'(R)K_B}{p(R)L^2}$ . The right-hand side of the inequality is larger than one as  $L^* > \hat{L}$  implies  $\kappa^* < \hat{\kappa}$  and  $b^* > \hat{b}$  such that  $R^* > \hat{R}$  and the expected return is smaller in the second best. Condition (36) requires  $\hat{\varphi} > \varphi^* \left[ 1 - \frac{1 - \kappa^*}{F'(X^*)} \frac{F''(X^*)L^*}{\kappa^*} \right]$ . Since we assume  $L^* > \hat{L}$ , this is only possible if  $\varphi$  decreases in  $L$  such that  $\hat{\varphi} > \varphi^*$ . However, it can be shown that  $\varphi$  is generally non-decreasing in  $L$ ; it is zero for  $L \leq K_B$  and diverges to infinity if  $L$  is close to the upper bound consistent with a feasible financing contract. Consequently, condition (36) is incompatible  $L^* > \hat{L}$ , and the second-best allocation has  $L^* < \hat{L}$ . *Q.E.D.*

**Proof of Corollary 1** To show that the second-best allocation can be implemented by capital requirements, we add the regulatory constraint  $\kappa \geq \kappa^*$  to program 2. The Lagrangian is:

$$\begin{aligned} \mathcal{L} = & p(R)[R - b(1 - \kappa)]L + \gamma(K_B - K) + \lambda [p(R) + p'(R)(R - b(1 - \kappa))] \\ & + \mu[p(R)b - \gamma] + \zeta[K_B - K] + \psi[\kappa - \kappa^*] \end{aligned}$$

The Kuhn-Tucker conditions are

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial L} &= p(R)(R - b) - \frac{\lambda p'(R)bK}{L^2} + \frac{\psi K}{L^2} = 0 \\ \frac{\partial \mathcal{L}}{\partial K} &= p(R)b - \gamma + \frac{\lambda p'(R)b}{L} - \zeta + \frac{\psi}{L} = 0 \\ \frac{\partial \mathcal{L}}{\partial \psi} &= \kappa - \kappa^* \geq 0; \quad \frac{\partial \mathcal{L}}{\partial \psi} \psi = \psi(\kappa - \kappa^*) = 0 \end{aligned}$$

The other conditions are similar to the market equilibrium (see, proof of proposition 2). If the regulatory constraint does not bind,  $\kappa > \kappa^*$ , complementary slackness requires  $\psi = 0$  and the first-order conditions coincide with those of the unregulated market equilibrium. Critically, the solution is then  $\kappa = \hat{\kappa}$ . Since  $\kappa^* > \hat{\kappa}$ , however, this outcome is impossible. Hence, the banker always chooses the corner solution  $\kappa = \kappa^*$ . Whenever bank capital is scarce, (CA) binds such that  $L = L^*$  and  $X = X^*$ . The corresponding bond return  $\gamma^* = F'(X^*)$  and capital requirements  $\kappa^*$  lead the same IC and PC as in the second best such that the constrained-efficient risk-return profile is chosen.

Whenever the regulator imposes a deposit rate ceiling  $b \leq b^*$ , the regulatory constraint is added to the banker's optimization problem. Using a similar argument as above, one can show that the banker always chooses  $b = b^*$ . From figure 3, one may conclude that several pairs  $\{\kappa, \gamma\}$  satisfy (IC) and (PC), once  $b$  equals  $b^*$ . However, only  $\kappa^*$  and  $\gamma^*$  are consistent with resource constraint and the choice of corporations: If the banker chose a slightly larger  $\kappa$ , incentive compatibility would imply a smaller target return (i.e., the IC-curve in figure 3 shifts to the left) but the bond return would fall due to increased corporate investment and the participation constraint thus allows for a larger target return (i.e., the PC-curve shifts to the right). As a result, the deposit rate determined by the intersection of IC and PC falls short of  $b^*$  such that the deposit rate ceiling does not bind. However, the banker would never choose such an outcome because if the regulatory constraint is slack, his optimal choice would be  $\hat{b} > b^*$ . *Q.E.D.*

**Proof of Lemma 2** Bank  $i$  solves program 6; the Lagrangian is:

$$\begin{aligned} \mathcal{L} = & p(R_i)[R_i - b_i(1 - \kappa_i)]L_i + \gamma(K_{Bi} - K_i) + \lambda_i [p(R_i) + p'(R_i)(R_i - b_i(1 - \kappa_i))] \\ & + \mu_i \left[ p(R_i)b_i - F' \left( 1 - \sum_{i=1}^N L_i \right) \right] + \zeta_i [K_{Bi} - K_i] \end{aligned}$$



Since  $X = 1 - \sum_{i=1}^N L_i$ , the corresponding first-order conditions are

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial L_i} &= p(R_i)(R_i - b_i) - \frac{\lambda_i p'(R_i) b_i K_i}{L_i^2} + \mu_i F''(X) = 0 \\ \frac{\partial \mathcal{L}}{\partial b_i} &= -p(R_i)(1 - \kappa_i)L_i - \lambda_i p'(R_i)(1 - \kappa_i) + \mu_i p(R_i) = 0 \\ \frac{\partial \mathcal{L}}{\partial R_i} &= \lambda_i [2p'(R_i) + p''(R_i)(R_i - b_i(1 - \kappa_i))] + \mu_i p'(R_i) b_i = 0 \\ \frac{\partial \mathcal{L}}{\partial K_i} &= p(R_i) b_i - \gamma + \frac{\lambda p'(R_i) b_i}{L_i} - \zeta_i = 0\end{aligned}$$

as well as the constraints (12), (PC), and (CA). Since  $\zeta_i > 0$ , the capital availability constraint again binds such that  $K_i = K_{Bi}$ . Rearranging the first-order condition w.r.t.  $L_i$  and substituting for  $\mu_i$  as well as using (PC) yields

$$F'(X) = \frac{p(R_i)R_i}{1 + \frac{\lambda_i p'(R_i) \kappa_i}{p(R_i) L_i} \left[ 1 - \frac{(1 - \kappa_i) L_i F''(X)}{p(R_i) b_i \kappa_i} \right] - \frac{(1 - \kappa_i) L_i F''(X)}{p(R_i) b_i}} \quad (37)$$

which describes the optimal choice of bank  $i$ . The Lagrange multipliers are determined as under perfect competition. In the symmetric Cournot-Nash equilibrium, obviously  $R_i = R$  and, by (PC),  $b_i = b$ . In addition,  $L_i = \frac{L}{N}$  where  $L$  denotes aggregate loans.  $K_{Bi} = \frac{K_B}{N}$  and  $\kappa_i = \frac{K_{Bi}}{L_i} = \kappa$  then imply  $\lambda_i = \frac{\lambda}{N}$  and  $\mu_i = \frac{\mu}{N}$ . Substituting this into (37) yields (20). For  $N \rightarrow \infty$  the third and fourth term in the denominator vanish, such that the allocation converges to the perfectly competitive equilibrium. *Q.E.D.*

**Proof of Proposition 4** Solving program 5 generally yields similar first-order conditions as in the baseline model (see proof of proposition 3). However, the first-order condition for  $X$  differs and there is an additional choice variable  $Q$ :

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial X} &= F'(X) - \mathbb{1}_{\{X < \bar{X}\}} \mu F''(X) - \eta = 0 \\ \frac{\partial \mathcal{L}}{\partial Q} &= 1 - \eta \leq 0\end{aligned}$$

Combining these two conditions with  $\frac{\partial \mathcal{L}}{\partial L} = 0$  and substituting for  $p(R)b$  using (CP), yields:

$$\max\{F'(X), 1\} = \frac{p(R)R}{1 + \frac{\lambda p'(R) \kappa}{p(R)L} \left[ 1 - \mathbb{1}_{\{X < \bar{X}\}} \frac{(1 - \kappa) F''(X)L}{p(R)b \kappa} \right]} \quad (38)$$

The l.h.s. is the marginal cost of bank lending (either the forgone return on corporate investment or early consumption), the r.h.s. captures its social marginal return. For low values of  $X$ , the latter is similar to the baseline model; for high values, it coincides with the private return that is a determinant of the market equilibrium. In addition, there is a discontinuous jump

at  $X = \bar{X}$  and  $L = \bar{L}$  because the pecuniary externality disappears as soon as investors' opportunity costs are constant (i.e., if  $L < \bar{L}$ ). First, a solution may emerge with  $X < \bar{X}$  and  $F'(X) > 1$ . The above condition and all constraints are thus identical to the standard model such that the allocations are similar. Early consumption is zero since in this case because  $\eta = F'(X) - \mu F''(X) > 1$  implies  $\frac{\partial \mathcal{L}}{\partial Q} < 0$ . This outcome requires  $L^* > \bar{L}$  or, equivalently,  $F'(X^*) > 1$  in the baseline model (proposition 3). It gives the first case of proposition 4.

If no such a solution results (i.e., the second best in the baseline model has  $F'(X) < 1$ ), it immediately follows from  $\frac{\partial \mathcal{L}}{\partial Q} = \frac{\partial \mathcal{L}}{\partial X} = 0$  that  $X^\circ = \bar{X}$  and  $F'(X^\circ) = 1$ . Condition (38) thus simplifies to:

$$1 = \frac{p(R)R}{1 + \frac{\lambda p'(R)\kappa}{p(R)L}}$$

Together with the constraints, this usually yields  $L^\circ \leq \bar{L}$  and  $Q^\circ = \bar{L} - L^\circ \geq 0$ . In this case, the second best and the market equilibrium are determined by the same conditions such that the two allocations coincide. This corresponds to the second case in proposition 4. However, one might also obtain  $L > \bar{L}$  which clearly violates  $X = \bar{X}$ . This may occur due to the discontinuity of the social marginal return, namely, if it is larger than one at  $X = \bar{X}$  but smaller than one for a slightly smaller value of  $X$ . In this boundary case, condition (38) is not exactly satisfied and the second best is characterized by  $L^\circ = \bar{L}$  and  $X^\circ = \bar{X}$ . Note that the market equilibrium still has  $F'(X) > 1$  such that the two allocations are not the same. This establishes the third case in proposition 4. This outcome results whenever in the baseline model, the market equilibrium (proposition 2) involves  $\hat{L} > \bar{L}$  such that the two private marginal returns earned in both sectors are larger than one but the second best involves  $\bar{L} > L^*$  and social marginal returns smaller than one. *Q.E.D.*

**Proof of Lemma 3** The target return is determined by the entrepreneur's first-order condition (27). Differentiating yields:

$$\frac{\partial R}{\partial r} = \frac{p'(R)}{2p' + p''(R - r)} > 0$$

As the banker's diversification choice and the deposit rate are jointly characterized by conditions (30) and (28), we set up the Jacobian matrix:

$$J = \begin{bmatrix} -C'''(z) & (1 - p(R))(1 - \kappa) \\ -(1 - p(R))b & 1 - z(1 - p(R)) \end{bmatrix}$$

The Jacobian determinant is

$$\nabla = -C'''(z)[1 - z(1 - p(R))]p + (1 - p(R))^2 b(1 - \kappa) < 0 \quad (39)$$

By similar considerations as in the baseline, it can be shown that the Jacobian determinant is

negative.<sup>41</sup> Using Cramer's rule, the sensitivities are:

$$\begin{aligned} \frac{\partial z}{\partial \kappa} &= \frac{(1-p(R))[1-z(1-p(R))]b}{\nabla} < 0 & \frac{\partial b}{\partial \kappa} &= \frac{(1-p(R))^2 b^2}{\nabla} < 0 \\ \frac{\partial z}{\partial \gamma} &= -\frac{(1-p)(1-\kappa)}{\nabla} \geq 0 & \frac{\partial b}{\partial \gamma} &= -\frac{C''(z)}{\nabla} > 0 \\ \frac{\partial z}{\partial r} &= \frac{p'(R)b(1-\kappa)}{\nabla} \frac{\partial R}{\partial r} \geq 0 & \frac{\partial b}{\partial r} &= \frac{p'(R)b[C''(z) + C'''(z)z]}{\nabla} \frac{\partial R}{\partial r} > 0 \end{aligned}$$

*Q.E.D.*

**Proof of Lemma 4** The entrepreneur chooses project return  $R$  according to (27). Following Hakenes and Schnabel (2011), the banker maximizes expected profit subject to (IC), (PC), and (CA) with the corresponding multipliers  $\lambda_1$ ,  $\lambda_2$ ,  $\mu_1$ , and  $\zeta$ :

$$\begin{aligned} \mathcal{L} = & [p(R)r - [1 - z(1 - p(R))]b(1 - \kappa) - C(z)]L + \gamma(K_B - K) + \lambda_1 [(1 - p(R))b(1 - \kappa) - C'(z)] \\ & + \lambda_2 [p(R) + p'(R)(R - r)] + \mu_1 [(1 - z(1 - p(R)))b - \gamma] + \zeta [K_B - K] \end{aligned}$$

He chooses loans  $L$ , bank equity  $K$ , portfolio diversification  $z$ , and the deposit rate  $b$ . The first-order conditions are

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial L} &= p(R)r - [1 - z(1 - p(R))]b - C(z) + \frac{\lambda_1(1 - p)bK}{L^2} = 0 \\ \frac{\partial \mathcal{L}}{\partial K} &= [1 - z(1 - p(R))]b - \gamma - \frac{\lambda_1(1 - p(R))b}{L} - \zeta = 0 \\ \frac{\partial \mathcal{L}}{\partial b} &= -[1 - z(1 - p(R))](1 - \kappa)L + \lambda_1(1 - p(R))(1 - \kappa) + \mu_1(1 - z(1 - p(R))) = 0 \\ \frac{\partial \mathcal{L}}{\partial z} &= -\lambda_1 C''(z) - \mu_1(1 - p)b = 0 \end{aligned}$$

as well as (27), (30), (PC), and (CA). Reformulating the first condition using (PC) and the first-order condition of corporations (3) to eliminate  $b$  as well as  $\bar{\theta}(r) = L$  to eliminate  $r$  yields (31). *Q.E.D.*

**Proof of Proposition 5** By replacing (IC) by the first-order conditions (27) and (30) and using  $\bar{\theta}(r) = L$ , one can rewrite program 6 as a Lagrangian with five constraints and the multipliers  $\lambda_1$ ,  $\lambda_2$ ,  $\mu_1$ ,  $\mu_2$ , and  $\eta$ :

$$\begin{aligned} \mathcal{L} = & F(X) + [p(R)R - C(z)]L - \frac{L^2}{2} + \lambda_1 [(1 - p(R))b(1 - \kappa) - C'(z)] + \lambda_2 [p(R) + p'(R)(R - r)] \\ & + \mu_1 [(1 - z(1 - p(R)))b - F'(X)] + \mu_2 [p(R)(R - r) - L] + \eta [1 - L - X] + \zeta (K_B - K) \end{aligned}$$

<sup>41</sup>The deposit rate implied by (PC) is finite, while the deposit rate implied by (IC) can be infinitely large if  $z \rightarrow 1$ . Given that the former exceeds the latter for all  $z \leq z_0$ , the IC-curve needs to be steeper than the PC-curve at the intersection point. The slopes are related to  $\nabla$ .

The first-order conditions are

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial L} &= p(R)R - C(z) - L + \frac{\lambda_1(1-p)bK}{L^2} - \mu_2 - \eta = 0 \\
\frac{\partial \mathcal{L}}{\partial K} &= -\frac{\lambda_1(1-p)b}{L} - \zeta = 0 \\
\frac{\partial \mathcal{L}}{\partial X} &= F'(X) - \mu_1 F''(X) - \eta = 0 \\
\frac{\partial \mathcal{L}}{\partial r} &= -\lambda_2 p'(R) - \mu_2 p(R) = 0 \\
\frac{\partial \mathcal{L}}{\partial b} &= \lambda_1(1-p)(1-\kappa) + \mu_1(1-z(1-p(R))) = 0 \\
\frac{\partial \mathcal{L}}{\partial R} &= [p + p'(R)R]L - \lambda_1 p'(R)b(1-\kappa) - \lambda_2[2p'(R) + p''(R)(R-r)] + \mu_1 p'(R)zb = 0 \\
\frac{\partial \mathcal{L}}{\partial z} &= -C'(z)L - \lambda_1 C''(z) - \mu_1(1-p)b = 0
\end{aligned}$$

as well as (27), (30), (CP), (LD) and (RC). Combining the first, third and fourth condition yields (33) that pins down the capital allocation. The Lagrange multipliers of (IC) are:

$$\begin{aligned}
\lambda_1 &= -\frac{[1-z(1-p(R))]C'(z)L}{[1-z(1-p(R))]C''(z) - (1-p)C'(z)} \leq 0 \\
\lambda_2 &= -\frac{L}{2p' + p''(R)(R-r)} \left[ p + p'(R)R + \frac{p'(R)b(1-\kappa)C'(z)}{(1-p)C''(z) - (1-p)C'(z)} \right] \leq 0
\end{aligned}$$

$\lambda_1$  is zero as soon as  $\kappa = 1$ , which implies  $C'(z) = 0$ ;  $\lambda_2$  equals zero if  $r = 0$  and  $\kappa = 1$  (i.e., no entrepreneurial and bank risk shifting). Therefore,  $\zeta > 0$  and the banker invests his entire private wealth as equity,  $K = K_B$ , as long as  $\kappa < 1$  (i.e.,  $K_B \geq \tilde{L}$ ) like in the baseline model. The pecuniary externalities are welfare-reducing whenever the social marginal return of bank lending is smaller than the private. Since the Lagrange multipliers are similar functions both in the market equilibrium and the second best, one can simply compare social and private returns using the first-order conditions (31) and (33) such that

$$\frac{\lambda_1(1-p(R))(1-\kappa)F''(X)}{1-z(1-p(R))} - \frac{\lambda_2 p'(R)}{p(R)} > 0$$

This condition can be expressed as (34) using the interest rate elasticities of loan demand and deposit supply:

$$\varepsilon_L = \frac{\partial L}{\partial r} \frac{r}{L} = -\frac{p(R)r}{L} < 0 \quad \varepsilon_D = \frac{\partial D}{\partial \gamma} \frac{\gamma}{D} = -\frac{\gamma}{DF''(X)} > 0$$

The former follows from (27), the latter from the participation constraints of investors and corporations (3). *Q.E.D.*

## 2.A.2 Numerical Example

This numerical example serves a purely illustrative purpose. We use the following functional forms:

$$p(R) = 1 - \frac{R - \underline{R}}{\bar{R}}, \quad F(X) = A[X^\alpha - \alpha X]$$

The production function satisfies the Inada conditions; the success probability has the support  $R \in [\underline{R}, \bar{R}]$  such that  $p(\underline{R}) = 1$  and  $p(\bar{R}) = \underline{R}/\bar{R} < 1$ . The parameters are set as follows:  $\underline{R} = 1$ ,  $\bar{R} = 2.4$ ,  $A = 3$ ,  $\alpha = 0.5$ ,  $K_B = 0.15$ ,  $V = 0.85$ . We compute four scenarios: The baseline example is scenario (1). In scenario (2), we assume that banks are better capitalized, which is captured by a larger supply of bank capital:  $K_B = 0.2$  and  $V = 0.8$ . Finally, scenario (3) introduces a more productive corporate sector, which is implemented by setting  $A = 4$ . For each scenario, a first best (FB), market equilibrium (ME), and second best (SB) are computed. The outcomes are shown in table 1.

	(1)			(2)			(3)		
	FB	ME	SB	FB	ME	SB	FB	ME	SB
Target return $R$	1.7	2.32	2.13	1.7	2.26	2.1	1.7	2.29	2.12
Success probability $p$	0.71	0.45	0.53	0.71	0.48	0.54	0.71	0.46	0.54
Bank lending $L$	0.69	0.56	0.51	0.69	0.58	0.53	0.61	0.49	0.44
Corp. investment $X$	0.31	0.44	0.49	0.31	0.42	0.47	0.39	0.51	0.56
Capital ratio $\kappa$	0.22	0.27	0.29	0.29	0.35	0.38	0.25	0.31	0.34
Deposit rate $b$	1.7	1.7	1.21	1.7	1.7	1.27	1.7	1.7	1.27
Welfare $W$	2.04	1.91	1.94	2.04	1.94	1.96	2.45	2.36	2.37
Payoff bankers $\pi^B$	0.18	0.27	0.34	0.24	0.31	0.38	0.18	0.25	0.3
Payoff corp. $\pi^F$	0.83	0.99	1.06	0.83	0.98	1.03	1.25	1.43	1.49
Payoff investors $\pi^I$	1.02	0.65	0.54	0.96	0.65	0.55	1.02	0.67	0.58
Cap. requirement $\kappa^*$			0.29			0.38			0.34
Licenses $N^*$			3			3			3

Table 1: *Numerical Example*

For each scenario, three allocations are shown: First best, Market equilibrium, and second best. (1) is the baseline scenario, in (2) the supply of bank capital  $K$  is larger, and in (3) corporates productivity  $A$  is higher.

In the baseline scenario, one can observe the effects of risk shifting when comparing first best and market equilibrium: Target return increases from 1.7 to 2.32, which reduces the success probability<sup>42</sup> from 71% to 45%. At the same time, the banking sector shrinks (from 69% to 56% of investment) due to the need to use scarce bank capital. Risk shifting leads to a welfare loss (agency costs) of roughly 6.4% of aggregate output, which is entirely borne by investors, whereas the welfare of bankers and corporations increases. When looking at the second best,

<sup>42</sup>The high failure probabilities arise due to perfect correlation of loan returns and the liner specification of  $p(R)$ .

one concludes that the pecuniary externality internalized by regulation accounts for almost one quarter of the welfare loss. Compared to the market equilibrium, the regulator chooses a slightly smaller and better capitalized banking sector, which alleviates risk shifting and results in a less risky loan portfolio. The expected payoffs of bankers and corporations increase by 26% and 7% respectively but investors receive a payoff that is 17% lower. In scenario (2), the supply of bank capital is 5 pp larger, which has no real effect in the first best. In the presence of moral hazard, however, this leads to banks that are both larger and better capitalized such that their loan portfolio is more efficient. Hence, the larger wealth endowment of bankers translates into improvement in quantity and quality. The banker's informational rent decreases (expected value falls from 0.24 to 0.23 in the SB). One can also observe a modest increase in social welfare. In scenario (3), the corporate sector is more productive: As a result, the first-best capital allocation has a larger corporate and a smaller banking sector. The latter also persists in the presence of moral hazard such that banks are better capitalized for a given wealth endowment. In the market equilibrium, for instance, the capital ratio is 4 pp higher compared to the baseline. This dominates the potentially adverse effect of higher funding cost and mitigates risk shifting overall. Interpreting the productivity increase as a positive technology shock, capital requirements are countercyclical (34% instead of 29%) in order to offset the adverse incentive effect of higher funding cost.

## Chapter 3

# The Optimal Adjustment of Bank Capital Regulation in a Downturn

Michael Kogler<sup>1</sup>

The procyclicality of bank capital regulation has become a key concern. This paper analyzes how capital requirements should adjust to economic shocks especially during a downturn. Whenever bank capital is scarce, optimal regulation trades off the low risk of a costly banking crisis against the investment capacity of the real sector. Adding a full-fledged model of the loan market reveals important equilibrium effects as changes in the state of the economy affect optimal capital requirements through the lending rate and the optimal risk level. The adjustment fundamentally differs between two shocks: In a capital crunch, optimal capital requirements are relaxed to prevent a sharp decline in lending and investment. If productivity decreases, however, they are tightened as preserving financial stability only entails a small cost.

**JEL Classification:** G21, G28

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### 3.1 Introduction

The interplay of the banking system in general and capital regulation in particular with the business cycle has figured prominently in the context of banking reform and is one of the main aspects in several policy reports.<sup>2</sup> The fundamental problem is well known: During a downturn, many banks experience negative funding shocks as, for example, more frequent loan losses weaken their capitalization while it is particularly challenging to raise new equity such that regulatory constraints become binding. At the same time, traditional, risk-sensitive capital requirements tighten as risk weights increase to account for the generally higher loan risk. In order to meet the regulatory requirements, banks thus deleverage and cut lending, which may even lead to a credit crunch. This clearly procyclical behavior aggravates the downturn with a potentially adverse feedback on financial stability. Yet, bank loans are riskier in bad times such that a larger capital buffer is necessary to prevent a costly banking crisis. In addition, the investment prospects in the real sector are often rather poor, and a smaller loan supply as a result of binding regulatory constraints may thus turn out to be less problematic because fewer investments would be realized even if funding was available. The conflicting goals of ensuring bank safety and preventing a further decline of investment and aggregate demand to some extent reflect the tension between micro- and macroprudential regulation. With Basel III, regulators try to mitigate the procyclicality of capital requirements through a countercyclical and a capital conservation buffer.<sup>3</sup> As a result, regulation tends to be tougher in good times when the risk of unsustainable lending booms and asset price bubbles is high and more relaxed in bad times when recapitalization is difficult.

This paper provides a normative analysis of how capital requirements should adjust to different (macro-)economic shocks. It presents a model of the optimal capital structure where equity provides a buffer against loan losses and thus lowers the risk of bank failure, which entails a social cost. As an innovation, we explicitly model the real sector consisting of bank-dependent entrepreneurs thereby endogenizing the loan market. This approach reveals important equilibrium effects that influence the optimal adjustment and allows identifying real sector determinants of capital regulation. At the core of this paper is an extensive comparative statics analysis with two scenarios: (i) a shortage of bank capital (henceforth: capital crunch) that limits banks' lending capacity and (ii) a lower productivity of entrepreneurs that reduces loan demand and the value of investment. The optimal capital requirements, which balance the trade-off between the stability of banks and the ability of entrepreneurs to finance profitable investments, relate to state of the economy through the lending rate, which acts as a *de facto* substitute for equity,

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<sup>2</sup>For example, Brunnermeier et al. (2009), Turner Review (2009), and FSB (2009).

<sup>3</sup>See sections III and IV in BCBS (2010).



and the welfare-maximizing level of bank risk. Their adjustment fundamentally differs between the two scenarios: Capital requirements should be relaxed in a capital crunch to prevent a contraction of lending but they should be stricter if productivity declines such that the lending rate and the value of investment are low. Importantly, optimal regulation allows the economy to adjust at two margins - risk and lending - whereas one of them is fixed under risk-sensitive or flat capital requirements.

The analysis builds on the literature on the real effects of capital regulation and, more generally, of funding shocks<sup>4</sup>: Since the introduction of the Basel accords, their real and especially their procyclical effects have been extensively studied.<sup>5</sup> As a first benchmark, the Modigliani-Miller theorem, however, implies that capital requirements do not have any pronounced real effects as they can be fulfilled with outside equity which should not raise the cost of capital. Such arguments have recently been emphasized, for instance, by Admati et al. (2011); quantitative simulations by Miles et al. (2012) imply only minor long-run effects on customers' borrowing costs even if capital requirements strongly increase. Nevertheless, equity can be scarce and expensive<sup>6</sup> especially during bad times such that capital requirements have the potential to affect lending and investment. Blum and Hellwig (1995) highlight two key frictions that create such real effects: First, banks do not recapitalize by issuing new equity and deleverage instead, second, firms cannot fully substitute bank loans with other funds. They show that whenever capital requirements are binding, equilibrium output and prices become more sensitive to aggregate demand shocks thereby amplifying macroeconomic fluctuations. Furthermore, Heid (2007) shows that banks may hold voluntary buffers in excess of capital charges. These buffers mitigate but do not offset the procyclical effects of capital requirements. Further theoretical contributions on the procyclicality of capital regulation include, among others, Estrella (2004), Zhu (2008), and Covas and Fujita (2010). On the empirical side, early evidence of how binding regulatory constraints affect lending is provided by Peek and Rosengren (1995a) who study the New England capital crunch in the early 1990s when capital requirements were actively enforced. They find that assets of banks subject to formal enforcement actions shrink significantly faster than those of banks without and that loans to bank-dependent borrowers are most strongly affected. Using a sample of French firms, Fraise et al. (2013) find that a one percentage point increase in bank capital requirements lowers credit by eight and firm borrowing by four percent. Hence, firms can only partly compensate the smaller loan supply. In a similar spirit, Aiyar et al. (2014) present evidence for the UK and stress the role of loans from

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<sup>4</sup>A seminal theoretical contribution is Holmström and Tirole (1997) who study the (heterogeneous) effects of shocks to the supply of different types of capital.

<sup>5</sup>For an overview about links between capital requirements and the real economy, see, Goodhart and Taylor (2006).

<sup>6</sup>For example due to tax benefits of debt finance or asymmetric information cost of equity and signaling considerations as emphasized by Myers and Majluf (1984).

foreign banks as substitutes. The procyclicality of capital requirements, in particular of Basel II, is documented, for example, by Kashyap and Stein (2004) and Gordy and Howells (2006) for American, Repullo et al. (2010) for Spanish, and Andersen (2011) for Norwegian banks. This paper contributes to the literature on the optimal adjustment of bank regulation to macroeconomic shocks: Kashyap and Stein (2004)<sup>7</sup> show that if the shadow value of bank capital varies over the cycle, optimal capital requirements should be countercyclical. More precisely, they argue for a family of risk curves, which map the risk of each asset into a capital charge, where each curve is associated with a specific shadow value. This preserves the sensitivity of capital requirements across asset categories with different risks but allows for an adjustment over the cycle. In a dynamic equilibrium model with time-varying loan risk, Repullo and Suarez (2013) compare the welfare properties of different regulatory systems and conclude that optimal capital requirements are procyclical but that their variation is less pronounced than that of Basel II for sufficiently large values of the social cost of bank failure. Several contributions analyze capital regulation in models with agency problems: Dewatripont and Tirole (2012) show that capital requirements allocate the control rights of bank shareholders and debtholders as to ensure managerial effort and prevent gambling for resurrection. Regulation should neutralize macroeconomic shocks that would otherwise distort incentives; this is achieved by countercyclical capital buffers or capital insurance. Repullo (2013) stresses the role of costly bank capital in a risk-shifting model: He studies the trade-off between mitigating risk shifting and preserving the lending capacity of banks. Given a shortage of bank capital, its shadow value increases and optimal capital requirements are relaxed. If they remained unchanged, banks would be safer but aggregate investment would sharply drop. Focusing on credit cycles, Gersbach and Rochet (2012) argue that countercyclical capital regulation implemented, for example, as an upper bound on short-term debt corrects the misallocation of credit between good and bad states of nature thereby dampening fluctuations. Several options how cyclically-varying capital regulation can be implemented have been suggested, in particular, direct and indirect smoothing rules for capital requirements [e.g., Gordy and Howells (2006), Brunnermeier et al. (2009), Repullo et al. (2010)] and the build-up of countercyclical buffers [e.g., FSB (2009), BCBS (2010)], which are envisaged by Basel III. Alternative proposals include dynamic provisioning, contingent convertibles and capital insurance [e.g., Kashyap et al. (2008)], and regulatory discretion. Yet, it is too early to present evidence about the consequences of such countercyclical measures but Jiménez et al. (2015) evaluate a comparable policy introduced in Spain already in 2000: dynamic provisions. These provisions are built up from retained earnings during a boom to cover loan losses in bad times where equity is scarce, and they are, in fact, similar to countercyclical capital buffers. They find that dynamic provisions significantly mitigate the fall of

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<sup>7</sup>The underlying model can be found in the 2003 working paper version.

bank lending and firm borrowing during the financial crisis. In the good times during the early 2000s, banks that had to build up larger provisions reduced their loan supply but firms could easily substitute by borrowing from less affected banks.

The main contribution of this paper is a comprehensive study of how optimal capital requirements adjust to changes in (macro-)economic conditions especially during a downturn. A full-fledged model of the real sector and the loan market identifies equilibrium effects associated with the lending rate that together with changes in the optimal risk level determine the regulatory adjustment. In addition, this extension allows analyzing the response to productivity shocks, which have not been studied so far despite their importance in macroeconomics. The model is most closely related to Repullo (2013) to which we add two innovations: the model of the real sector and the role of bank capital as a buffer. The latter is more conventional than the incentive effect but requires positively correlated loan returns.

The remainder of this paper is organized as follows: Section 3.2 outlines the model. Section 3.3 characterizes the equilibrium and analyzes optimal capital requirements and its adjustment. It also provides a numerical example. Finally, section 3.4 concludes.

## 3.2 The Model

We develop a static, partial equilibrium model of the optimal capital structure of banks. The economy is populated by four types of risk-neutral agents: entrepreneurs representing the real sector and banks, investors (bank shareholders), and depositors representing the financial sector. Banks attract deposits and equity from depositors and investors and provide loans to entrepreneurs, who can invest in profitable but risky projects. Whenever the project fails, the entrepreneur defaults and the bank incurs a loan loss. The risk characteristics crucially depend on whether the economy experiences a recession, which is revealed after projects were initiated: Usually, only idiosyncratic risk matters such that the bank can diversify its loan portfolio. In a recession, however, systemic risk materializes and the defaults of entrepreneurs are positively correlated. As a result, a bank may fail whenever too many borrowers simultaneously default and its equity cannot fully absorb all losses. Bank failure entails social costs that are not internalized by banks and thus provide a rationale for regulation. The timing is as follows: (i) banks attract capital from depositors and investors and lend to entrepreneurs who invest, (ii) it is revealed whether project risks are independent (normal state) or positively correlated (recession), and (iii) the projects mature and the contracts are settled.

The following friction ensures that capital requirements have the potential to affect the real economy:

**ASSUMPTION 1** *Entrepreneurs can finance their projects with bank loans only.*

Hence, entrepreneurs are bank-dependent and do not raise funds directly from investors or depositors. Evidence of Fraisse et al. (2013) and Jiménez et al. (2015) supports this assumption especially during bad times. In a broader context, this of course concerns only some firms like, for example, small businesses, while others can access the capital market. Another friction - whether banks raise new equity or deleverage to satisfy capital requirements - endogenously emerges depending on the scarcity of bank capital.

### 3.2.1 Entrepreneurs

The real sector consists of a continuum of measure one of penniless entrepreneurs. Each of them can undertake a risky investment project characterized by:

**ASSUMPTION 2** *The unit-size project yields a binary return*

$$\tilde{R} = \begin{cases} R, & 1 - p_0 \\ \alpha, & p_0 \end{cases}$$

with  $R > 1 > \alpha$ . The net present value is positive:  $\mu \equiv (1 - p_0)R + p_0\alpha - 1 > 0$ .

Subsequently, we interpret the return  $R$  as the entrepreneur's productivity and  $\alpha$  as the liquidation value. If the project fails, the latter is appropriated by the lender and  $1 - \alpha$  equals the loss given default. Failure and success probability,  $p_0$  and  $1 - p_0$ , are *ex ante* probabilities that consist of an idiosyncratic and a systemic component; the latter allows for correlated failures. The loan demand is modeled as in Repullo and Martínez-Miera (2010): Entrepreneurs face heterogeneous opportunity costs,  $u \sim U[0, 1]$ . They may represent, for instance, forgone labor income or the value of leisure. Only an entrepreneur whose opportunity cost is smaller than the expected net return on investment borrows and invests:

$$u \leq (1 - p)(R - r_L) \equiv \hat{u}(r_L) \tag{1}$$

$\hat{u}$  defines the marginal entrepreneur who is just indifferent between investing and choosing the outside option. Since opportunity costs are uniformly distributed,  $\hat{u}$  also equals the fraction of investing entrepreneurs (i.e., with opportunity costs below the threshold) and thus the loan demand, which decreases in the lending rate  $r_L$  and the *ex ante* project risk  $p_0$  and increases in productivity  $R$ . The surplus of an active entrepreneur equals  $(1 - p_0)(R - r_L) - u$ ; the aggregate surplus of the real sector is  $\pi^E = \int_0^{\hat{u}} (1 - p_0)(R - r_L) - u du$ .

Since they undertake a single investment, the correlation of projects matters little for individual entrepreneurs. However, it is instrumental for banks as they may fail whenever too many entrepreneurs simultaneously default. We suggest an intuitive and tractable model of project

correlation across entrepreneurs: The economy may experience either normal conditions or a recession, which is revealed after the projects are initiated and determines to what extent failures are independent or correlated:

**ASSUMPTION 3** *In normal times (probability  $1 - \theta$ ), projects are independent and each of them succeeds with probability  $1 - p$  and fails with probability  $p$ . In a recession (probability  $\theta$ ), a fraction  $x$  of projects immediately fails where  $x \in [0, 1]$  is distributed according to some continuous, differentiable distribution function  $F(x)$ . The remaining projects continue and succeed with probability  $1 - p$  and fail with probability  $p$*

Hence,  $x$  captures the systemic and  $p$  the idiosyncratic risk component. Projects are generally independent but a recession is associated with an adverse shock to a stochastic number of projects, which thus immediately fails. This represents a macroeconomic shock that has the potential to affect all entrepreneurs at the same time like, for example, a fall in aggregate demand or - in a small, open economy - a sudden appreciation of the currency. Figure 1 illustrates the possible outcomes: In normal times, the project succeeds with probability  $1 - p$  and fails with probability  $p$ . In a recession, a fraction  $x$  of all projects fails due to the shock, whereas the projects unaffected by the shock either succeed (share  $1 - p$ ) or fail (share  $p$ ) according to idiosyncratic risk. The stochastic variable  $x$  measures the severity of a recession, high realizations point to a severe recession.

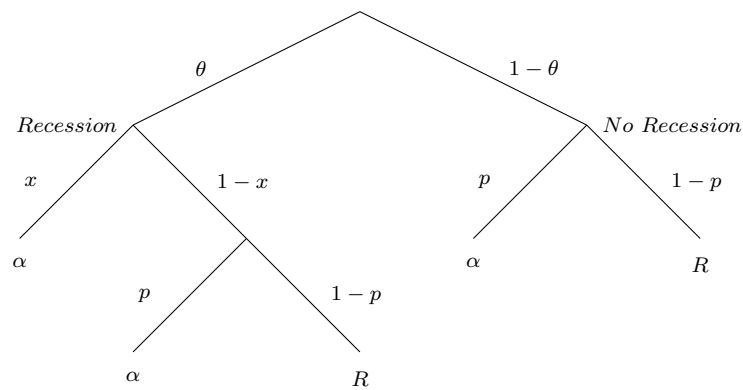


Figure 1: *Probability Tree*

Eventually, table 1 summarize a project's success and failure probabilities *ex ante* as well as in a recession and in normal times using  $x_0 \equiv E(x) = \int_0^1 x dF(x)$ . Intuitively, a recession revises the failure probability up compared to the project-specific failure probability  $p$ .

### 3.2.2 Banks

There is a continuum of measure one of banks that lend to entrepreneurs; more specifically, they provide unit-size loans to a mass  $L$  of active entrepreneurs. Each bank can raise funds from

	Success	Failure
Ex ante	$1 - p_0 = (1 - p)(1 - \theta x_0)$	$p_0 = p + \theta x_0(1 - p)$
Recession	$(1 - p)(1 - x)$	$p + x(1 - p)$
No Recession	$1 - p$	$p$

Table 1: *Probabilities*

two sources: deposits (share  $1 - k$ ) and bank capital (share  $k$ ). Bank owners are protected by limited liability. Deposits are elastically supplied at the risk-free (gross) interest rate normalized to one but depositors require a compensation for bearing the bank's failure risk giving rise to a risk-adjusted deposit rate  $r \geq 1$ . One might alternatively interpret  $r$  as the risk-free rate plus an actuarially fair deposit insurance premium. Bank capital is provided by investors (i.e., outside shareholders) who require an expected (gross) return on equity  $\gamma \geq 1$ .

Bank risk crucially depends on whether the economy is in a recession or not: In general, loans are uncorrelated because a fraction  $1 - p$  is repaid and a fraction  $p$  fails. Hence, the portfolio is diversified and the bank is safe. In a recession, however, a stochastic fraction  $p + x(1 - p)$  of loans fail, namely, a share  $x$  due to the adverse shock and a share  $(1 - x)p$  due to project-specific risk. The bank thus receives the full repayment  $r_L$  from a fraction  $(1 - x)(1 - p)$  of borrowers and the liquidation value  $\alpha$  from a fraction  $p + (1 - x)p$ . It succeeds as long as enough loans are repaid which requires the share of entrepreneurs who receive an adverse shock to be smaller than the failure threshold  $\hat{x}$  given by:

$$(1 - \hat{x})(1 - p)r_L + [p + \hat{x}(1 - p)]\alpha - r(1 - k) = 0 \quad (2)$$

Hence, the liabilities of the bank,  $r(1 - k)L$ , are just covered by the assets consisting of repaid and liquidated loans. In other words, the bank's end-of-period equity is zero. Obviously, the failure threshold increases in the deposit rate and in idiosyncratic project risk and decreases in the capital ratio, the lending rate, and the liquidation value. Importantly, the deposit rate is endogenous because depositors require a risk-adjusted interest rate. As soon as the recession is more severe and a larger number of borrowers defaults, the loss is so large that the bank's equity is negative and its liabilities are not fully covered. Bank failures are correlated because banks are identical and defaults correlated, which gives rise to a systemic banking crisis if  $x > \hat{x}$ . Consequently, the banks survive in a mild recession when only a few entrepreneurs default due to the shock. Whenever the shock is more severe, banks fail such that the recession transforms into a systemic banking crisis. The *ex ante* probabilities of a mild recession and a banking crisis are  $\theta F(\hat{x})$  and  $\theta[1 - F(\hat{x})]$  respectively.

Since bank owners are protected by limited liability such that their payoff is zero in case of

failure, the bank's expected surplus is:

$$\begin{aligned} \pi^B = & \theta \int_0^{\hat{x}} (1-x)(1-p)r_L + [p+x(1-p)]\alpha - r(1-k)dF(x)L \\ & + (1-\theta)[(1-p)r_L + p\alpha - r(1-k)]L - \gamma kL \end{aligned} \quad (3)$$

It consists of the expected profit in a recession (with probability  $\theta$ ) and in normal times (with probability  $1-\theta$ ) net of the required return on equity. In both states, the profit equals gross interest income from repaid and the liquidation value of failed loans minus deposit repayment. To maximize its surplus, the bank determines the capital structure (i.e., the capital ratio  $k$ ) and the loan supply  $L$ .

Eventually, we add the assumption that a banking crisis is costly for society and rely on reduced-form social cost characterized by:

**ASSUMPTION 4** *A banking crisis entails a social cost  $c$  per unit of loans.*

These costs represent, for example, the cost of bank runs, the loss of lender-borrower relationships or disruptions to the payment systems.<sup>8</sup> The failure of banks to internalize these cost is the reason why the market equilibrium is inefficient, which provides a rationale for capital regulation. This is a common motivation in the literature applied, for instance, by Kashyap and Stein (2004), Repullo (2013), and Repullo and Suarez (2013).

### 3.2.3 Depositors and Investors

The supply side is modeled as in Repullo (2013) with an elastic deposit and a fixed bank capital supply: On the one hand, risk-neutral depositors elastically supply deposits as long as they yield an expected return equal to the (gross) risk-free interest rate that is normalized to one. Hence, there is market discipline as the interest rate compensates depositors for bearing the bank's failure risk<sup>9</sup> such that:

$$E \left[ \min \left\{ r, \frac{(1-p)(1-x)r_L + [p+x(1-p)]\alpha}{1-k} \right\} \right] = 1 \quad (4)$$

One may interpret this condition as the participation constraint of depositors: Whenever bank succeeds, the bank pays an interest rate  $r$ . In case of failure, however, each depositor inherits a share  $\frac{1}{(1-k)L}$  of its assets  $[(1-p)(1-x)r_L + (x+(1-x)p)\alpha]L$ . Consequently, depositors earn the deposit rate in normal times or in a mild recession (which occur with probability  $1-\theta$  and

<sup>8</sup>Note that wealth losses of depositors (or the cost of providing deposit insurance) are fully internalized as deposits are correctly priced.

<sup>9</sup>Alternatively, suppose that deposits are insured and banks pay an actuarially fair insurance premium.

$\theta F(\hat{x})$  respectively) and inherit the assets in a banking crisis:

$$[1 - \theta + \theta F(\hat{x})]r + \theta \int_{\hat{x}}^1 \frac{(1-p)(1-x)r_L + [p + x(1-p)]\alpha}{1-k} dF(x) = 1 \quad (5)$$

Since they are paid a risk-adjusted interest rate, depositors' expected surplus is zero:  $\pi^D = 0$ . As long as the deposit rate satisfies the participation constraint, they are willing to supply any quantity.

On the other hand, investors supply an amount  $K$  of bank capital and require an expected return on equity  $\gamma$  which is at least one:

$$K(\gamma) = \begin{cases} K, & \text{if } \gamma \geq 1 \\ 0, & \text{if } \gamma < 1 \end{cases}$$

Hence, the expected surplus of investors is  $\pi^I = (\gamma - 1)K(\gamma) \geq 0$ . Whenever the supply is small, bank capital is scarce such that a trade-off emerges between financial stability in the sense of a low bank risk and lending and investment. A fixed supply of bank capital is typical for models of funding shocks and the effects of capital regulation such as Holmström and Tirole (1997) and Repullo (2013). This formulation allows capturing such shocks by comparative statics. An alternative is an exogenous excess return on equity such as in Repullo and Suarez (2013).

### 3.2.4 Markets

In this economy, three markets exist - a market for loans, deposits, and bank capital. The loan market clears as soon as  $L = \hat{u}$  such that the loan supply equals the fraction of entrepreneurs who invest. This pins down the lending rate  $r_L$ . Given the perfectly elastic supply, the deposit market is in equilibrium whenever banks promise a deposit rate that satisfies the participation constraint of depositors (4). Eventually, the market for bank capital is in equilibrium if  $K(\gamma) = kL$  thereby determining the return on equity. However, this market may not clear if bank capital is abundant in supply such that  $K > kL > 0$  even if the required returns on equity and deposits are the same ( $\gamma = 1$ ).

### 3.2.5 State of the Economy

The state of the economy characterizes the (macro-)economic conditions. We examine the optimal adjustment of capital requirements to a financial and a real shock and focus on two parameters: the availability of bank capital<sup>10</sup> given by the fixed supply  $K$  and entrepreneurs'

<sup>10</sup>In our static setting where banks raise new equity, the interpretation of changes in the supply of bank capital appears suitable. In a dynamic model, a broader interpretation would also include shocks to the current



productivity  $R$ . The supply of bank capital, first of all, affects banks. As soon as they face binding capital requirements and borrowers are bank-dependent, a shortage of bank capital - a capital crunch - may force banks to cut lending and deleverage, which has real effects as it limits entrepreneurs' investment. The empirical relevance of capital crunches is documented, for example, by Bernanke and Lown (1991) and Peek and Rosengren (1995b). Such a scenario is also at the core of Repullo's (2013) analysis. This scenario represents a financial shock that can be the result of swings in investors' moods, optimism and risk aversion.

The project return  $R$ , in contrast, characterizes entrepreneurs' investment prospects and captures technology or productivity shocks that feature prominently in macroeconomics. It is a crucial determinant of entrepreneurs' investment decisions and thus influences the loan demand. Optimal regulation may adjust because of equilibrium effects associated with the lending rate and changes in the value of projects that influence the underlying trade-off between financial stability and investment.

### 3.3 Equilibrium Analysis

This section characterizes two allocations: the market equilibrium and the social optimum where all costs associated with bank failure are internalized. The latter is the reason for market failure in the sense that banks are inadequately capitalized and may provide too large an amount of loans. Subsequently, we show how the optimal allocation can be decentralized using capital requirements and study their adjustment to economic shocks.

An outcome of key interest in both allocations is bank risk: It is jointly determined by the identity that equalizes assets and liabilities (2) and the participation constraint of depositors (4) that pin down the failure threshold and the deposit rate respectively:

**LEMMA 1** *A bank fails in a recession if a fraction  $x > \hat{x}$  of entrepreneurs immediately default. This threshold is characterized by*

$$1 - k - \alpha - (r_L - \alpha)(1 - p)H(\hat{x}) = 0 \quad (6)$$

where

$$H(\hat{x}) = (1 - \theta)(1 - \hat{x}) + \theta \int_{\hat{x}}^1 F(x)dx$$

is a decreasing function of  $\hat{x}$  with  $H'(\hat{x}) = -[1 - \theta + \theta F(\hat{x})] < 0$ ,  $H(0) = 1 - \theta x_0$  and  $H(1) = 0$ . The failure threshold increases in the capital ratio, the lending rate, and the liquidation value.

**Proof:** See Appendix 3.A.

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capitalization, for example, due to loan losses.

Condition (6) relates bank risk to the capital structure and the lending rate. Well-capitalized banks that earn a high lending rate are particularly safe. Moreover, a bank can be risk-free whenever it succeeds in repaying deposits even if all borrowers simultaneously default (i.e., the default rate equals  $\hat{x} = 1$ ). This requires a capital ratio of (at least)  $1 - \alpha$ , which suffices to cover the loss given default. In the extreme case  $\alpha = 0$ , this would require an all-equity financed bank.

### 3.3.1 Market Equilibrium

The market equilibrium provides a benchmark: Each bank determines its capital structure  $k$  and loan supply  $L$  as well as the interest rate offered to depositors  $r$  in order to maximize the expected surplus  $\pi^B$  which is given in (2) subject to depositors' participation constraint (5). By substituting the latter into the objective function to eliminate  $r$ , one obtains the consolidated problem:

$$\pi^B = \max_{k,L} [(1 - p_0)r_L + p_0\alpha - (1 - k) - \gamma k] L \quad (7)$$

The bank's optimal choices are summarized in

**LEMMA 2** *The bank's capital ratio is indeterminate,  $k \in [0, 1]$ , if  $\gamma = 1$  and zero,  $k = 0$ , if  $\gamma > 0$ . The loan supply is elastic at the lending rate*

$$r_L = \frac{1 - p_0\alpha}{1 - p_0} \quad (8)$$

*such that banks earn a zero expected surplus:  $\pi^B = [(1 - p_0)r_L + p_0\alpha - 1]L = 0$ .*

**Proof:** Substituting the participation constraint of depositors (5) into the objective function of the bank (2) yields the consolidated problem (7). The indeterminacy of the capital structure follows from the first-order condition  $\frac{\partial \pi^B}{\partial k} = 1 - \gamma \leq 0$ ;  $\frac{\partial \pi^B}{\partial L} = (1 - p_0)r_L + p_0\alpha - (1 - k) - \gamma k = 0$  implies that banks provide loans until they earn a zero expected surplus; substituting either  $\gamma = 1$  or  $k = 0$  gives (8). *Q.E.D.*

The loan supply is elastic because of the linear technology and the elastic supply of deposits. Hence, the lending rate exactly compensates banks for bearing the project risk leading to zero expected profits. In other words, the bank itself (i.e., the inside shareholders) does not earn a rent. If it incurred a convex cost or relied on scarce equity, however, the loan supply would not be perfectly elastic. In line with Modigliani-Miller, the capital structure is indeterminate: Since equity has no advantage over debt because the latter is correctly priced such that wealth losses of depositors are fully internalized, the bank is indifferent as long as both types of capital have the same costs. Whenever bank capital is more expensive (i.e.,  $\gamma > 1$ ), the capital ratio

is zero. Hence, only a required return on equity of one is consistent with equilibrium such that at least some banks have a positive capital ratio. The irrelevance of the capital structure is of course a strong result: It would disappear in the presence of guarantees or tax distortions, which imply a strict preference for debt, or bank borrowing frictions (e.g., limited pledgeable income).

Entrepreneurs decide about investment: A project is undertaken if the expected profit exceeds the idiosyncratic opportunity cost  $u$ . Derived from the extensive margin, loan demand equals the fraction of entrepreneurs with sufficiently low opportunity cost,  $\hat{u}(r_L)$ , defined in (1). Together with loan market equilibrium,  $L = \hat{u}(r_L)$ , this yields:

**LEMMA 3** *Equilibrium lending and investment is:*

$$L = (1 - p_0)R + p_0\alpha - 1 = \mu \quad (9)$$

*It increases in the project return and is insensitive to the bank capital supply.*

**Proof:** Investment immediately follows from the market clearing condition,  $L = \hat{u}(r_L)$ , by substituting (1) and (8) for loan demand and lending rate. *Q.E.D.*

Investment equals the project's expected net return: This follows from entrepreneurs' investment choice at the extensive margin combined with the risk-adjusted lending rate (8). The latter guarantees that entrepreneurs earn the project's expected net return,  $(1 - p_0)(R - r_L) = \mu$ , such that a fraction  $\hat{u} = \mu$  of them invests.

### 3.3.2 The Regulator's Problem

In the market equilibrium, the social cost of a banking crisis,  $C = \theta[1 - F(\hat{x})]cL$ , is not internalized. Welfare  $W$  consists of the expected surplus of all agents net of the social cost,  $W = \pi^E + \pi^B + \pi^I - C$ . Substituting  $K(\gamma) = kL$  as well as eliminating the deposit rate in (5) and (6) yields:

$$W = \int_0^{\hat{u}} (1 - p_0)(R - r_L) - u du + [(1 - p_0)r_L + p_0\alpha - 1 - \theta(1 - F(\hat{x}))c] L \quad (10)$$

The first term is expected surplus of the real sector; the second term captures the surplus of the financial sector (i.e., of banks and investors) net of the social costs associated with bank failure. The regulator determines lending and investment, the marginal entrepreneur, the capital ratio of banks, and the lending rate in order to maximize welfare thereby fully internalizing all social costs. Recall that the lending rate does affect welfare because of its effect on bank risk, which matters whenever failure entails a cost. In principle, the lending rate

should thus be as high as possible to minimize bank risk but it is restricted: The marginal entrepreneur,  $\hat{u}$ , needs to earn a zero surplus in order to invest. This adds a participation constraint of entrepreneurs. Substituting  $L = \hat{u}$ , which holds in equilibrium, the optimization problem of a welfare-maximizing regulator is:

**PROGRAM 1** *The regulator determines lending and investment  $L$ , banks' capital ratio  $k$ , and the lending rate  $r_L$  to maximize social welfare*

$$\max_{k, L, r_L} [\mu - \theta(1 - F(\hat{x}))c]L - \frac{L^2}{2} \quad (11)$$

*subject to the participation constraint of entrepreneurs,  $(1 - p_0)(R - r_L) = L$ , and the capital availability constraint,  $K \geq kL$ .*

In contrast to Modigliani-Miller's irrelevance theorem, the capital structure has welfare consequences as a higher capital ratio reduces bank risk and thus the social cost of failure. The capital ratio is chosen according to the first-order condition

$$c\theta f(\hat{x}) \underbrace{\frac{1}{(r_L - \alpha)[1 - \theta + \theta F(\hat{x})]}}_{\frac{\partial \hat{x}}{\partial k}} = \lambda_1 \quad (12)$$

where  $\lambda_1$  is the Lagrange multiplier of the capital availability constraint. The left-hand side captures the marginal gains of a higher capital ratio, namely, the lower risk and failure cost. The marginal cost equal the shadow value of bank capital captured by the multiplier. By the Envelope theorem, the latter measures the welfare contribution of bank capital  $\frac{\partial W}{\partial K} = \lambda_1$ . Whenever equity at least covers the loss given default,  $k \geq 1 - \alpha$  (see lemma 1), and banks are safe, we have  $\frac{\partial \hat{x}}{\partial k} = 0$  such that the shadow value of bank capital is zero and additional equity has no welfare effect.

Lending and investment are determined according to the first-order condition

$$\mu - L - \theta[1 - F(\hat{x})]c - \lambda_1 k - \lambda_2 = 0 \quad (13)$$

where  $\lambda_2$  denotes the Lagrange multiplier of the participation constraint. Intuitively, the marginal welfare gains from lending (i.e., the expected return of financing an additional project) equal the marginal cost consisting of the opportunity and social failure cost. Expansion also tightens both the participation and the capital availability constraint thereby raising bank risk due to a reduction of lending rate or capital ratio.

### 3.3.3 Equilibrium Allocation

Based on the first-order conditions and constraints of program 1, one can derive the socially optimal allocation:

**PROPOSITION 1** *The failure threshold  $\hat{x}^*$  and bank lending  $L^*$  are jointly determined by the system:*

$$J^1(L^*, \hat{x}^*) = \mu - L^* - \theta[1 - F(\hat{x}^*)]c - \frac{c\theta f(\hat{x}^*)}{1 - \theta + \theta F(\hat{x}^*)} \left[ \frac{1 - \alpha + \frac{H(\hat{x}^*)L^*}{1 - \theta x_0}}{\left(R - \frac{L^*}{1 - p_0} - \alpha\right)(1 - p)} - H(\hat{x}^*) \right] = 0 \quad (14)$$

$$J^2(L^*, \hat{x}^*) = K - \left[ 1 - \alpha - \left(R - \frac{L^*}{1 - p_0} - \alpha\right)(1 - p)H(\hat{x}^*) \right] L^* = 0 \quad (15)$$

Lending  $L^* \leq \mu$  increases in the supply of bank capital,  $\frac{\partial L^*}{\partial K} \geq 0$ , and productivity,  $\frac{\partial L^*}{\partial R} > 0$ . The failure threshold  $\hat{x}^*$  increases in the supply of bank capital,  $\frac{\partial \hat{x}^*}{\partial K} \geq 0$ , but may increase or decrease in productivity. This allocation requires the capital ratio:

$$k^* = 1 - \alpha - \left(R - \frac{L^*}{1 - p_0} - \alpha\right)(1 - p)H(\hat{x}^*) \quad (16)$$

**Proof:** See Appendix 3.A.

Compared to the market equilibrium, condition (14) implies that lending and investment are usually smaller and the lending rate is higher. The reason is that internalizing the social cost of a banking crisis requires the use of scarce bank capital.

Essentially, the optimal allocation trades off the benefit of a lower bank risk against smaller lending and investment. This trade-off emerges as long as bank capital, which is necessary to improve the stability and resilience of banks, is scarce. Therefore, a larger supply relaxes the capital availability constraint such that more investments are financed without increasing risk and bank risk decreases by improving their capitalization. An increase in entrepreneurs' productivity, in contrast, makes the projects more valuable thereby tilting the trade-off more in favor of investment. In order to mobilize additional funds, the failure threshold of banks likely falls such that the failure risk is higher. This outcome materializes as long as capital requirements are tight and the risk of failure is low. The optimal capital structure given by (16) ensures that the balance sheet of each bank is consistent with the socially optimal failure threshold  $\hat{x}^*$ . This is the reason why the capital structure is not irrelevant à la Modigliani-Miller. Instead, the capital ratio mechanically follows from the definition of the failure threshold, (6), and implements the optimal risk level.

The supply of bank capital can be large enough to make banks risk-free such that they succeed in a recession so severe that all loans fail ( $x = 1$ ) and only the liquidation value is recovered:

**COROLLARY 1** *If the supply of bank capital exceeds  $K \geq (1 - \alpha)\mu \equiv K_0$ , the capital ratio is  $k^* = 1 - \alpha$  such that banks are risk-free,  $\hat{x}^* = 1$ , and lending and investment are similar to the market equilibrium,  $L^* = \mu$ .*

**Proof:** A risk-free bank (i.e.,  $\hat{x} = 1$ ) requires  $k \geq 1 - \alpha$  (see lemma 1); it implies  $\frac{\partial \hat{x}}{\partial k} = \frac{\partial \hat{x}}{\partial r_L} = 0$  such that  $\lambda_1 = \lambda_2 = 0$ . Hence,  $L = \mu$  follows from (14) and the participation constraint of depositors requires  $r_L = (1 - p_0\alpha)/(1 - p_0)$ . This outcome is only feasible if  $K \geq K_0$  according to the capital availability constraint (15). *Q.E.D.*

Although lending and investment are similar to the unregulated market equilibrium, the latter is not necessarily efficient because the capital structure is indeterminate: On average, banks' capitalization may be sufficient but in the absence of regulation it is possible that some banks have too small a capital ratio  $k < 1 - \alpha$  and are risky. Whenever bank capital is abundant in supply ( $K \geq K_0$ ), the trade-off between financial stability and real investment disappears and a high capital ratio does not entail any costs for the real economy. This case is consistent with the key argument of Admati et al. (2011).

### 3.3.4 Optimal Capital Regulation

Internalizing the social costs of a systemic banking crisis provides a rationale for regulation, which allows decentralizing the optimal allocation in a market economy. Essentially, the regulator requires that banks have the optimal capital structure:

**COROLLARY 2** *The optimal allocation can be implemented by minimum capital requirements*

$$k \geq 1 - \alpha - (r_L - \alpha)(1 - p)H(\hat{x}^*) \equiv k^*(r_L, x^*) \quad (17)$$

*that increase in the failure threshold and decrease in the lending rate and the liquidation value. Capital requirements bind if  $K \leq K_0$ .*

**Proof:** See Appendix 3.A.

The capital requirements are a function of the optimal failure threshold  $\hat{x}^*$  (henceforth: target risk), the lending rate  $r_L$  and the liquidation value  $\alpha$ : A lower target risk naturally requires more equity, while a higher lending rate and liquidation value allow reducing the capital ratio without leading to higher bank risk. They increase the bank's income,  $(1 - x)(1 - p)r_L + (p + (1 - x)p)\alpha$ , thereby providing an additional buffer such that the same failure risk materializes even with a smaller capital ratio. Consequently, a high lending rate or liquidation value are substitutes for capital on the 'risk front'. A similar substitution effect is found by Repullo and Suarez (2013) for the capital structure of banks that hold voluntary buffers because of potentially binding

regulatory constraints in the future. Therefore, the state of the economy - entrepreneurs' productivity and the supply of bank capital - influences capital requirements through two channels: (i) target risk and (ii) equilibrium lending rate. While the former is optimally chosen by the regulator, the latter is determined by the market. As soon as the supply of bank capital is large enough to make banks risk-free without limiting investment (i.e.,  $K \geq K_0$ ), however, capital requirements equal the loss given default  $k = 1 - \alpha$  and are insensitive to economic shocks.

Implementing the optimal allocation (proposition 1) with capital requirements is straightforward: The optimal capital structure varies with the lending rate and thus ensures by construction that a bank's failure threshold is indeed  $\hat{x}^*$ . In addition, it implements the optimal lending scale  $L^*$ : Banks maximize their expected surplus  $\pi^B$  subject to the regulatory constraint  $k \geq k^*(r_L, \hat{x}^*)$ . From the first-order condition with respect to loans  $(1-p_0)r_L + p_0\alpha - 1 - (\gamma-1)k = 0$ , the loan demand of entrepreneurs  $\hat{u} = (1-p_0)(R - r_L)$ , and loan market clearing  $L = \hat{u}$ , one finds that loans

$$L = \mu - (\gamma - 1)k \quad (18)$$

decrease in the capital ratio and in the required return on equity. If equity earns no excess return over debt (i.e., if  $\gamma = 1$ ), however, lending is independent of the capital structure and similar to the market equilibrium. Together with market clearing for bank capital,  $K = kL$ , this condition determines equilibrium lending and return on equity: Since capital requirements are binding, market clearing coincides with the capital availability constraint in the regulator's program. Therefore, the lending is scale optimal:  $L = L^*$ .<sup>11</sup> The return on equity endogenously adjusts: As long as bank capital is scarce,  $K < K_0$ , such that  $k^* < 1 - \alpha$ , the market for bank capital clears thereby determining loans  $L = L^* < \mu$ . From condition (18), equity earns an excess return compared to deposits  $\gamma > 1$ . If  $K > K_0$ , capital requirements make banks risk-free such that the externality vanishes and maximum lending is optimal  $L^* = \mu$ . Accordingly, equity earns the same return as deposits,  $\gamma = 1$ .<sup>12</sup>

### Capital Requirements and the State of the Economy

This section studies the optimal adjustment of capital requirements in two different scenarios: a capital crunch, that is, a contraction of the bank capital supply  $K$ , and an adverse shock to entrepreneurs' productivity  $R$ . The capital crunch captures a key concern in the procyclicality debate<sup>13</sup>, while productivity shocks play a central role in macroeconomics as one of the driving forces of the business cycle. As discussed above, two channels - target risk and the

<sup>11</sup>Since the demand monotonically increases in  $L$  and the supply is fixed, the solution is  $L = L^*$ .

<sup>12</sup>Note that the capital requirements are binding if  $\gamma > 1$  but can be slack if  $\gamma = 1$ ; in the second case, banks may choose a higher capital ratio than  $1 - \alpha$  but they never lend more than  $\mu$ .

<sup>13</sup>See, for instance, Repullo (2013).

equilibrium lending rate - link capital regulation to the state of the economy. The adjustment is characterized by:

**PROPOSITION 2** *Optimal capital requirements  $k^*(r_L, \hat{x}^*)$  increase in the supply of bank capital,  $\frac{\partial k(r_L, \hat{x}^*)}{\partial K} > 0$ , and decrease in entrepreneurs' productivity,  $\frac{\partial k(r_L, \hat{x}^*)}{\partial R} < 0$ . Whenever the supply of bank capital is abundant,  $K \geq K_0$ , capital requirements are independent of the state of the economy.*

**Proof:** See Appendix 3.A.

A larger supply of bank capital allows (i) increasing the loan supply and (ii) raising the capital ratio to reduce bank risk (i.e., raise the failure threshold  $\hat{x}$ ). Proposition 1 shows that a combination of both is optimal, which drives the response of the capital structure: First, a larger supply of loans reduces the equilibrium lending rate given that the demand is unaffected. This lowers the bank's interest revenue such that it can absorb fewer loan losses. Only a higher capital ratio can preserve the risk level. Second, reducing target risk is optimal, which requires an even higher capital ratio. Both effects clearly imply tighter capital requirements. Conversely, the optimal response to a capital crunch is to relax them: On the one hand, the contraction of the loan supply generates a positive equilibrium effect through a higher lending rate, which allows reducing the capital ratio without affecting bank risk. On the other hand, tolerating a higher risk level is optimal as the decline of investment would otherwise be too strong. Thus, regulation is countercyclical in the sense that capital requirements are tightened (relaxed) if more (less) bank capital is available. This result is qualitatively similar to Repullo (2013).

A positive technology shock or, more generally, attractive investment prospects increase the value of the projects such that even entrepreneurs with high opportunity costs find it profitable to invest and loan demand increases. Productivity affects capital requirements in two ways: First, the higher loan demand increases the lending rate and the bank's interest income. This allows for a lower capital ratio without undermining financial stability. Second, tolerating a higher failure risk is usually optimal especially if capital requirements are tight. This implies a further decrease in the capital ratio. Even in case target risk is lower, the effect of a higher lending rate prevails, and the capital ratio unambiguously decreases if entrepreneurs become more productive. The somewhat ambiguous response of bank risk is precisely due to these two counteracting effects: the higher lending rate versus the lower capital ratio. The main purpose of relaxing capital requirements whenever investment opportunities improve is to allow banks to accommodate the higher loan demand such that they can fund more projects despite a fixed capital supply. If investment prospects worsen, in contrast, capital requirements should be tightened to account for the declining lending rate and to exploit the low project value and loan demand in order to maintain or even reduce bank risk. In other words, preserving or



even improving financial stability only entails a relatively small welfare cost. This finding can be related to the 'cleansing effect' of recessions emphasized, among others, by Caballero and Hammour (1994): Bank regulation should support such an effect by cutting funds for low productivity investments with a small net surplus and aim at improving financial stability instead. Hence, regulation has procyclical implications in the sense that tighter capital requirements restrict lending in case of a productivity decline.

The analysis offers three main insights: First, optimal regulation is related to the state of the economy through target risk and the equilibrium lending rate. Second, the cyclical adjustment fundamentally differs depending on the type of economic shock: Regulation is clearly procyclical in case of productivity shocks but countercyclical with regard to fluctuations in the supply of bank capital. In part, this difference arises because of an opposite equilibrium effect: A contraction of the bank capital supply leads to a higher lending rate as banks reduce their loan supply. This, in turn, allows for a lower capital ratio without raising bank risk. An adverse productivity shock, in contrast, lowers loan demand such that the lending rate falls, which mechanically requires a higher capital ratio to avoid higher bank risk. In particular, the regulator may adjust target risk: In case of a shortage of bank capital, a higher risk should be tolerated, whereas the response to a declining productivity is often to reduce risk. Intuitively, the latter can be achieved at a lower cost because of the rather unattractive investment prospects. Third, whenever a downturn involves both declining productivity and a shortage of bank capital at the same time, the optimal adjustment depends on the relative magnitude of the two effects.

### Comparison

This section compares the optimal adjustment to that of two alternative systems: flat and risk-sensitive capital requirements. Defining a constant ratio of bank capital to total assets, the former are similar in kind to the leverage ratio envisaged in Basel III. The latter define a minimum ratio of capital to risk-weighted assets and essentially target a particular risk level such as the target one-year solvency probability of 99.9% in Basel II (corresponding to a failure probability of 0.1% in our framework); risk-sensitive capital requirements remain an essential part of Basel III.

In case banks are subject to flat capital requirements,  $k = \bar{k}$ , their failure threshold is determined by  $1 - \bar{k} - \alpha - (r_L - \alpha)(1 - p)H(\hat{x}) = 0$ . Thus, bank risk decreases in the capital requirement, the lending rate, and the liquidation value. Taking into account loan demand and market clearing, lending and the return on equity are jointly determined by the bank's first-order condition and the equilibrium in the bank capital market

$$L = \mu - (\gamma - 1)\bar{k}, \quad K = \bar{k}L$$

In particular, lending and investment are simply a multiple of the bank capital supply:  $L = \frac{K}{k}$ . Whenever the supply of bank capital increases, banks increase loans by a factor  $\frac{1}{k}$ . In contrast, a higher loan demand due to more productive entrepreneurs only increases the lending rate and the return on equity thereby offsetting any quantity response. As soon as the bank capital supply satisfies  $K \geq \bar{k}\mu$ , the bank chooses  $L = \mu$  such that equity earns no excess return,  $\gamma = 1$ . In the risk-sensitive system, the failure threshold essentially becomes a policy parameter,  $\hat{x} = \hat{x}'$ . Intuitively, the regulator sets capital requirements consistent with a particular probability of a banking crisis. Condition (6) implies:

$$k(r_L, \hat{x}') = 1 - \alpha - (r_L - \alpha)(1 - p)H(\hat{x}')$$

The only difference to optimal capital requirements is the exogenous target risk.<sup>14</sup> Again, lending and interest rates follow from the bank's first-order condition combined with loan market clearing

$$\begin{aligned} L &= \mu - (\gamma - 1) [1 - \alpha - (r_L - \alpha)(1 - p)H(\hat{x}')] = 0, \\ K &= [1 - \alpha - (1 - p)(r_L - \alpha)H(\hat{x}')] L \end{aligned}$$

with  $r_L = R - \frac{L}{1-p_0}$ . Differentiating market clearing using  $r_L$  from the second condition implies that lending increases in both the bank capital supply and entrepreneurs' productivity. The adjustment of capital requirements is driven by changes in the lending rate: Since the latter falls if banks can access more capital such that the loan supply increases, capital requirements are tightened to avoid higher bank risk. In case of a higher productivity, in contrast, the loan demand and lending rate increase and the higher revenue from repaid loans provides an additional buffer implying a lower capital ratio. The cyclical adjustment is thus qualitatively similar to that of optimal capital requirements but it is entirely driven by changes in the equilibrium lending rate, whereas a welfare-maximizing regulator also adjusts the target risk. Hence, one may expect that the adjustment is less pronounced. Again, bank lending equals  $\mu$  as soon as  $K \geq (1 - \alpha) \left(1 - \frac{H(\hat{x}')}{1-\theta x_0}\right) \mu$  such that  $\gamma = 1$ . In such a case, capital requirements are  $k \geq (1 - \alpha) \left(1 - \frac{H(\hat{x}')}{1-\theta x_0}\right)$  and thus independent of the state of the economy.

Table 2 summarizes how the economy adjusts to (i) a capital crunch and (ii) a decline in productivity depending on the regulatory system. Both optimal and risk-sensitive capital requirements are relaxed if the bank capital supply falls and tightened if productivity deteriorates. However, the extent of their responses differs: Generally, an economy with optimal regulation adjusts at both margins - risk and lending - to a shock, whereas an economy with risk-sensitive capital requirements adjusts lending only. In a capital crunch, optimal capital requirements are relaxed

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<sup>14</sup>In case the latter was appropriately chosen and adjusted (i.e., if  $\hat{x}' = \hat{x}^*$ ), the allocation would coincide with the optimal allocation.

	Capital Requirements		
	Optimal	Flat	Risk-Sensitive
Capital Crunch ( $K \downarrow$ )			
Capital Ratio	$\downarrow$	$\leftrightarrow$	$\downarrow$
Failure Risk	$\uparrow$	$\downarrow$	$\leftrightarrow$
Lending	$\downarrow$	$\downarrow$	$\downarrow$
Adverse Productivity Shock ( $R \downarrow$ )			
Capital Ratio	$\uparrow$	$\leftrightarrow$	$\uparrow$
Failure Risk	$\uparrow$	$\uparrow$	$\leftrightarrow$
Lending	$\downarrow$	$\leftrightarrow$	$\downarrow$

Table 2: *Adjustment in a Downturn*

in order to prevent a massive contraction of the loan supply thereby tolerating a higher failure risk, whereas risk-sensitive capital requirements target a fixed risk level and are only relaxed because of a higher lending rate. Flat capital requirements are, by definition, independent of the state of the economy. A shortage of bank capital directly lowers the loan supply, which is a multiple of bank capital, and investment; through a higher equilibrium lending rate, this even makes banks safer. In this system, an adverse productivity shock only increases failure risk as lower loan demand drives down the lending rate but the loan volume is completely insensitive due to the inelastic loan supply. Despite being less valuable, the same number of projects is undertaken. These responses characterize an economy with scarce bank capital. If the latter is available in abundant supply, a shortage of bank capital does not have any real effects but an adverse productivity shock is associated with smaller lending and, in case of flat capital requirements, higher bank risk.

### Numerical Example

In this section, we compute the equilibrium of the model and provide a numerical example in order to illustrate the adjustment to adverse financial and real shocks. The purpose of this example is purely illustrative. The baseline calibration is  $R = 1.5$ ,  $p_0 = 0.2$ ,  $\alpha = 0.55$ ,  $\theta = 0.3$ ,  $c = 0.1$ ,  $K = 0.03$ .<sup>15</sup> Furthermore, the adverse shock  $x$  is uniformly distributed on the unit interval. The expected net return  $\mu$ , which equals investment in the unregulated market equilibrium, is 0.31. Hence, bank capital is clearly scarce as  $K = 0.03 < 0.1395 = (1 - \alpha)\mu$ . The optimal allocation is characterized by lending of 0.2710, a capital ratio of 11%, and a (gross) lending rate of 1.161. Banks fail in a recession as soon as more than 34.6% of their borrowers default which corresponds to an *ex ante* failure probability of 19.6%; social welfare

<sup>15</sup>Following Repullo and Martinez-Miera (2010), we set the liquidation value  $\alpha$  similar to the Basel II IRB approach, which suggests a loss given default (i.e.,  $1 - \alpha$ ) of 0.45 for senior claims on corporates (foundation approach); see par. 273 in BCBS (2004).

(aggregate surplus) equals 0.042. We simulate two scenarios depending on whether optimal, flat or risk-sensitive capital requirement are in place: (i) a capital crunch where the supply of bank capital  $K$  falls by one third to 0.02 and (ii) an adverse productivity shock where the project return falls by ten percent to 1.35 such that the expected net return  $\mu$  decreases to 0.19. The values of the baseline allocation are used to fix the flat capital requirements ( $\bar{k} = 11\%$ ) and target risk in the risk-sensitive system ( $\hat{x}' = 0.346$ ). Contrary to optimal regulation, either the capital ratio or failure risk remain constant.

	Capital Requirements		
	Optimal	Flat	Risk-Sensitive
Capital Crunch (K -33.3%)			
Capital Requirement (in pp)	-3.65	-	-2.54
Failure Risk (in pp)	+2.32	-3.36	-
Lending (in %)	-0.6	-33.32	-13.51
Welfare (in %)	-1.67	-12.62	-3.33
Adverse Productivity Shock (R -10%)			
Capital Requirement (in pp)	+7.91	-	+3.66
Failure Risk (in pp)	-4.75	+7.51	-
Lending (in %)	-41.70	-	-24.83
Welfare (in %)	-63.81	-82.38	-66.67

Table 3: *Numerical Example*

In a capital crunch, optimal capital requirements are relaxed from 11.1 to 7.42 percent: This significantly mitigates the decline of lending (-0.6%), which would fall by one third if capital requirements were not adjusted or still by more than 13 percent if only a passive adjustment as a result of the higher lending rate occurred. However, it moderately raises the probability of a banking crisis from 19.6 to 21.9 percent. The shortage of bank capital only causes a small welfare loss under optimal and risk-sensitive capital regulation; flat capital requirements perform significantly worse. The former is remarkable because the responses of risk and lending clearly differ between the optimal and risk-sensitive system. Since an adverse productivity shock reduces loan demand and makes investment less valuable, it is optimal to exploit this and to strongly increase capital requirement from 11 to almost 19 percent in order to reduce bank risk by 4.75 percentage points. Lower loan demand and tighter regulation cause a strong decline of lending by 41.7 percent. In the risk-sensitive system, capital requirements are only passively adjusted to account for the lower lending rate and lending falls by roughly one quarter. The adjustment under flat capital requirements markedly differs: The resource allocation remains unchanged but as the lower loan demand reduces the gross lending rate from 1.16 to 1.01, financial stability is in jeopardy with banks' failure probability strongly increasing to more

than 27 percent. In general, the welfare loss defined in terms of aggregate surplus<sup>16</sup> is higher than during a capital crunch partly because, in addition to distortions of risk or lending, all entrepreneurs are less productive. Again, optimal perform slightly better than risk-sensitive capital requirements, whereas flat capital requirements clearly exacerbate the welfare loss.

### 3.3.5 Entrepreneurial Moral Hazard

Borrowing and lending is often characterized by frictions, for instance, borrowers who are protected by limited liability and cannot be costlessly monitored by their lenders may have an incentive to allocate funds to riskier investments or to deliberately reduce effort. Adverse selection and moral hazard essentially make the lending rate a critical determinant of loan risk as shown by Stiglitz and Weiss (1981). Subsequently, we add such a credit friction to the model but stick to a formulation with private benefits in the spirit of Holmström and Tirole (1997) instead of different project returns<sup>17</sup>. The purpose of this extension is twofold: (i) it provides a robustness check and (ii) it allows us to study the impact of entrepreneurial moral hazard on bank capital requirements.

Suppose that the effort of an entrepreneur is critical for the project's success. More specifically, the entrepreneur may exert effort such that the project succeeds with an *ex ante* probability  $1 - p_0$  or exert no effort ('shirking') such that the success probability falls to  $1 - p'_0$  with  $p'_0 = p_0 + \Delta p_0$  with  $\Delta p_0 > 0$ .<sup>18</sup> Shirking yields private benefits  $b$  for the entrepreneur but makes the project unprofitable  $(1 - p'_0)R + p'_0\alpha - 1 < 0$ . Importantly, the bank does not observe effort, which gives rise to entrepreneurial moral hazard. As a result, the lending contract needs to be incentive-compatible as to guarantee effort:

$$(1 - p_0)(R - r_L) \geq (1 - p'_0)(R - r_L) + b \quad \Rightarrow \quad R - r_L \geq \frac{b}{\Delta p_0} \equiv \beta \quad (19)$$

Essentially, moral hazard limits the lending rate by an upper bound  $R - \beta$ . The parameter  $\beta$  is a measure of corporate governance; higher values point to a more severe agency problem. It ultimately depends on the institutional quality in a country and thus on factors like, for example, investor protection or transparency. A regulator does not observe effort either and thus needs to choose an incentive-compatible allocation. Subsequently, we focus on a binding incentive compatibility constraint,  $r_L = R - \beta$ , which implies that the agency problem is

<sup>16</sup>This is the reason why the relative welfare losses are so large; if welfare is defined in terms of (gross) output, they are substantially smaller.

<sup>17</sup>This allows separating project return and corporate governance such that the cyclical adjustment is better comparable to the baseline model.

<sup>18</sup>Shirking increases the idiosyncratic project risk by  $\Delta p$  such that  $\Delta p_0 = (1 - \theta x_0)\Delta p$  and  $p'_0 = p_0 + \Delta p_0 = p + \Delta p + \theta x_0[1 - (p + \Delta p)]$ .

severe enough, and the baseline allocation would not be incentive-compatible.<sup>19</sup> Hence, the participation constraint is slack and the regulator's choices are subject to the binding incentive compatibility constraint:

**PROGRAM 2** *The regulator maximizes welfare by choosing the capital ratio  $k$ , lending  $L$ , and the lending rate  $r_L$*

$$\max_{k, L, r_L} [\mu - \theta(1 - F(\hat{x}))c]L - \frac{L^2}{2}$$

*subject to the incentive compatibility constraint of entrepreneurs,  $r_L = R - \beta$ , and the capital availability constraint,  $K \geq kL$ .*

Solving this program yields the second-best equilibrium allocation:

**LEMMA 4** *Bank lending and failure threshold are determined by the system*

$$J^1(L, \hat{x}') = \mu - L' - c\theta[1 - F(\hat{x}')] - \frac{c\theta f(\hat{x}')}{1 - \theta + \theta F(\hat{x}')} \left[ \frac{1 - \alpha}{(1 - p)(R - \beta - \alpha)} - H(\hat{x}') \right] = 0 \quad (20)$$

$$J^2(L, \hat{x}') = K - [1 - \alpha - (R - \beta - \alpha)(1 - p)H(\hat{x}')]L = 0 \quad (21)$$

*Lending increases in the supply of bank capital  $K$  and entrepreneurs' productivity  $R$  but decreases in the corporate governance parameter  $\beta$ . The failure threshold increases in the supply of bank capital but the sensitivity with respect to productivity and corporate governance can be of either sign.*

**Proof:** See Appendix 3.A.

The first-order condition for loans and the capital availability constraint are similar to the baseline model apart from the fixed lending rate. The equilibrium allocation involves capital regulation:

**PROPOSITION 3** *Banks are subject to optimal capital requirements*

$$k'(r_L, \hat{x}') = 1 - \alpha - (r_L - \alpha)(1 - p)H(\hat{x}')$$

*with  $r_L = R - \beta$  that increase in the supply of bank capital,  $\frac{\partial k'(r_L, \hat{x}')}{\partial K} > 0$ , and the corporate governance parameter,  $\frac{\partial k'(r_L, \hat{x}')}{\partial \beta} > 0$ , and decrease in entrepreneurs' productivity,  $\frac{\partial k'(r_L, \hat{x}')}{\partial R} < 0$ .*

**Proof:** See Appendix 3.A.

<sup>19</sup>However, moral hazard must not be too severe,  $\beta \leq \mu$ , as banks would otherwise earn negative expected profits or their shareholders a negative return. This follows from  $\pi^B = [(1 - p)r_L + p\alpha - 1 - (\gamma - 1)k]L = [\mu - \beta - (\gamma - 1)k]L \geq 0$ , using  $r_L = R - \beta$ .  $\beta > \mu$  would lead to full credit rationing. Whenever  $K \geq K_0$ , the lending rate is small such that the IC is slack;  $r_L = (1 - p\alpha)/(1 - p) < R - \beta$ . Hence, entrepreneurial moral hazard may only arise if scarce bank capital is required to internalize the social cost of bank failure.

This proposition has two main implications: First, moral hazard leads to an artificially low lending rate as higher rates would destroy incentives, an effect reinforced by a poor corporate governance. Since banks earn a smaller interest income and are *ceteris paribus* riskier, the optimal capital ratio increases such that poor governance of firms and entrepreneurial projects requires tighter bank regulation. In the presence of such frictions, optimal regulation thus depends on a country's institutional quality. Second, the adjustment of capital requirements to economic shocks is qualitatively similar to the baseline model without moral hazard. However, the mechanisms differ: Since the lending rate is fixed, some of the equilibrium effects that are relevant in the standard model disappear. Capital requirements are relaxed in capital crunch only because tolerating a higher bank risk is optimal and not due to a declining lending rate. The tightening in case of an adverse productivity shock, in contrast, still results from the two effects described above: The lending rate decreases to preserve the incentive of entrepreneurs, which, in turn, requires a higher capital ratio to keep failure risk constant. In addition, the regulator may adjust the latter in either way but even if a higher risk level is tolerated, the first, positive effect prevails.

### 3.4 Conclusion

This paper provides a normative analysis of the cyclical adjustment of capital regulation, the purpose of which is to internalize the social costs of a systemic banking crisis. The latter originates from the real sector, which may suffer from an adverse macroeconomic shock in a recession, such that correlated defaults lead to bank failure. As long as bank capital is scarce, optimal regulation balances the trade-off between financial stability and the investment capacity of the real sector. Two channels link optimal capital requirements to the state of the economy: target risk and the equilibrium lending rate. The latter, which, contrary to related models like Kashyap and Stein (2004) and Repullo (2013), is endogenized by a full-fledged model of the real sector, plays an important role as a *de facto* substitute for bank capital on the 'risk front' and thus strongly influences the optimal regulatory adjustment. The main finding is that there are striking differences depending on the driving force of an economic downturn: If the supply of bank capital falls, banks face difficulties to raise equity such that they may reduce the loan supply. Therefore, capital requirements should be less strict: On the one hand, a smaller loan supply raises the lending rate, which has a stabilizing effect by making banks safer due a higher interest income. On the other hand, tolerating a higher bank failure risk is optimal in order to prevent a sharp fall of lending and investment. In a downturn primarily characterized by poor investment prospects and a low loan demand of entrepreneurs, capital requirements should be tighter: Declining lending rates undermine a bank's resilience such that the risk level is only

preserved at a higher capital ratio. More importantly, the number of attractive investments is small; such circumstances even allow a regulator to further improve financial stability by tighter capital requirements at a relatively small welfare cost. Consequently, regulation should be tough whenever bank capital is easily available and only few investments are promising but can be relaxed whenever equity is scarce and investment prospects are good. Contrary to flat or risk-sensitive capital requirements, optimal regulation allows the economy to adjust to shocks at two different margins - lending and risk - whereas one of them is *de facto* fixed in the two alternative systems, which exacerbates the welfare losses in a downturn. The main findings also result in the presence of entrepreneurial moral hazard, which makes optimal regulation sensitive to additional factor such as corporate governance and institutional quality. Eventually, the supply of bank capital can be large enough to make banks safe without harming investment. In this case, capital requirements are insensitive to economic shocks.

How do these findings compare with the countercyclical buffer envisaged in Basel III? It is of course difficult to interpret such a buffer, which is essentially a dynamic concept as the buffer is accumulated during periods of excess credit growth and effectively relaxed in a downturn, in the context of our static framework. One implication of our results is that it makes a difference whether credit growth is mainly supply- or demand-driven as capital requirements should indeed be tightened in the first but relaxed in the second case to accommodate the higher demand. Hence, the regulator should identify the precise source of credit growth and activate the buffer primarily in case attractive funding conditions of banks let their loan supply growing rapidly. A possible approach would be to compare the growth of corporate and SME loans to overall credit growth. If the former grow more than proportionately, this may point to attractive investment prospects and strong loan demand, which do not justify tighter capital buffers. On the aggregate level, the regulator may also take into account the growth of investment in plants and equipments. In line with the focus on the real sector, our analysis of course mainly concerns corporate and business loans that finance productive real investments; credit growth driven by a strong demand for mortgages, however, does not necessarily imply that relaxing capital requirements is optimal because it may rather reflect a real estate bubble instead of more productive and valuable investments.

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### 3.A Appendix

**Proof of Lemma 1** The central condition follows from combining (2) and (5): Using integration by parts, the participation constraint can be written as:

$$\theta \left[ \alpha - [(1-p)(1-\hat{x})r_L + (p+\hat{x}(1-p))\alpha]F(\hat{x}) + (r_L - \alpha)(1-p) \int_{\hat{x}}^1 F(x)dx \right] \\ + [1 - \theta + \theta F(\hat{x})]r(1-k) = 1 - k$$

The definition of the failure threshold implies  $(1-p)(1-\hat{x})r_L + (p+\hat{x}(1-p))\alpha = r(1-k)$ , which can be used to eliminate  $r(1-k)$  such that

$$\theta \left[ \alpha + (r_L - \alpha)(1-p) \int_{\hat{x}}^1 F(x)dx \right] + (1-\theta)[(1-p)(1-\hat{x})r_L + (p+\hat{x}(1-p))\alpha] = 1 - k$$

which can be rearranged to get (6). Eventually, differentiating this condition yields the sensitivities

$$\frac{\partial \hat{x}}{\partial k} = \frac{1}{[1 - \theta + \theta F(\hat{x})](1-p)(r_L - \alpha)} > 0 \\ \frac{\partial \hat{x}}{\partial r_L} = \frac{H(\hat{x})}{[1 - \theta + \theta F(\hat{x})](r_L - \alpha)} > 0 \\ \frac{\partial \hat{x}}{\partial \alpha} = \frac{1 - (1-p)H(\hat{x})}{[1 - \theta + \theta F(\hat{x})](1-p)(r_L - \alpha)} > 0$$

where the latter uses  $H(\hat{x}) \leq 1 - \theta x_0$ . *Q.E.D.*

**Proof of Proposition 1** Program 1 can be stated as a Lagrangian

$$\mathcal{L}(k, L, \lambda_1, \lambda_2) = [\mu - \theta(1 - F(\hat{x}))c]L - \frac{L^2}{2} + \lambda_1[K - kL] + \lambda_2[(1 - p_0)(R - L) - L]$$

which uses  $L = \hat{u}$  in equilibrium. The corresponding first-order conditions are

$$\frac{\partial \mathcal{L}}{\partial k} = \frac{c\theta f(\hat{x})L}{(1-p)(r_L - \alpha)[1 - \theta + \theta F(\hat{x})]} - \lambda_1 L = 0 \\ \frac{\partial \mathcal{L}}{\partial L} = \mu - (1 - F(\hat{x}))c - L - \lambda_1 k - \lambda_2 = 0 \\ \frac{\partial \mathcal{L}}{\partial r_L} = \frac{c\theta f(\hat{x})H(\hat{x})L}{(r_L - \alpha)[1 - \theta + \theta F(\hat{x})]} - \lambda_2(1 - p_0) = 0$$

as well as participation and capital availability constraint. The first condition is equivalent to equation (12) and implies a positive capital ratio. Thus, one can rearrange (6) to express the capital ratio as a function of the risk level:  $k = 1 - \alpha - (1-p)(r_L - \alpha)H(\hat{x})$ . It is more

convenient and intuitive to substitute this expression for  $k$  in the above conditions and to treat  $\hat{x}$  as the unknown.

The problem can be reduced to the system (14) - (15) with two equations and two unknowns:  $L$  and  $\hat{x}$ . Substituting for the Lagrange multipliers, the capital ratio, and the lending rate in  $\frac{\partial \mathcal{L}}{\partial L} = 0$  yields equation  $J_L^1(\hat{x}, L) = 0$ . The second equation,  $J_L^2(\hat{x}, L) = 0$ , is the capital availability constraint where we substitute for  $k$  using  $r_L = R - \frac{L}{1-p}$ . The system has the solutions  $\hat{x} = 1$  and  $L = \mu$  as soon as  $K \geq K_0$ , which allows for  $k = 1 - \alpha$ . Totally differentiating yields the Jacobian

$$J = \begin{bmatrix} J_L^1 & J_{\hat{x}}^1 \\ J_L^2 & J_{\hat{x}}^2 \end{bmatrix}$$

where  $J_i^j = \frac{\partial J^j}{\partial i}$  with  $i = \{L, \hat{x}\}$  and  $j = \{1, 2\}$  and

$$\begin{aligned} J_L^1 &= - \left[ 1 + \frac{c\theta f(\hat{x}) [1 - \alpha + (1-p)(R - \alpha)H(\hat{x})]}{[1 - \theta + \theta F(\hat{x})](1 - p_0)(1-p)(r_L - \alpha)^2} \right] < 0 \\ J_{\hat{x}}^1 &= \frac{c\theta f(\hat{x})L}{(r_L - \alpha)(1 - p_0)} + \frac{c\theta [\theta f(\hat{x})^2 - (1 - \theta + \theta F(\hat{x}))f'(\hat{x})] \left[ k + \frac{(1-p)H(\hat{x})L}{1-p_0} \right]}{[1 - \theta + \theta F(\hat{x})]^2(r_L - \alpha)} \geq 0 \\ J_L^2 &= - \left[ k + \frac{(1-p)H(\hat{x})L}{1-p_0} \right] < 0 \\ J_{\hat{x}}^2 &= -(1-p)(r_L - \alpha)[1 - \theta + \theta F(\hat{x})]L < 0 \end{aligned}$$

The Jacobian determinant is positive:

$$\nabla = J_L^1 J_{\hat{x}}^2 - J_L^2 J_{\hat{x}}^1 > 0$$

The comparative statics are obtained using Cramer's rule. A larger supply of bank capital increases lending and the failure threshold:

$$\frac{\partial L}{\partial K} = \frac{J_{\hat{x}}^1}{\nabla} \geq 0, \quad \frac{\partial \hat{x}}{\partial K} = -\frac{J_L^1}{\nabla} > 0$$

A higher productivity of entrepreneurs increases lending and but the response of the failure threshold is ambiguous:

$$\frac{\partial L}{\partial R} = \frac{-J_R^1 J_{\hat{x}}^2 + J_R^2 J_{\hat{x}}^1}{\nabla} > 0, \quad \frac{\partial \hat{x}}{\partial R} = \frac{-J_L^1 J_R^2 + J_L^2 J_R^1}{\nabla} = -\frac{k J_R^1 - \frac{c\theta(1-p)f(\hat{x})H(\hat{x})^2 L}{(1-p_0)(r_L - \alpha)[1 - \theta + \theta F(\hat{x})]}}{\nabla}$$

where  $J_R^k$  for  $k = \{1, 2\}$  are given by

$$J_R^1 = 1 - p_0 + \frac{c\theta f(\hat{x})}{1 - \theta + \theta F(\hat{x})} \frac{1 - \alpha + \frac{(1-p)H(\hat{x})L}{1-p_0}}{(1-p)(r_L - \alpha)^2} > 0, \quad J_R^2 = (1-p)H(\hat{x})L > 0$$

Note that  $\frac{\partial \hat{x}}{\partial R}$  is usually negative unless the equilibrium capital ratio is very low and, at the same time, the social cost of bank failure is very high. *Q.E.D.*

**Proof of Corollary 2** Substituting the capital ratio (17) into the definition of the failure threshold (6) shows that bank risk is, by construction, optimal:  $\hat{x} = \hat{x}^*$ . Each bank chooses loans and capital structure as to maximize its expected profit  $\pi^B$  defined in (2) subject to the regulatory constraint  $k \geq k^*$ . The Lagrangian is

$$\mathcal{L}(k, L, \eta) = [(1 - p_0)r_L + p_p\alpha - (1 - k) - \gamma k]L + \eta[k - k^*]$$

where  $\eta$  is the Lagrange multiplier of the regulatory constraint. The corresponding first-order conditions are:

$$(1 - p)r_L + p\alpha - 1 - (\gamma - 1)k = 0, \quad -(\gamma - 1) + \eta = 0, \quad \eta(k - k^*) = 0$$

Substituting  $r_L = R - \frac{L}{1-p}$  using loan market clearing and the definition of the marginal entrepreneur, yields bank lending:

$$L = \mu - (\gamma - 1)k$$

If  $K < K_0$ , capital requirements are  $k^* < 1 - \alpha$ . First, we show that the regulatory constraint binds: Suppose banks chose a higher capital ratio  $k > k^*$ , dividing market clearing,  $K = kL$ , by  $k$  would yield  $K/k = L = \mu - (\gamma - 1)k$ . The left-hand side falls short of optimal lending such that  $L < L^* = K/k^*$ , which is smaller than  $\mu$  according to proposition 1. From above, we have  $\gamma > 1$  and  $\eta > 0$ , which is incompatible with complementary slackness. Consequently, capital requirements are binding:  $k = k^*$ . By substituting  $k^* = K/L^*$  into the market clearing condition,  $K = k^*L$ , one observes that bank provide the optimal amount of loans,  $L = L^*$ .

Whenever  $K \geq K_0$ , capital requirements are  $k^* = 1 - \alpha$ . Banks choose  $k \in [1 - \alpha, K/\mu]$  such that from market clearing,  $K \geq k[\mu - (\gamma - 1)k]$ , w  $\gamma = 1$  (which implies  $\eta = 0$  and allows for a possibly non-binding regulatory constraint) and banks choose optimal lending  $L = \mu$ . An even higher capital ratio,  $k > K/\mu$  would lead to an inefficiently small amount of loans but is ruled out by complementary slackness. *Q.E.D.*

**Proof of Proposition 2** Using the definition of capital requirements, (17), the sensitivity w.r.t. the bank capital supply  $K$  is

$$\frac{\partial k^*(r_L, x^*)}{\partial K} = -(1 - p)H(\hat{x})\frac{\partial r_L}{\partial K} + (r_L - \alpha)(1 - p)[1 - \theta + \theta F(\hat{x}^*)]\frac{\partial \hat{x}^*}{\partial K} > 0$$

where  $\frac{\partial r_L}{\partial K} = -\frac{1}{1-p} \frac{\partial L^*}{\partial K} < 0$ ; the positive sign follows from  $\frac{\partial L}{\partial K} > 0$  and  $\frac{\partial \hat{x}^*}{\partial K} > 0$  given by proposition 2. Similarly, one can derive the sensitivity w.r.t. productivity  $R$

$$\frac{\partial k^*(r_L, x^*)}{\partial R} = -(1-p)H(\hat{x})\frac{\partial r_L}{\partial R} + (r_L - \alpha)(1-p)[1 - \theta + \theta F(\hat{x}^*)]\frac{\partial \hat{x}^*}{\partial R}$$

where  $\frac{\partial r_L}{\partial R} = 1 - \frac{1}{1-p_0} \frac{\partial L^*}{\partial R} = \frac{(1-p_0)\nabla + J_R^1 J_{\hat{x}}^2 - J_R^2 J_{\hat{x}}^1}{(1-p_0)\nabla} > 0$ . However, the sign of  $\frac{\partial \hat{x}^*}{\partial R}$  is ambiguous. Using the sensitivities from the proof of proposition 2, one can show that optimal capital requirements decrease in productivity:

$$\begin{aligned} \frac{\partial k^*}{\partial R} &= -\frac{1-p}{\nabla} \left[ H(\hat{x}) \frac{(1-p_0)\nabla + J_R^1 J_{\hat{x}}^2 - J_R^2 J_{\hat{x}}^1}{1-p_0} + k(r_L - \alpha)[1 - \theta + \theta F(\hat{x})]J_R^1 - \frac{c\theta(1-p)f(\hat{x})H(\hat{x})^2 L}{(1-p_0)} \right] \\ &= -\frac{(1-p)k}{\nabla} [H(\hat{x})J_{\hat{x}}^1 + (r_L - \alpha)[1 - \theta + \theta F(\hat{x})]J_R^1] < 0 \end{aligned}$$

Alternatively, one can derive this result using the capital availability constraint: Since the supply is fixed and lending increases in  $R$ , the capital ratio necessarily falls. Once  $K \geq K_0$ , the optimal capital requirements  $k = 1 - \alpha$  are clearly independent of both entrepreneurs' productivity and the bank capital supply. *Q.E.D.*

**Proof of Lemma 4** If the incentive compatibility constraint binds such that  $r_L = R - \beta$ , the equilibrium conditions are (20), the first-order condition w.r.t  $L$  substituting for the Lagrange multiplier  $\lambda = \frac{cf(\hat{x})}{1-F(\hat{x})} \frac{\partial \hat{x}}{\partial k}$ , and (21), the capital availability constraint substituting for  $k$  and  $r_L$ . Differentiating (20) - (21) yields the Jacobian with:

$$\begin{aligned} J_L^1 &= -1 < 0, & J_{\hat{x}}^1 &= \frac{c\theta [\theta f(\hat{x})^2 - f'(\hat{x})(1 - \theta + \theta F(\hat{x}))] k}{(r_L - \alpha)(1-p)(1 - \theta + \theta F(\hat{x}))^2} \geq 0 \\ J_L^2 &= -k < 0, & J_{\hat{x}}^2 &= -(r_L - \alpha)(1-p)(1 - \theta + \theta F(\hat{x}))L < 0 \end{aligned}$$

The Jacobian determinant is positive:  $\nabla = J_L^1 J_{\hat{x}}^2 - J_L^2 J_{\hat{x}}^1 > 0$ . Applying Cramer's rule, we find that larger supply of bank capital increases lending and the failure threshold

$$\frac{\partial L}{\partial K} = \frac{J_{\hat{x}}^1}{\nabla} > 0, \quad \frac{\partial \hat{x}}{\partial K} = -\frac{J_L^1}{\nabla} > 0$$

and that higher productivity increases lending but has an ambiguous effect on the failure threshold

$$\frac{\partial L}{\partial R} = \frac{-J_R^1 J_{\hat{x}}^2 + J_R^2 J_{\hat{x}}^1}{\nabla} > 0, \quad \frac{\partial \hat{x}}{\partial R} = \frac{J_R^2 - k J_R^1}{\nabla}$$

Note that  $J_R^i$  for  $i = \{1, 2\}$  are

$$J_R^1 = 1 - \alpha + \frac{c\theta f(\hat{x})}{1 - \theta + \theta F(\hat{x})} \frac{1 - \alpha}{(r_L - \alpha)^2 (1 - p)} > 0, \quad J_R^2 = (1 - p)H(\hat{x})L > 0$$

Poor corporate governance of entrepreneurs lowers lending but has an ambiguous impact on

the failure threshold

$$\frac{\partial L}{\partial \beta} = \frac{-J_{\beta}^1 J_{\hat{x}}^2 + J_{\beta}^2 J_{\hat{x}}^1}{\nabla} < 0, \quad \frac{\partial \hat{x}}{\partial \beta} = \frac{J_{\beta}^2 - k J_{\beta}^1}{\nabla}$$

with  $J_{\beta}^j$  for  $j = \{1, 2\}$ .

$$J_{\beta}^1 = -\frac{c\theta f(\hat{x})}{1 - \theta + (\hat{x})(r_L - \alpha)^2(1 - p)} < 0, \quad J_{\beta}^2 = -(1 - p)H(\hat{x})L < 0$$

*Q.E.D.*

**Proof of Proposition 3** The positive response of capital requirements  $k' = 1 - \alpha - (R - \beta - \alpha)H(\hat{x})$  to a larger supply of bank capital is due to a higher failure threshold  $\frac{\partial \hat{x}'}{\partial K} > 0$ . The sensitivity w.r.t. productivity follows from

$$\begin{aligned} \frac{\partial k'}{\partial R} &= -(1 - p)H(\hat{x}) + (r_L - \alpha)(1 - p)[1 - \theta + \theta F(\hat{x})] \frac{\partial \hat{x}}{\partial R} \\ &= -\frac{(1 - p)k [H(\hat{x})J_{\hat{x}}^1 + (r_L - \alpha)[1 - \theta + \theta F(\hat{x})]J_{\beta}^1]}{\nabla} < 0 \end{aligned}$$

and is negative. Similarly, the sensitivity w.r.t. the corporate governance parameter is

$$\begin{aligned} \frac{\partial k'}{\partial \beta} &= (1 - p)H(\hat{x}) + (r_L - \alpha)(1 - p)[1 - \theta + \theta F(\hat{x})] \frac{\partial \hat{x}}{\partial \beta} \\ &= \frac{(1 - p)k [H(\hat{x})J_{\hat{x}}^1 - (r_L - \alpha)[1 - \theta + \theta F(\hat{x})]J_{\beta}^1]}{\nabla} > 0 \end{aligned}$$

and positive. These two effects are also implied by the response of bank lending in the presence of a fixed bank capital supply. *Q.E.D.*





## Chapter 4

# Banks and Sovereigns: A Model of Mutual Contagion

Alexander Gruber and Michael Kogler<sup>1</sup>

This paper develops a model of the bank-sovereign nexus and studies the implications of government guarantees for risk and welfare. We combine financial and sovereign debt fragility that ultimately originate from risky bank loans: Beyond the impact on banks, a bad realization of the stochastic loan return may cause a sovereign default due to deposit insurance cost or an erosion of the tax base. Deposit insurance can either trigger or prevent a sovereign default. It may also raise domestic welfare by avoiding significant liquidation costs and by effectively shifting the public debt burden onto foreign bondholders. The preferential regulatory treatment of sovereign risks induces banks to purchase government bonds such that they are sensitive to the fiscal state. In particular, bond holdings create the possibility of an adverse feedback such that banks fail because of a sovereign default but would survive otherwise. At least in fiscally sound countries, there might also be a tension between fiscal and financial stability because higher bond returns provide a buffer such that banks can absorb more loan losses.

**JEL Classification:** G11, G21, G28, H63

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## 4.1 Introduction

The recent financial crisis has emphatically demonstrated that bank and sovereign risks are inherently and inevitably intertwined. A crisis of the banking industry may trigger disastrous consequences for the economy as a whole and induce the governments to intervene. In fact, rescue packages for distressed banks and other systemically important financial institutions took center stage in many countries in the recent past. Given that the size of the banking sector often corresponds to a multiple of GDP, the sovereign exposure to such financial risks was exorbitant in many cases. This is especially true for the euro area where the fiscal responsibility for such interventions still lies within national borders although banks have long expanded beyond. As a result, public debt levels successively increased: According to Laeven and Valencia (2012), the public debt-to-GDP ratio increased by almost 20 percentage points in the euro area between 2008 and 2011; this increase was particularly sharp in Ireland (72pp), Greece (45pp), and Spain (31pp). The economic viability of the GIIPS - Greece, Ireland, Italy, Portugal and Spain - and their ability to repay their outstanding debt was suddenly at stake. The abrupt awareness of countries' vulnerability and possible sovereign defaults drove apart the bond spreads in the euro area. Banks, however, had built up a large sovereign exposure as documented by the 2014 EBA stress test: Belgian banks, for example, held euro area sovereign bonds worth 16 percent of total assets. Italian (14 percent) and German, Portuguese, and Spanish banks (between 10 and 13 percent) showed a similar exposure (ESRB, 2015). The preferential treatment of sovereign bonds in the Basel accords was certainly conducive to this trend. Especially in the GIIPS countries, bond holdings are characterized by a significant home bias: Domestic bonds represented 85 percent of banks' (Euro area) sovereign exposure in Italy, and 87 percent in Ireland, 93 percent in Spain and Portugal, and 98 percent in Greece (ESRB, 2015). As the creditworthiness of certain governments decreased, banks were forced to reappraise some of these positions and - as for Greece's debt haircut - to take real losses. A vicious spiral with negative spillovers from banks to sovereigns and *vice versa* emerged. An even more disastrous credit crunch and further contagion between euro area member states could so far only be averted by massive policy interventions and bailouts.

On closer inspection, the crisis thus revived our awareness for the inherent fragility of banks, which fund themselves with unparalleledly low levels of equity, and their unique interconnectedness with other banks, sovereigns, and market participants. These characteristics set banks apart from ordinary companies and provide the basis for their systemic relevance. Although influential strands of literature consider this fragility a necessary disciplining device, it proved to be a source of financial instability associated with severe negative consequences such as bank runs and contagion. A more critical assessment has thus been advocated by Pfliederer (2014),

Admati and Pfleiderer (2010) and Admati and Hellwig (2013), who question the upside of this 'self-imposed' fragility and draw attention to the negative consequences for bank governance, financial stability, and welfare.

This paper contributes to the emerging literature on the bank-sovereign nexus in several ways: First of all, it develops a comprehensive theoretical framework that highlights the interplay of bank and sovereign risks by combining a fully-fledged model of banks, which are invested in risky assets, with a classical version of sovereign debt fragility with multiple equilibria. This allows us to capture the key mechanisms of contagion between banks and sovereigns, namely, government guarantees, taxation, and sovereign bond holdings. Importantly, the focus on risks which emerge from the bank's asset side captures a stylized fact of the recent crisis. After all, the latter originated in the sub-prime mortgage market. Existing literature on the bank-sovereign nexus has primarily dealt with contagion issues coming from the public sector. Furthermore, the paper explores the consequences of government guarantees for depositors on sovereign risk and domestic welfare, which sets it apart from other contributions that focus on the implications of *ex ante* bailouts à la Acharya et al. (2014). The welfare and risk effects crucially depend on the (avoided) cost of a disorderly bank liquidation and on the possibility to shift bailout cost onto foreign bondholders. Notably, we find that the provision of deposit insurance can either trigger or prevent a sovereign default. Finally, we investigate the implications of tighter capital requirements for bank and sovereign risks in a setting in which government bonds receive preferential treatment in the sense that they do not need to be backed by equity (as in Basel III): This setup provides strong incentives for banks to invest in such assets, which makes them sensitive to the fiscal state. In turn, this creates the possibility for adverse feedback loops in which banks may be weakened or even fail because the government defaults. Interestingly, relatively low levels of fiscal fragility may actually improve financial stability since higher bond returns provide a buffer which improves banks' robustness to poor loan performance. This relationship reverses, however, when a certain level of fiscal fragility is exceeded. Stricter capital requirements are likely to enhance the resilience of sovereigns and banks in our set-up although the analysis also points at potential countervailing effects.

The remainder of this paper is organized as follows: Section 4.2 first reviews the related literature, and section 4.3 then introduces the model. Subsequently, section 4.4 characterizes potential equilibria and examines the consequences of providing government guarantees on sovereign risk and domestic welfare. Section 4.5 discusses a variant with capital regulation and section 4.6 eventually concludes.

## 4.2 Literature

This paper particularly relates to the literature on financial and sovereign debt fragility as well as to recent contributions on the interaction of bank and sovereign risks: Financial fragility is often modeled by a combination of risky bank assets and small equity. A tractable approach that exemplifies this key feature is a stochastic loan return as in Dermine (1986) and Boyd et al. (2009): Bad realizations of borrowers' returns translate into loan losses, which, if large enough, may wipe out a bank's equity. On the liquidity side, Diamond and Dybvig (1983) investigate the role of excess maturity transformation for banks' inherent susceptibility to runs. They show that a 'good' equilibrium with optimal risk sharing between depositors with different liquidity needs may give way to a 'bad' one, in which all depositors panic and withdraw their deposits.<sup>2</sup> Bank risks, however, must not be examined in isolation. Instead, they are intimately linked through at least two mechanisms: interbank lending and fire sales. Following Diamond and Dybvig (1983), Allen and Gale (2000) develop a network model of interbank lending. Although the latter is beneficial *per se* and allows for optimal risk sharing in order to withstand independent liquidity shocks, it may lead to contagion in case of correlated shocks. Depending on the network structure and the liquidation value of the bank's assets, the crisis of a single institution may then spread over to other banks and become systemic. Likewise, Shleifer and Vishny (1992, 2011) identify the contagious effect of fire sales: They argue that banks which face substantial liquidity withdrawals might be forced to quickly liquidate parts of their assets at a dislocated price. That, in turn, may cause a further deterioration of other banks' balance sheets, which subsequently forces them to sell their assets as well; either because they violate regulatory standards or because depositors start to withdraw. Furthermore, Diamond and Rajan (2011) relate fire sales to the freeze of credit markets. They show that the prospect of future fire sales alone suffices to depress the current asset prices and to cause a 'seller's strike' *ex ante*. Eventually, Greenwood et al. (2015) develop a model of contagion through fire sales and focus on each bank's exposure and contribution to system-wide deleveraging.

Sovereign debt fragility on the other hand arises because a government's ability or willingness to repay its debt may depend on the interest rate, which, in turn, hinges on investors' expectations about future debt repayment. This gives rise to multiple equilibria and self-fulfilling debt crises: If investors are pessimistic about debt repayment, they require a high interest rate, which increases the debt burden and weakens fiscal stability thus justifying their pessimism. In a seminal contribution, Calvo (1988) shows that such a mechanism can be generated by the possibility of debt repudiation, which may lead to multiple equilibria. In our paper, we

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<sup>2</sup>Another branch of the literature, for example, Diamond and Rajan (2000, 2005) emphasizes the importance of financial fragility as a commitment device in the presence of a hold-up problem.

subsequently rely on a textbook version of this model by Romer (2001), who essentially replaces debt repudiation by a stochastic tax revenue. Detragiache (1996) shows that some of these equilibria materialize as a liquidity crisis while Cole and Kehoe (2000) focus on a so-called crisis zone where sovereign risk depends on market participants' expectations and study its fundamental determinants as well as optimal debt policy. The empirical relevance of multiple equilibria in the context of sovereign debt is documented, for example, in Reinhart and Rogoff (2011) or De Grauwe and Ji (2013).

Recent events have raised the need for a more integrated view on financial and sovereign debt fragility thereby laying the ground for topical research on the bank-sovereign nexus, to which this paper contributes. On the theoretical side, Bolton and Jeanne (2011), for example, stress the role of sovereign bonds as a collateral in interbank lending. Sovereign risk compromises this function and hampers a bank's lending capacity. An extension to a two-country model shows that banks tend to diversify their bond holdings and that this diversification, although beneficial *ex ante*, may trigger financial contagion *ex post*. In a similar spirit, Gennaioli et al. (2014) relate the strength of financial institutions to cross-country capital flows and the governments' decision to default. The authors conclude that better financial institutions increase capital inflows to a country and reduce the attractiveness of government default. Cooper and Nikolov (2013) connect the model of sovereign debt fragility by Calvo (1988) with the model of bank fragility by Diamond and Dybvig (1983) and focus on two channels of mutual contagion: banks' sovereign bond holdings and explicit or implicit government guarantees. They find that a sudden drop in confidence in the sovereign's creditworthiness may abruptly shift the economy to a pessimistic equilibrium associated with costly bank runs. They also study the role of deposit insurance, which may prevent runs but also exacerbate a looming fiscal crisis. Using a global games approach, Leonello (2015) shows that government guarantees connect banks' withdrawal and governments' roll-over risks as the actions of depositors and bondholders become strategic complements. Guarantees may trigger a feedback loops between a banking and sovereign debt crisis. Motivated by the Irish example, Acharya et al. (2014) study the impact of bank bailouts on sovereign risk. A bailout alleviates the under-provision of financial services due to debt overhang but also provokes distortive taxation of the non-financial sector. The latter can be avoided by a sovereign default, which, however, further weakens the solvency of banks. The intimate linkages between financial and sovereign risk are also documented by empirical evidence: Acharya et al. (2014), for example, show that the recent crisis and the corresponding bailouts caused a risk transfer to the government while Battistini et al. (2013) point out the significant home bias of European banks' sovereign bond portfolios and its negative consequences. Similarly, Mody and Sandri (2012) provide evidence for the strong impact of the banking sector's performance on risk premia on euro area sovereign bonds. Furthermore, they highlight that

problems in the banking sector exert particularly negative effects in countries with low growth prospects and high initial debt burdens. Bénassy-Quéré and Roussellet (2014) provide quantitative simulations to show how implicit government guarantees for systemic banks undermine fiscal sustainability measured by the gap between the tax rate necessary for a sustainable debt ratio and the current tax rate. They find that such guarantees tend to increase the tax gap but there is considerable heterogeneity across EU countries and depending on how the bailout cost are measured. Reinhart and Rogoff (2011) eventually demonstrate that these insights hold for a long-run perspective as well. Using data from nearly two centuries, they find that sovereign debt crises have been frequently preceded by banking crises in the past.

### 4.3 The Model

This section outlines the baseline model: The main source of risk in the economy is bank loans (e.g., mortgages, consumer or commercial loans, asset-backed securities) characterized by a stochastic return: Bad realizations, which may, for example, reflect a large share of non-performing loans or write-offs on asset-backed securities, may cause substantial losses that quickly wipe out a bank's small equity - a feature that captures the asset risk dimension of financial fragility. Bank risk may then spread to the sovereign through two channels - government guarantees and taxation - and may trigger a sovereign default, which, in turn, may exert adverse feedback effects due to the sovereign bond holdings of banks. Sovereign debt fragility is therefore the second source of risk in the economy. It arises due to the interaction of investors' expectations about sovereign risk and the required return on government bonds. Hence, multiple equilibria, which differ in the extent and mechanisms of bank-sovereign contagion, may emerge.

There are two periods and the model economy is populated by three types of agents: First, there exists a continuum of measure one of identical *banks*. Each bank is funded by exogenous equity  $E$  and raises an amount  $D$  of deposits from households, which are protected by a deposit insurance scheme. A bank can invest into two types of assets: (i) bank loans which yield a stochastic return and (ii) sovereign bonds. Consistent with our focus on systemic crises, loan returns are correlated across banks. Bank owners are risk-neutral and protected by limited liability; they receive the bank's final-period equity and consume at date 2. Second, risk-averse, identical *households* derive utility from consumption at both dates. They earn labor income modeled as a deterministic endowment at both dates; income is larger at date 1 than at date 2:  $W_1 > W_2$ . In order to smooth consumption, they deposit savings  $D$  with the bank. Third, the *government* assumes two roles: It issues sovereign bonds  $B$  to cover exogenous initial expenditures or to roll-over legacy debt; these are purchased by banks and risk-neutral

international investors. In order to repay its outstanding obligations, the government raises tax revenue at date 2. Moreover, the government also provides deposit insurance, which is tax-funded and - if actually provided - equivalent to rescue package for distressed banks. The time line is as follows:

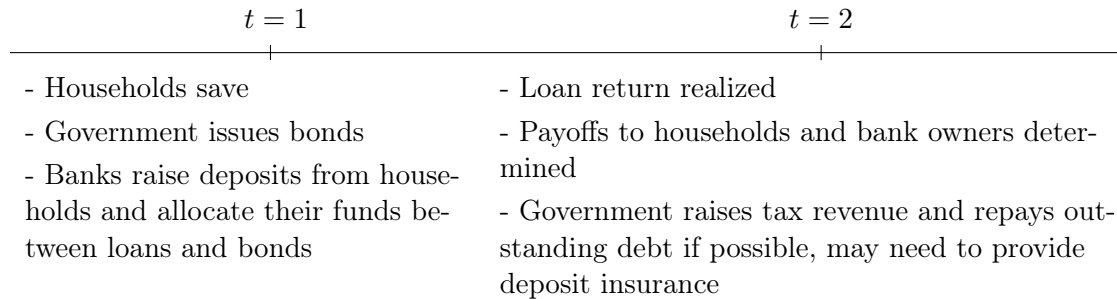


Figure 1: *Time Line*

### 4.3.1 Banks

The main characteristic of banks in our model is that they operate a risky technology, a feature shared with Dermine (1986) and Boyd et al. (2009), and are endowed with little equity. These models essentially build on a lender-borrower framework à la Jaffee and Modigliani (1969), complemented with the risk of bank failure due to correlated loan returns and an oligopolistic loan market à la Cournot. Motivated by our focus on the bank-sovereign nexus, we replace the risk-free asset in Boyd et al. (2009) by sovereign bonds, the risk-return profile of which endogenously emerges, and include equity to have a richer capital structure. To keep the analysis tractable, however, we rely on perfectly competitive banks and omit an explicit model of borrowers. These twists generate a framework where the bank assumes an active role and allow us to derive novel insights about the mechanisms of contagion as well as the impact of government guarantees.

The bank funds itself by exogenous equity  $E$  and deposits  $D$  raised from households. Since deposits are insured, they earn the (gross) risk-free interest rate normalized to one. The bank allocates these funds among two assets: First, an amount  $L$  is invested in loans that are characterized by assumption 1.

**ASSUMPTION 1** *Loans yield a stochastic (gross) return  $A$  per unit;  $A \in [0, \bar{A}]$  is distributed according to some continuous twice-differentiable distribution function  $F(A)$  with  $E(A) = \int_0^{\bar{A}} AdF(A) > 1$ . Conditional on bank failure, depositors can recover at most a liquidation value  $vA$  with  $v \leq 1$ .*

Hence, loans are risky and may trigger bank failure in case they perform poorly. They can be interpreted as credit to small businesses that invest in risky projects. Assumption 1 implies

that the liquidation of bank loans is costly;  $v < 1$  may, for instance, represent a bank run scenario where a shock triggers an immediate, disorderly liquidation of the bank. Assets may then have to be sold at a dislocated price. Alternatively, suppose that loan collection requires specific skills as in Diamond and Rajan (2000). If the bank fails, its owners receive a zero payoff and depositors cannot force them to use the bank's capabilities on their behalf such that they lose a fraction of each loan's value. Second, the bank can purchase an amount  $G$  of sovereign bonds with a binary payoff  $\tilde{R}$  which equals  $R \geq 1$  (per unit) if the government is solvent (with probability  $1 - p$ ) and zero otherwise (with probability  $p$ ). The bank observes the return on sovereign bonds  $R$  as well as the sovereign default probability  $p$ , both of which it takes as given. Since bank owners are protected by limited liability and only consider the upside of their bank's investments, the bank maximizes its expected equity value  $E[\max\{\pi, 0\}]$  by solving:

**PROGRAM 1** *The bank chooses loans  $L$ , sovereign bonds  $G$ , and deposits  $D$  to maximize its expected equity value*

$$\max_{L,G,D} \int_{A^*}^{\bar{A}} AL + \tilde{R}G - DdF(A) \quad (1)$$

*subject to a funding constraint*

$$L + G = E + D \quad (2)$$

$A^*$  is the minimum realization of the loan return, for which the bank succeeds (failure threshold):

$$A^* = \max \left\{ \frac{D - \tilde{R}G}{L}, 0 \right\} \quad (3)$$

The bank fails as soon as the stochastic loan return falls short of  $A^*$ ; this threshold crucially depends on sovereign bond repayment. Importantly, the latter is not exogenous as it depends on the realized loan return. Hence, the bank forms expectations about the bond repayment conditional on its own performance: If bank and sovereign risks were independent, the bank would simply earn an *ex ante* return on bonds equal to  $[1 - F(A^*)](1 - p)R$ , that is, the probability that it succeeds times the expected return on sovereign bonds. Since bank loans are the main source of risk in the economy, however, bank and sovereign risks are interconnected. Consequently, the bank determines the asset allocation using the probability of bond repayment conditional on its own survival,  $1 - p_C$ , instead of the 'true' repayment probability,  $1 - p$ , such that its expected return on sovereign bonds equals  $[1 - F(A^*)](1 - p_C)R$ . From Bayes' theorem, the conditional default probability  $p_C = \text{Prob}(\text{Bonds not repaid} | \text{Bank survives})$  is:

$$p_C = \frac{\text{Prob}(\text{Bonds not repaid, bank survives})}{\text{Prob}(\text{Bank survives})} = \frac{\max\{\int_{A^*}^{\bar{A}} dF(A), 0\}}{1 - F(A^*)} = \frac{\max\{p - F(A^*), 0\}}{1 - F(A^*)}$$



$\hat{A} = F^{-1}(p)$  denotes the realization of the stochastic loan return consistent with the sovereign default probability  $p$ . The integral captures all realizations of the stochastic loan return for which the bank survives and the government defaults (i.e.,  $A^* \leq A < \hat{A}$ ). Figure 2 illustrates how bank risk depends on the repayment of sovereign bonds for two given values of  $\hat{A}$ .

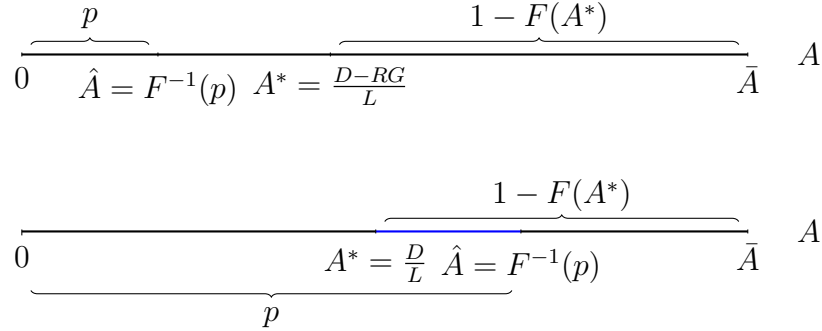


Figure 2: Bank Risk and Bond Repayment

If sovereign is lower than bank risk such that bonds are always repaid as long as the bank succeeds (i.e., if  $p \leq F(A^*)$  and  $\tilde{R} = R$  at  $A = A^*$ ) as shown in the upper part, the conditional default probability,  $p_C$ , is zero because for no realization banks survive and the government defaults. Thus, the bank essentially considers them risk-free and earns an *ex ante* bond return  $[1 - F(A^*)]R$ . If, in contrast, sovereign risk is higher than bank risk (i.e., if  $p > F(A^*)$  and  $\tilde{R} = 0$  at  $A = A^*$ ) as shown in the lower part, there is a possibility that the bank survives but bonds are not repaid (shown in blue). The conditional default probability equals  $p_C = \frac{p - F(A^*)}{1 - F(A^*)}$ , and banks earn an *ex ante* bond return of  $[1 - F(A^*)](1 - p_C)R = (1 - p)R$ . The failure threshold is *ceteris paribus* higher due to losses on bonds. Combining the two cases, the expected bond return from the bank's perspective is  $[1 - \max\{F(A^*), p\}]R$ . The optimization problem is:

$$\max_{L, D} \int_{A^*}^{\bar{A}} ALdF(A) + [1 - \max\{F(A^*), p\}]R(D + E - L) - [1 - F(A^*)]D \quad (4)$$

The first two terms capture the expected returns on loans and bonds, respectively, the third term represents the expected repayment to depositors. Moreover, one can determine which of the two cases explained above materializes (i.e., whether  $F(A^*) \geq p$  or  $F(A^*) < p$ ) based on the sovereign default probability  $p$ : The bank's failure thresholds depending on bond repayment -  $A^*_{|\tilde{R}=R}$  and  $A^*_{|\tilde{R}=0}$  - are illustrated in figure 3. As noted above, a sovereign default immediately shifts up this threshold and weakens the bank's capacity to withstand a poor loan performance. As long as bonds are repaid (i.e., if the government honors its debt for  $A = A^*$ ), holding them reduces the bank's exposure to loan risk, and it can withstand worse realizations of  $A$ . Hence, bank risk is higher whenever a bank holds many loans and only few bonds such that the failure threshold (lower curve) increases in loans. In this scenario, a bank features the highest possible

risk level, which corresponds to  $A^* = \frac{D}{D+E}$ , in case it does not hold any sovereign bonds but only loans (i.e.,  $L = D + E$  and  $G = 0$ ). As soon as the bonds are not repaid, however, banks are more vulnerable because large bond holdings merely translate into losses such that the failure threshold (upper curve) decreases in loans. In this case,  $A^* = \frac{D}{D+E}$  exactly denotes the minimum feasible level of bank risk instead, which materializes if the bank is exclusively invested in loans. One can thus define a critical probability of sovereign default:

$$\bar{p} = F\left(\frac{D}{D+E}\right)$$

Since bank and sovereign risks are interconnected, bond repayment is endogenous and related to banks' risk profile: First, if  $p \leq F(A^*)$ , bond repayment at  $A = A^*$  requires that  $p < \bar{p}$ . Otherwise,  $p$  would exceed the *highest* possible level of bank risk in this case,  $\bar{p}$ , and contradict the initial assumption that bonds are repaid if the bank succeeds,  $p \leq F(A^*)$ . Second, if  $p > F(A^*)$ , no repayment at  $A = A^*$  requires  $p \geq \bar{p}$  as  $p$  would otherwise lie below the *lowest* possible level of bank risk,  $\bar{p}$ , again violating the initial assumption. Consequently, the bank's failure threshold can be defined in terms of the sovereign default probability  $p$ :

$$A^* = \begin{cases} \max\left\{\frac{D-R(D+E-L)}{L}, F^{-1}(p)\right\}, & \text{if } p \leq \bar{p} \\ \min\left\{\frac{D}{L}, F^{-1}(p)\right\}, & \text{if } p > \bar{p} \end{cases} \quad (5)$$

Intuitively,  $p \leq \bar{p}$  implies that the bank is at least as vulnerable as the government and that the latter can withstand a worse realization of  $A$ . Hence, the bank still receives the bond repayment at the failure threshold (i.e.,  $\tilde{R} = R$ ). The reverse is true for  $p > \bar{p}$ .

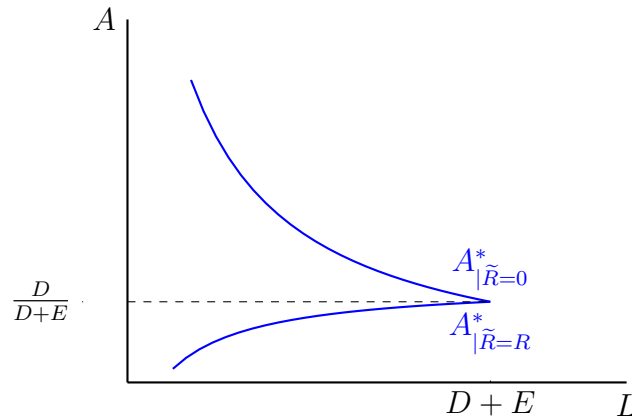


Figure 3: *Bank's Failure Threshold*

From figure 3, one may also conclude that whenever, for a given bond return, the sovereign default threshold  $\hat{A} = F^{-1}(p)$  is in the area below (above) the lower (upper) of these two curves, bank failure is more (less) likely than a sovereign default as the government withstands a worse

realization of the loan return. Moreover, if it lies in the area between the two curves, the bank will survive as long as bonds are repaid (since  $A^*_{|\bar{R}=R} < A$ ) but will fail as soon as they are not (since  $A^*_{|\bar{R}=0} > A$ ). Hence, the bank fails as soon as the government does not repay the bonds. Such a case captures the idea of an adverse feedback as a sovereign default immediately pushes banks into bankruptcy.

One can now solve the bank's optimization problem, (4), separately for these two cases using the failure thresholds specified in (5). The solution yields optimal bank size and asset allocation. Since the objective function is increasing in deposits in both cases, the bank's demand for deposits  $D$  is indeterminate and perfectly elastic at the risk-free interest rate, which is normalized to one.<sup>3</sup> As a result, the bank is willing to accept any amount of deposits supplied by households such that its size  $D + E$  is predetermined by equity endowment and household savings.<sup>4</sup> Similarly, expected bank profits are a linear or convex function of loans, which implies that no interior maximum  $L \in (0, D + E)$  exists. This feature essentially reduces the problem to a binary comparison of expected profits from exclusively investing in either loans ( $L = D + E$ ) or sovereign bonds ( $L = 0$ ).<sup>5</sup> A bank chooses the former as long as  $\pi(D + E) \geq \pi(0)$ . The results are summarized in:

**LEMMA 1** *The bank's deposit demand  $D$  is perfectly elastic. The cutoff  $R'$  is defined as follows:*

$$R' = \frac{1}{1-p} \left[ E(A) + \int_0^{\frac{D}{D+E}} F(A) dA - \frac{pD}{D+E} \right] \quad (6)$$

*$R'$  decreases in bank equity  $E$  if  $p < \bar{p}$  but increases if  $p > \bar{p}$ . The bank holds an amount*

$$L = \begin{cases} D + E, & \text{if } R \leq R' \\ 0, & \text{if } R > R' \end{cases} \quad (7)$$

*of loans and purchases an amount  $G = D + E - L$  of sovereign bonds. The bank's failure threshold is:*

$$A^* = \begin{cases} \frac{D}{D+E}, & \text{if } R \leq R' \\ F^{-1}(p), & \text{if } R > R' \end{cases} \quad (8)$$

**Proof:** See Appendix 4.A.1.

<sup>3</sup>This feature that keeps the subsequent analysis tractable arises due to perfect competition for deposits and the absence of any (convex) cost. In Boyd et al. (2009), for example, Cournot competition ensures an interior solution.

<sup>4</sup>The critical default probability  $\bar{p}$  is independent of the bank's choices and thus taken as given.

<sup>5</sup>This is consistent with the finding of Rochet (1992) that in the presence of deposit insurance without actuarially fair premia, value-maximizing banks have a convex objective function and fully specialize in one risky asset.

The bank invests in the asset that promises a higher expected return from its own perspective. This choice is graphically illustrated in figure 4, where the shaded area represents allocations for which the bank decides to exclusively hold loans and  $R'$  defines the critical bond return for which the bank is just indifferent between loans and bonds. If sovereign bonds yield a low return given their risk profile, the bank chooses to provide loans. If the return of bonds exceeds  $R'$ , however, the bank exclusively purchases sovereign bonds.

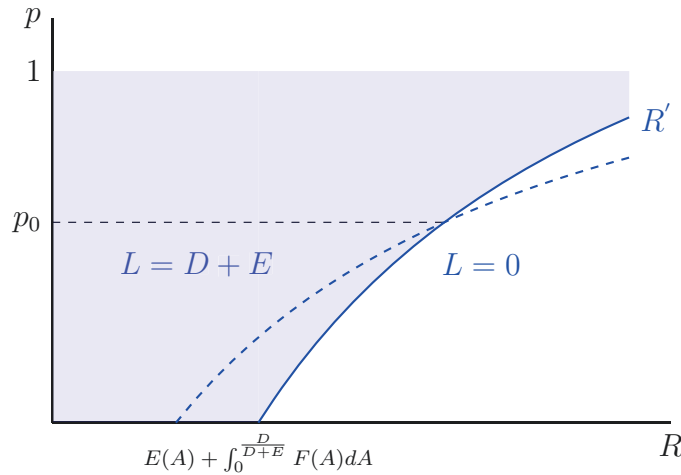


Figure 4: *Bank's Asset Allocation*

The cut-off critically depends on the two assets' risk-return profile: If the likelihood of a sovereign default  $p$  increases, bonds become less attractive and banks are only willing to buy them when they are compensated by a higher return in case of success. In the absence of limited liability,  $R'$  would simply be pinned down by the equalization of expected returns,  $E(A) = (1-p)R$ , represented by the dashed line in figure 4. Limited liability, which means that the bank owners do not need to repay the deposits in case of failure, distorts this choice. This effect is captured by the second and third term of expression (6). As a result, limited liability induces the bank to invest in a riskier asset allocation. More precisely, it distorts this choice at the extensive margin in favor of loans if bonds are relatively safe,  $p < p_0 \equiv \frac{D+E}{D} \int_0^{\frac{D}{D+E}} F(A)dA$ , and in favor of bonds if loans are relatively safe,  $p > p_0$ , respectively.

### 4.3.2 Households

Households consume  $C_t$  and earn labor income  $W_t$  at both dates, where  $W_1 > W_2$ . There is no discounting. Since their income at date 1 is higher and households smooth consumption, they save and deposit their savings,  $D$ , with the bank. Their date 2-consumption is subject to taxation with tax rate  $t$  such that date 2 consumption spending is  $(1+t)C_2$ . Households consider deposits safe and deposit insurance credible.<sup>6</sup> Deposits earn the (gross) risk-free rate

<sup>6</sup>This is possible since the government has the fiscal capacity to provide it, which is ensured by assumption.

normalized to one such that the household's optimization problem is:

$$\max_D u(\underbrace{W_1 - D}_{C_1}) + Eu(\underbrace{\frac{W_2 + D}{1 + t}}_{C_2}) \quad (9)$$

We rely on the logarithmic utility function  $u(C_t) = \log(C_t)$  to keep the analysis tractable as households' decisions are independent of the tax rate: Income and substitution effect just offset each other, and the choice is independent of the uncertain date 2-tax rate.

**LEMMA 2** *Due to log utility, savings amount to*

$$D = \frac{W_1 - W_2}{2} \quad (10)$$

*and do not depend on the tax rate. The consumption profile presents itself as follows:*

$$C_1 = \frac{W_1 + W_2}{2} \quad C_2 = \frac{W_1 + W_2}{2(1 + t)}$$

**Proof:** Follows from the first-order condition of (9) using the log utility function. *Q.E.D.*

### 4.3.3 Government

The government's role is essentially shaped by three key characteristics: debt, taxes, and default. First of all, the government issues an exogenous amount  $B$  of sovereign bonds at date 1 either to roll over legacy debt or to cover initial expenditures. These bonds promise a gross return  $R$  and are sold to domestic banks and to risk-neutral international investors. The former's demand equals  $G$ , the latter's is perfectly elastic as long as they earn an expected bond return that equals the risk-free (gross) interest rate:

$$(1 - p)R = 1 \quad (11)$$

This key condition ensures 'fair' pricing of sovereign bonds. The presence of foreign investors is crucial in this regard as the bank's asset allocation is distorted by limited liability and risk-averse households refrain from buying risky bonds in general.<sup>7</sup> We therefore impose the following assumption on the bond volume  $B$ :

**ASSUMPTION 2**  $B > \frac{W_1 - W_2}{2} + E$

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<sup>7</sup>To be indifferent between deposits which are considered safe due to deposit insurance, they would require an additional risk premium.

This ensures that the amount of available government bonds is large enough to meet the demand of domestic banks even if they invest all their funds in sovereign bonds (i.e., if  $G = D + E$ ) and that a fraction of bonds is held by foreign investors. The share of these securities held by domestic banks is therefore defined as:

$$\omega = \frac{G}{B}$$

Moreover, the government raises taxes from households and bank owners at date 2 in order to (i) repay its debt and (ii) to fund the deposit insurance scheme if necessary. In principle, the tax is designed as a consumption tax<sup>8</sup>  $t$  but it is subsequently expressed in terms of the equivalent income tax  $\tau \in [0, 1]$ , which is more intuitive.<sup>9</sup> The tax rate  $\tau$  guarantees a balanced budget. It is, however, constrained by an upper bound  $\bar{\tau} \leq 1$ .  $\bar{\tau} = 1$  seems to be a natural maximum for the tax capacity although institutional limitations, tax evasion and other frictions may in fact justify a smaller ceiling. This idea is related to Cooper and Nikolov (2013) although, in their model, the ceiling is stochastic and the very source of sovereign risk. The tax ceiling  $\bar{\tau}$  satisfies two conditions:

**ASSUMPTION 3** (i)  $\bar{\tau} \geq \frac{2B}{W_1 + W_2}$ , (ii)  $W_2 > E$

Whereas the former guarantees - in conjunction with assumption 2 - that deposit insurance is feasible and credible even for a complete loss on loans,<sup>10</sup> the latter ensures that  $\bar{\tau} \leq 1$  is indeed possible. Yet, the government may eventually default even though it manages to successfully bail-out depositors. This occurs if it fails to raise sufficient tax revenue to cover all cost, namely, deposit insurance and outstanding debt. Importantly, default entails a full haircut on sovereign bonds, which is a common assumption in related models such as Cooper and Nikolov (2013). Deposit insurance, in contrast, is still provided if necessary.

The very reason of a sovereign default is therefore the government's two-way exposure to the risky banks loans: After all, loan performance (i.e., the realization of the stochastic return  $A$ ) influences (i) date 2-consumption of bank owners and the tax base as well as (ii) the cost of providing deposit insurance in case of bank failure. Hence, a sovereign default eventually occurs due to weak fundamentals rather than strategic considerations like in Calvo (1988). One can derive a precise sovereign default threshold  $\hat{A}$ : The government repays its debt if the realized loan return exceeds  $\hat{A}$  and defaults otherwise. This threshold determines the default probability

<sup>8</sup>This is to keep the analysis tractable. A classical income tax would make deposits sensitive to the tax rate (see section 4.3.2) and require households to correctly anticipate the tax policy depending on bank and sovereign risks.

<sup>9</sup>Recall the relationship between  $\tau$  and the consumption tax  $t$ , i.e.,  $1 - \tau = \frac{1}{1+t}$ .

<sup>10</sup>In an extreme case where loans completely fail and sovereign bonds are not repaid, the cost of deposit insurance is  $D$ . Substituting for  $B$  in the first inequality using assumption 2; maximum date 2 tax revenue  $\bar{\tau}(D + W_2)$  exceeds the cost.

$p$ :

$$p = F(\hat{A}) \quad (12)$$

First of all, suppose that the bank survives because its loan portfolio performs well (i.e.,  $A \geq A^*$ ). Deposit insurance is not needed in such a scenario and the government's date 2 expenditures entirely consist of the debt repayment. Taxes are levied on consumption spending of both households,  $W_2 + D$ , and bank owners,  $AL + RG - D$ , such that the tax rate follows from the balanced budget condition:

$$BR = \tau[AL + R(D + E - L) + W_2] \quad (13)$$

As soon as the level of  $\tau$  implied by this condition exceeds the ceiling  $\bar{\tau}$ , the government defaults because it would need to impose an unfeasibly high tax rate to collect sufficient revenue. The reason for that is the low tax base due to insufficient dividend income of bank owners. Substituting for  $\tau$  in expression (13) yields the sovereign default threshold:

$$\hat{A}_{|A \geq A^*} = \max \left\{ \frac{D - R(D + E - L)}{L} + \frac{BR - \bar{\tau}(D + W_2)}{\bar{\tau}L}, 0 \right\} \quad (14)$$

Second, suppose that banks fail due to poor loan performance (i.e.,  $A < A^*$ ). The government incurs cost of deposit insurance which equal guaranteed deposits net of the residual value of bank assets:

$$DC(A) = D - AL - R(D + E - L) \quad (15)$$

Added to the bond repayment, they constitute the second part of the government's date 2 expenditures. The balanced budget condition pins down the tax rate:

$$BR + DC(A) = \tau(D + W_2) \quad (16)$$

Again, the government defaults whenever  $\tau \geq \bar{\tau}$ . But as opposed to (13) above, the constellation is now relatively worse since the tax base is lower and depositors have to be bailed out. Combining (15) and (16) yields the sovereign default threshold:

$$\hat{A}_{|A < A^*} = \max \left\{ \frac{D - R(D + E - L)}{L} + \frac{BR - \bar{\tau}(D + W_2)}{L}, 0 \right\} \quad (17)$$

The government's default threshold  $\hat{A}$  as well as the bank failure threshold  $A^*$ , which follows from (5), are illustrated by the blue and red lines in figure 5, respectively. This reveals the existence of three possible outcomes: First, the government tends to be relatively more stable than banks (i.e.,  $\hat{A} < A^*$ ) whenever the interest rate on its debt imposed by foreign bondholders is relatively low and falls short of the cutoff  $R_0$ . This corresponds to classical bank-sovereign

contagion as a poor loan performance causes bank failure, which may eventually trigger a sovereign default because of deposit insurance cost. Second, the government is less stable than banks (i.e.,  $\hat{A} > A^*$ ) in case the bond return is relatively large and exceeds the cutoff  $R_1$ . This represents an outcome where the debt burden is so large that the government may even default in the absence of bank failure; low bank dividends and tax revenue are sufficient to trigger a sovereign default. Third, bank and sovereign risks coincide in an interim region,  $R_0 < R < R_1$ : Banks would survive for the loan return  $A = \hat{A}$  but fail as soon as they incur losses on their sovereign bond holdings. This captures an adverse feedback that arises because a mediocre loan performance triggers a sovereign default, which, in turn, puts banks in jeopardy.

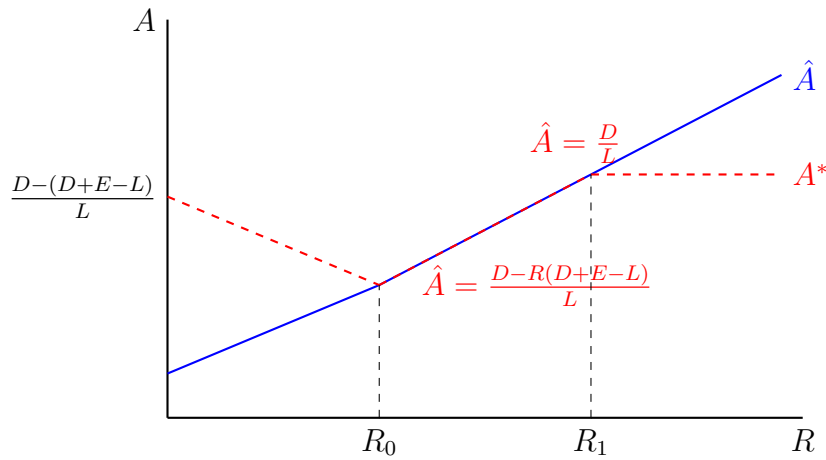


Figure 5: *Sovereign Default Threshold*

Note that these three cases exactly correspond to those in figure 3 but are now characterized in terms of the bond return.<sup>11</sup> It can be shown that the default threshold  $\hat{A}$  is described by (17) for  $R \leq R_0$  and by (14) for  $R > R_0$ . Graphically, the corresponding curves intersect at the cutoff  $R = R_0$ ; the sovereign default threshold represented by the solid blue line has a kink but is continuous. Both cutoffs follow from  $\hat{A} = A^*$ , that is, equalizing (17) and  $A^* = \frac{D-R(D+E-L)}{L}$  as well as (14) and  $A^* = \frac{D}{L}$ . Using  $G = \omega B$  yields:

$$R_0 = \frac{\bar{\tau}(D + W_2)}{B} \quad (18)$$

$$R_1 = \frac{\bar{\tau}(D + W_2)}{(1 - \omega\bar{\tau})B} \quad (19)$$

Note that  $R_0 > 1$  is due to the first part of assumption 3. Obviously, these two cutoffs coincide whenever banks do not hold any sovereign bonds (i.e.,  $\omega = 0$ ): In such a case, the third outcome, which entails an adverse feedback, vanishes as banks are not exposed to sovereign risk at all. The latter scenario is, in contrast, more likely to be an equilibrium outcome if banks hold a

<sup>11</sup>A summary of these cases can be found in Appendix 4.A.2.



large share of sovereign bonds (i.e.,  $\omega$  and  $R_2$  are large).

Consequently, one may rewrite the government's default threshold as

$$\hat{A} = \begin{cases} \frac{D-R(D+E-L)}{L} + \max\left\{\frac{BR-\bar{\tau}(D+W_2)}{L}, \frac{BR-\bar{\tau}(D+W_2)}{\bar{\tau}L}\right\}, & \text{if } R \leq R_2 \\ \bar{A}, & \text{if } R > R_2 \end{cases} \quad (20)$$

where  $R_2 = \frac{\bar{\tau}[\bar{A}L+W_2]}{(1-\omega\bar{\tau})B}$  denotes the bond return above which the government defaults with certainty (i.e., it defaults even if the maximum loan return  $\bar{A}$  is realized). The first term in curly brackets is relevant if  $R \leq R_0$  while the second expression is applicable for  $R > R_0$ . Obviously, in both cases, the sovereign default threshold positively depends on the debt burden  $BR$  and the size of the commitment to deposit insurance  $D$ , but negatively on the tax capacity  $\bar{\tau}$  and the bank's assets  $L$  and  $G = D + E - L$ , which effectively reduces the costs of providing deposit insurance by raising the bank's liquidation value.

#### 4.3.4 Market Clearing

At date 1, the markets for deposits and government bonds clear:

$$W_1 - C_1 = D, \quad B = G + (1 - \omega)B$$

The deposit supply consists of households' labor income that is not consumed, the bond supply is exogenous; banks invest an amount  $G$  in bonds, and the remainder is purchased by international investors as long as the return is fair. Aggregating these constraints using the balance sheet identity  $L + G = D + E$  yields the date 1 aggregate budget constraint

$$C_1 + L + B = W_1 + E + (1 - \omega)B \quad (21)$$

which implies that consumption, investment (lending), and government expenditures are funded by the domestic endowment of households and bank owners and the capital inflow from international investors. At date 2, consumption of households and bankers equal:

$$C_2 = (1 - \tau)(D + W_2), \quad C_2^B = (1 - \tau) \max\{AL + G\tilde{R} - D, 0\}$$

Substituting  $\tau[D + W_2 + \max\{AL + G\tilde{R} - D, 0\}] = B\tilde{R} + \max\{D - AL - G\tilde{R}, 0\}$  from the government's budget constraint yields the aggregate budget constraint at date 2:

$$C_2 + C_2^B = W_2 + AL - (1 - \omega)B\tilde{R} \quad (22)$$

Consumption depends on the realization of the loan return  $A$  and on the bond repayment. In the absence of a sovereign default (i.e.,  $\tilde{R} = R$ ), there is a capital outflow as bonds are repaid to foreign investors. In case of a sovereign default, there is no such outflow. Combining (21) and (22) and noting that  $E(\tilde{R}) = (1 - p)R = 1$  in equilibrium implies that expected consumption is financed by labor income, equity endowment, and the surplus earned on loans such that the model is closed:

$$C_1 + E(C_2) + E(C_2^B) = W_1 + W_2 + E + [E(A) - 1]L \quad (23)$$

## 4.4 Equilibrium Analysis

### 4.4.1 Equilibrium Allocation

Combining the optimal decisions of banks and households as well as the government's policy establishes the following proposition:

**PROPOSITION 1** *The equilibrium allocation  $\{A^*, \hat{A}, D, G, L, p, R, R'\}$  is characterized by conditions (2), (6) - (8), (10) - (12), and (20). From (20), the sovereign default threshold for  $L = D + E$  is*

$$\hat{A}_{|L=D+E} = \begin{cases} \frac{D}{D+E} + \max \left\{ \frac{BR - \bar{\tau}(D+W_2)}{D+E}, \frac{BR - \bar{\tau}(D+W_2)}{\bar{\tau}(D+E)} \right\}, & \text{if } R \leq R_2 \\ \bar{A}, & \text{if } R > R_2 \end{cases} \quad (24)$$

with  $R_2 = \frac{\bar{\tau}[\bar{A}(D+E)+W_2]}{B}$ . Two types of equilibria may exist:

- The 'good' equilibrium with  $p_g < 1$  and  $R_g < R_2$  exists if (i)  $\exists R \in [1, R_2)$  such that  $F[\hat{A}_{|L=D+E}(R)] \leq 1 - \frac{1}{R}$  and (ii)  $F[\hat{A}_{|L=D+E}(R_g)] \leq \frac{D+E}{D} \left[ E(A) + \int_0^{\frac{D}{D+E}} F(A)dA - 1 \right]$ .
- The 'bad' equilibrium with  $p_b = 1$  and  $R_b \rightarrow \infty$  always exists.

In each equilibrium, banks exclusively hold loans such that  $L = D + E$ ,  $A^* = \frac{D}{D+E}$ , and  $\hat{A} = \hat{A}_{|L=D+E}$ .

**Proof:** See Appendix 4.A.1.

Multiple equilibria arise because investors' expectations about a sovereign default determine their required bond return, which, in turn, influences the government's debt-servicing cost and its default probability. Such dynamics may turn into a self-fulfilling prophecy, which eventually results in one of the equilibria outlined in proposition 1. This is a standard occurrence in many models of public debt crises as exemplified in Romer (2001) and Cooper and Nikolov (2013). In our model, however, the uncertainty about the government's ability to repay originates from

risky banks that either affect expenditures or tax revenue rather than a shock to the sovereign's fiscal position itself.

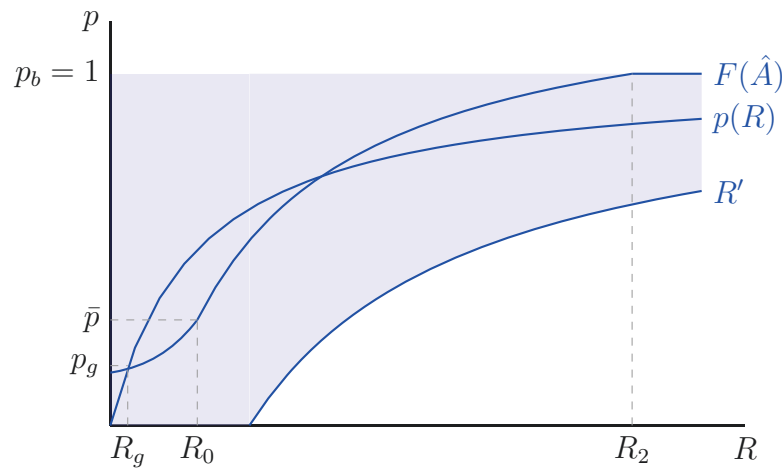


Figure 6: *Multiple Equilibria*

Figure 6 illustrates a combination with two equilibria given a bell-shaped density function:<sup>12</sup> The 'good' equilibrium is characterized by a low bond return  $R_g$  and a moderate default probability  $p_g$ . The 'bad' equilibrium features an infinitely high bond return for which the government defaults with certainty (i.e.,  $R_2 \rightarrow \infty$  and  $p_b = 1$ ). The stability of these equilibria is consistent with the debt crisis model of Romer (2001). An additional equilibrium with intermediate bond return and default probability may exist conditional on the 'good' equilibrium. It is, however, unstable under plausible dynamics. Both equilibria are located in the shaded area above  $R'$ , where banks prefer to hold loans such that only international investors purchase sovereign bonds. Graphically, an equilibrium is determined by the intersection of bond pricing and default curve  $p(R)$  and  $F(\hat{A})$ . The latter is a simple transformation of the default threshold. The result that a bank unconstrained by any regulatory requirements never purchases fairly priced, domestic sovereign bonds is one of the key insights of the baseline model and requires some comments: Sovereign bonds would need to yield a relatively high return ( $R > R'$ ) in order to be more attractive than loans (i.e., to yield a higher expected return taking into account all effects of limited liability). Since foreign investors price government bonds fairly, however, such a high return would only be consistent if sovereign risk is comparatively high as well. As soon as banks only hold sovereign bonds, though, there is no risk in the economy, and the sovereign default probability equals zero implying a low bond return.<sup>13</sup> An equilibrium with sufficiently attractive bond returns for banks is, therefore, inconsistent with fair bond pricing.

<sup>12</sup>Depending on the shape of the distribution function, more than two stable equilibria might exist (see Cooper and Nikolov (2013)) for a graphical illustration). The additional equilibria share features of the 'good' type.

<sup>13</sup>Nevertheless, the 'bad' equilibrium may still exist but banks then exclusively hold loans.

Yet, we observe considerable sovereign bond holdings of the banking sector and a significant home bias in reality. This can be explained by several factors: First, deviations from fair pricing of bonds may offer attractive returns, at least temporarily. Central bank stimuli and other demand-side effects currently serve as important examples. Second, capital<sup>14</sup> and liquidity requirements may limit the lending capacity and force the bank to (partly) invest in alternative assets that might be associated with lower returns. Importantly, the Basel accords generally consider sovereign bonds as safe such that their risk weight is zero; they are also eligible for the new liquidity requirements. Third, sovereign bonds play an important role as a collateral for interbank borrowing and repo transactions, which provides another rationale.<sup>15</sup>

Intuitively, a country is likely to end up in the 'good' equilibrium whenever it is fiscally sound, that is, its public debt level  $B$  is low or the tax capacity  $\bar{\tau}$  high. Optimistic expectations about the sovereign's creditworthiness then translate into low debt-servicing cost. As in both equilibria, the bank exclusively holds loans, defaults with probability  $\bar{p}$  and - depending on whether  $R_g < R_0$  as illustrated in figure 6 or not - may be more or less stable than the government. In particular, the adverse feedback outcome discussed above is ruled out in the baseline allocation. The 'good' equilibrium exists as long as bond returns  $R$  exist, for which (i) the default lies below the bond pricing curve and the (ii) the bank prefers loans to bonds as  $R \leq R'$ . This holds true if the country is fiscally sound such that its default probability implied by the threshold  $\hat{A}$  is small for low bond returns. Sovereign risk may even vanish in the 'good' equilibrium if the amount of outstanding bonds and deposit insurance obligations is lower than the potential tax income at date 2 even for a complete loss on loans, that is, if  $B + D \leq \bar{\tau}(D + W_2)$  such that the default threshold is  $\hat{A} = 0$  for  $R = 1$  and sovereign bonds are indeed risk-free.

The 'bad' equilibrium, in contrast, materializes when a self-fulfilling spiral of pessimism translates into an excessively high bond return such that the government defaults with certainty. Given that bonds are never repaid in this scenario, however, no investor is willing to purchase them in the first place. Since the bank is exclusively invested in loans anyway, it is always more stable than the government (i.e.,  $A^* < \hat{A} = \bar{A}$ ).<sup>16</sup> The 'bad' equilibrium is particularly relevant as soon as the 'good' does not exist: This may occur, for instance, in case of a highly indebted country with an insufficient tax capacity. Hence, its actual default probability exceeds the default probability implied by fair bond pricing for all finite values of  $R$ . Graphically, this means that default and bond pricing curve never intersect and only coincide in the limit.

<sup>14</sup>Capital regulation is explored in section 4.5.

<sup>15</sup>See Bolton and Jeanne (2011) for a model of interbank borrowing with risky sovereign bonds.

<sup>16</sup>The government can still collect sufficient revenue to provide deposit insurance due to assumption 3.

### 4.4.2 Bank and Sovereign Risks

Since banks exclusively hold loans in equilibrium, they are not exposed to sovereign risk and thus insensitive to fiscal fundamentals. They fail whenever loans perform so poorly that their date 2 equity is wiped out and deposits are not covered anymore. Hence, the failure threshold equals the leverage ratio:

$$A^* = \frac{D}{D + E}$$

Obviously, bank risk increases in deposits,  $\frac{\partial A^*}{\partial D} > 0$ , and decreases in equity,  $\frac{\partial A^*}{\partial E} < 0$ . The latter provides a buffer to absorb loan losses and unambiguously lowers bank risk.

Sovereign risk, in contrast, crucially depends on banks' loan performance and capital structure. Recall that there are two different cases how an equilibrium may emerge: First, banks may be more vulnerable than the government ( $A^* \geq \hat{A}$ ). This is the case whenever the latter is fiscally sound such that it pays low interest rates in equilibrium,  $R_g < R_0$ , as illustrated in figure 6. Contagion then runs from the banking sector to the government and is driven by the cost of deposit insurance or rescue packages as it recently happened in Ireland and Spain. Second, banks may be more stable than the government ( $A^* < \hat{A}$ ). This always occurs in the 'bad' equilibrium and can also be a property of the 'good' one if the debt servicing cost are rather high such that  $R_g > R_0$ . The tax potential of households is quite small in this scenario compared to the public debt level  $B$ . Bank-sovereign contagion thus occurs because loans do not perform well enough such that bank dividends and the tax base are low. As a result, the government cannot raise sufficient revenue to repay its outstanding debt. This may, to some extent, capture the case of highly indebted countries like Italy and Greece, in which the tax base has often been small due to tax evasion and lax fiscal authorities. In general, the government defaults as soon as the necessary tax rate to cover date 2 expenditures (debt repayment  $BR$  and possibly deposit insurance cost  $DC$ ) is no longer feasible. Its default threshold  $\hat{A}$  follows directly from condition (24). A sovereign default involves a full haircut on sovereign bonds whereas deposit insurance is still provided. The sensitivities of default probability  $p = F(\hat{A})$  and bond return  $R$  can be summarized as follows:

**COROLLARY 1** *In the 'good' equilibrium, the sensitivities of the sovereign default probability are as follows:  $\frac{\partial p}{\partial \bar{\tau}} < 0$ ,  $\frac{\partial p}{\partial B} > 0$ , and  $\frac{\partial p}{\partial E} < 0$ ; these imply  $\frac{\partial R}{\partial \bar{\tau}} < 0$ ,  $\frac{\partial R}{\partial B} > 0$ , and  $\frac{\partial R}{\partial E} < 0$ . Sovereign risk decreases in the tax capacity and bank equity but increases in the public debt burden.*

**Proof:** See Appendix 4.A.1.

A higher tax capacity, a lower public debt burden, and a banking sector funded by more equity reduce sovereign risk in the 'good' equilibrium and thus depress its debt-servicing costs. This result is not surprising: A sound fiscal policy and a well-capitalized banking sector are widely

considered to improve a country's fiscal stability. This is due to the fact that - in equilibrium - default probability and bond return need to be consistent with each other: If public debt  $B$  increases, for instance, the default probability rises as well. The bond return adjusts upwards until it is consistent with the higher sovereign risk.

### 4.4.3 Deposit Insurance and Sovereign Risk

Interestingly, one can make use of this model to show why government guarantees may either preserve fiscal stability by preventing costly bank failures or jeopardize it by putting the government itself into distress. The latter was, for instance, the case in Ireland and, to a lesser extent, in Spain. For that purpose, we compare sovereign risk in the baseline model where deposit insurance is provided whenever necessary with sovereign risk in a hypothetical scenario in which the government deviates from its commitment and does not rescue distressed banks. The latter describes the relevant alternative to rescue packages frequently employed in the current crisis. Yet, deposits were considered safe because the explicit or implicit government guarantees in place were credible. Hence, focusing on an *ex post* deviation from the guarantee better captures the alternative than an allocation without deposit insurance at all. While the sovereign default threshold in the baseline model is given by (20), the default threshold without deposit insurance,  $\hat{A}_N$ , is subsequently determined by

$$BR = \bar{\tau} \left[ \underbrace{D + W_2}_{\text{Households' Inc.}} + \underbrace{\hat{A}_N(D + E) - D}_{\text{Bankers' Inc.}} \right] \quad (25)$$

or

$$BR = \bar{\tau} \left[ \underbrace{W_2 + v\hat{A}_N(D + E)}_{\text{Households' Inc.}} \right] \quad (26)$$

depending on whether banks are solvent at  $A = \hat{A}_N$ . These conditions follow from the government's date 2 budget constraint. The solvency of banks matters because the assets' liquidation value is smaller than one ( $v < 1$ ) in the absence of deposit insurance as described for assumption 1. This may be rationalized by a bank run that requires an immediate and costly liquidation of the assets. The default threshold for a government that deviates from its initial commitment follows from (25) and (26):

$$\hat{A}_N = \begin{cases} \frac{BR - \bar{\tau}W_2}{v\bar{\tau}(D+E)} & \text{if } R < \max\{R_0 - \frac{\bar{\tau}(1-v)D}{B}, 1\} \\ \frac{D}{D+E} & \text{if } \max\{R_0 - \frac{\bar{\tau}(1-v)D}{B}, 1\} \leq R < R_0 \\ \hat{A}, & \text{if } R \geq R_0 \end{cases} \quad (27)$$

The discontinuity is entirely due to  $v < 1$ , which causes a further erosion of the tax base as soon as banks fail. In fact, the liquidation costs associated with bank failure are the very reason for a sovereign default if  $R \in \left[ R_0 - \frac{\bar{\tau}(1-v)D}{B}, R_0 \right]$ . For  $R \geq R_0$ , the thresholds with and without deposit insurance just coincide as the government defaults because of insufficient tax revenue and is more vulnerable than banks anyway. Accordingly, a government that deviates defaults with probability  $p_N = F(\hat{A}_N)$ . Note that sovereign bonds are not fairly priced *ex post* in such a scenario.

Interestingly, it is not *a priori* clear how the provision of deposit insurance influences sovereign risk. This is because there are two countervailing effects. The choice to refrain from a bailout spares important expenses but also triggers considerable liquidation costs captured by  $v < 1$ , which reduces the tax base. The magnitude of the latter is thus crucial for the impact of deposit insurance on sovereign risk.

**PROPOSITION 2** *Deposit insurance lowers sovereign risk (i.e.,  $p < p_N$ ) if the loan liquidation value  $v$  is sufficiently small:*

$$v < \min \left\{ \frac{BR - \bar{\tau}W_2}{\bar{\tau}[BR - \bar{\tau}W_2 + (1 - \bar{\tau})D]}, 1 \right\} \equiv v_m(R) \quad (28)$$

*In the 'good' equilibrium both cases are possible; in the 'bad' equilibrium  $p = p_N$  holds irrespective of the liquidation value  $v$ .*

**Proof:** See Appendix 4.A.1.

Proposition 2 is illustrated in figure 7: In the shaded area, the liquidation value of bank loans is small ( $v \leq v_m$ ) such that providing deposit insurance indeed prevents a massive erosion of the tax base because liquidation costs would cause a significant drop in household income and tax revenue otherwise. Government guarantees therefore reduce sovereign risk ( $p < p_N$ ). If the liquidation value is large, in contrast, this effect is moderate and outweighed by the cost of deposit insurance that may even jeopardize fiscal stability ( $p > p_N$ ). For  $R \leq R_0$ , the commitment towards deposit insurance thus tends to reduce sovereign risk as long as liquidation cost are sizable or debt-servicing cost are high. If, in equilibrium,  $R > R_0$ , however, the government defaults irrespective of bank failure such that sovereign risk is independent of the provision of deposit insurance. Intuitively, the fiscal state is so weak that the cost of deposit insurance are small compared to the debt burden.

Figure 8 shows two examples that illustrate the impact of deposit insurance on sovereign default.  $\tau$  and  $\tau_N$  are the tax rates necessary to cover the government's outstanding obligations as a function of the loan performance,  $A$ , depending on whether the government honors its guarantees. The tax rate clearly decreases in  $A$  because higher loan returns increase the available

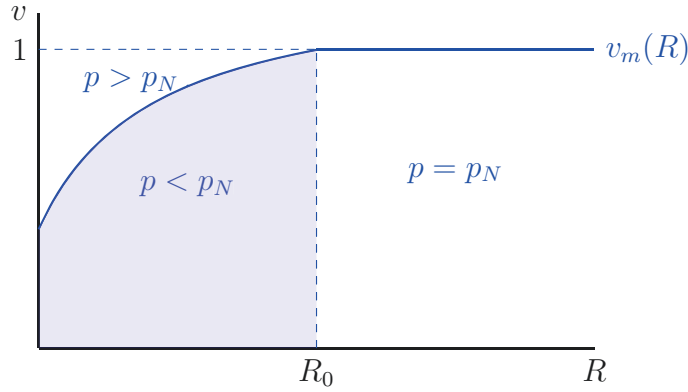


Figure 7: *Deposit Insurance and Sovereign Risk*

resources (i.e., the tax base) or reduce the cost of deposit insurance. Recall that the sovereign default threshold,  $\hat{A}$ , is determined by the intersection of  $\tau$  and the maximum feasible tax rate  $\bar{\tau}$ . The left panel illustrates a scenario where deposit insurance triggers a sovereign default: If the realized bond return is between  $\hat{A}_N$  and  $\hat{A}$  (in the blue-shaded area), fulfilling the commitment towards depositors requires a tax rate  $\tau$  that is infeasible such that the government defaults. Providing no deposit insurance, in contrast, requires a tax rate  $\tau_N$  that is still below the ceiling  $\bar{\tau}$ . Such a scenario may occur if the liquidation value of bank loans is large ( $v > v_m$  in figure 7). In the right panel, in contrast, providing deposit insurance prevents a sovereign default if loan return  $A$  is between  $\hat{A}$  and  $\hat{A}_N$ . This is due to a small liquidation value ( $v < v_m$  and  $R < R_0$  in figure 7), which leads to a massive erosion of tax base and revenue in the absence of government guarantees.

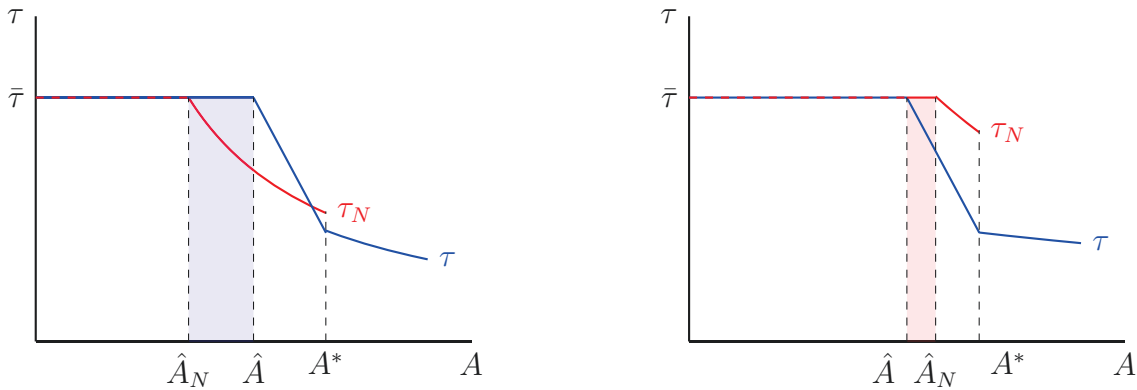


Figure 8: *Default Mechanisms and Deposit Insurance*

#### 4.4.4 Deposit Insurance and Welfare

Another closely associated issue about government guarantees and rescue packages is whether they are welfare-improving: We focus on the question of whether it is efficient to provide deposit insurance in case the bank fails or whether a deviation from the initial commitment can raise



domestic welfare.<sup>17</sup> Since households' savings and their date 1 consumption are independent of an *ex post* decision on whether to satisfy the commitment or not, it is sufficient to look at date 2 domestic welfare, which consists of households' and bankers' utility derived from consumption:

$$V_2 = u(C_2^H) + C_2^B$$

In principle, we compare two different welfare profiles at date 2, namely, domestic welfare with and without deposit insurance. For that purpose, however, it suffices to compare the consumption levels.

### Consumption Profile

We first characterize aggregate consumption at date 2, which consists of households' and bankers' consumption  $C_2 = C_2^H + C_2^B$ : Due to non-linearities associated with default and policy interventions,  $C_2$  is a non-continuous function of the stochastic loan return  $A$ .

If the government provides deposit insurance and bails out distressed banks, aggregate consumption equals  $C_2 = [1 - \tau(A)][D + W_2 + \max\{A(D + E) - D, 0\}]$ . Recall that bankers consume only as long as  $A > A^*$ . After substituting for the tax rate  $\tau$  using the government's budget constraints (13) and (16), one obtains:

$$C_2 = \begin{cases} W_2 + A(D + E) - BR & \text{if } A \geq \hat{A} \\ W_2 + A(D + E) & \text{if } A < \hat{A} \end{cases} \quad (29)$$

Hence, aggregate consumption equals total income net of public debt; the discrete jump at the sovereign default threshold  $\hat{A}$  results from the full haircut on public debt. The latter reduces the tax burden as well as the tax rate at date 2 thereby raising domestic consumption. The tax rate<sup>18</sup> may, however, still be positive if a deposit insurance scheme needs to be funded. This consumption profile generally emerges in both equilibria. In the 'bad' equilibrium, however, the government defaults first, which implies that there is no public debt that needs to be repaid at date 2. Aggregate consumption is captured by the lower part of (29) since  $\hat{A} = \bar{A}$ .

Whenever a government does not provide deposit insurance, its potential expenditures at date 2 only come to  $BR$ . Compared to the scenario above, consumption differs in two fundamental ways: First, the default threshold changes to  $\hat{A}_N$  given by (27); second, liquidation costs reduce the value of the bank's assets to  $v$  as soon as the bank fails (i.e., if  $A < A^*$ ). While the former affects consumption indirectly because of taxation, the latter reduces income and consumption

<sup>17</sup>We again focus on an *ex post* deviation instead of a scenario without deposit insurance at all as it is consistent with the fact that investors and depositors often indeed expected governments to rescue distressed banks.

<sup>18</sup>Assumption 3 ensures that it never exceeds  $\bar{\tau}$ .

directly. After substituting for the tax rate  $\tau_N$  using the government's budget constraints (13) and (16), the following consumption profile arises:

$$C_2^N = \begin{cases} W_2 + [1 - \mathbf{1}_{A < A^*}(1 - v)]A(D + E) - BR & \text{if } A \geq \hat{A}_N \\ W_2 + [1 - \mathbf{1}_{A < A^*}(1 - v)]A(D + E) & \text{if } A < \hat{A}_N \end{cases} \quad (30)$$

The term in square brackets equals one if the bank succeeds and  $v$  otherwise such that loans are worth only  $vA(D + E)$  in case the bank fails in a disorderly way.

### Welfare Implications

Deposit insurance therefore affects consumption and welfare (i) by preventing a costly liquidation of the bank's assets and (ii) through its effect on the sovereign default threshold. While the former always increases consumption, the effect of the latter is ambiguous and strongly depends on how guarantees affect sovereign risk (see proposition 2). A binary comparison of the two consumption profiles  $C_2$  and  $C_2^N$  yields the following corollary:

**COROLLARY 2** *If in equilibrium (i)  $R \geq R_0$  or (ii)  $R < R_0$  and  $v \geq v_m(R)$ , deposit insurance can always increase domestic welfare. If (iii)  $R < R_0$  and  $v < v_m(R)$ , the welfare effect depends on the realization of  $A$ : It can be positive for  $A \notin [\hat{A}, \hat{A}_N]$  but is negative for  $A \in [\hat{A}, \hat{A}_N]$ .*

**Proof:** This follows from the comparison of the consumption profiles (29) and (30) using the default threshold  $\hat{A}_N$  given by (27). The positive effect in (i) and (ii) is due to  $\hat{A} \geq \hat{A}_N$ . To show (iii), one compares (29) and (30): The result is  $C_2 > C_2^N$  for  $A < \hat{A}$  and  $A \in (\hat{A}_N, A^*)$  due to  $v < 1$  and  $C_2 < C_2^N$  for  $A \in [\hat{A}, \hat{A}_N]$ . The latter requires  $BR > (1 - v)A(D + E)$  which follows from the last inequality after substituting for consumption. If satisfied for the maximum value  $A = \hat{A}_N$ , this relation is obviously true for all  $A \in [\hat{A}, \hat{A}_N]$ :  $\hat{A}_N$  is at most  $\frac{D}{D+E}$  such that  $BR > (1 - v)D$ . This is ensured by assumption 2, which requires  $B > D$ . *Q.E.D.*

One can relate these cases to the three regions in figure 7: In the first case, which corresponds to the region  $p = p_N$ , the provision of deposit insurance does not affect sovereign risk such that  $\hat{A}$  and  $\hat{A}_N$  coincide. It is still welfare-improving if a bank failure would imply positive liquidation costs (i.e., if  $v < 1$ ). If depositors can recover the full liquidation value of the bank's assets ( $v = 1$ ), however, deposit insurance is essentially a zero-sum game because the costs increase the tax burden one-to-one without affecting consumption. In the second case, which is highlighted by region  $p > p_N$ , providing deposit insurance increases domestic consumption as it (i) prevents costly liquidation and (ii) raises sovereign risk thus shifting the cost of deposit insurance onto foreign bondholders. In the third case, as indicated by the region  $p < p_N$ , however,

these effects have opposite signs: While preventing costly liquidation is still welfare-improving, providing deposit insurance makes a sovereign default less likely. Hence, there are fewer opportunities to remove the debt burden. The second, negative effect dominates whenever present, that is, if loan performance is such that government guarantees indeed prevent a sovereign default,  $A \in [\hat{A}, \hat{A}_N]$ . This is shown by the shaded area in the right panel of figure 8. The intuition is that loans are performing quite poorly. The positive effect of preventing additional liquidation costs, which are proportional to the loans' realized value, is thus dominated by the negative effect of not shifting the public debt burden to foreign investors. If  $A$  is outside this region, however, a sovereign default is independent of deposit insurance and only the positive effect of avoiding costly liquidation exists.

The welfare implications of government guarantees crucially depend also on the type of equilibrium. In the 'bad' one, where sovereign default occurs with certainty and  $R > R_0$ , the first of the three cases matters. Fulfilling the commitment to depositors is welfare-improving only in the presence of liquidation cost and a zero-sum game, where deposit insurance is essentially paid by the households themselves through higher taxes, otherwise. In the 'good' equilibrium, however, deposit insurance may become decisive for welfare.

Moreover, the welfare properties of deposit insurance may have implications for the credibility of deposit insurance: In the first two cases, rescuing distressed banks is always optimal *ex post* such that a benevolent government will indeed rescue a failing bank. Deposit insurance is then both time-consistent and credible. As a side effect, it could be argued that the disciplining role of depositors through the threat of bank runs - as claimed in Diamond and Rajan (2000), for example - can therefore not be rationalized under such circumstances. In the third case, however, the government might have an incentive to deviate from its initial commitment depending on the performance of bank loans. Deposit insurance could be time-inconsistent in such a scenario but is still provided due to legal obligations. Agents may otherwise anticipate that the commitment might not be fulfilled and revise their expectations. Households, for instance, might demand a risk-adjusted deposit interest rate while investors would impose a different bond return due to implications of deposit insurance for sovereign default.

Eventually, the finding of a potentially welfare-improving sovereign default requires some comments. Clearly, the possibility to remove the debt (and tax) burden by defaulting on bonds that are exclusively held by foreign investors in equilibrium raises domestic consumption and welfare. However, a default in our model only occurs due to bad fundamentals, namely, if the government cannot collect sufficient revenue to cover all its date 2 expenditures. This sets it apart from contributions, which model default as a strategic decision. In our model, defaulting on bonds would thus always be optimal *ex post* regardless of the fiscal capacity such that only the 'bad' equilibrium would prevail. The result that sovereign default is welfare-improving

should, however, be interpreted with some caution for several reasons. First, a static framework does not capture negative future effects such as damaged reputation and limited access to the international capital market. Second, a sovereign default may entail high macroeconomic and political costs, for example, employment losses in the public sector, political instability or social unrest. This could be easily added to the model either as reduced-form social cost or - following Cooper and Nikolov (2013) - as lower date 2 labor income  $W_2$ .<sup>19</sup> Third, a considerable fraction of sovereign bonds is often held by domestic investors such as banks, pension funds, and insurance companies. The domestic welfare gain of defaulting on these bonds is likely to be smaller in reality. Fourth, a default implies a full haircut on bondholders while the residual remains with the government.

## 4.5 Capital Regulation

The bank's asset allocation has been unconstrained in the model so far. In reality, however, banks face numerous regulatory restrictions, in particular, capital requirements. A key aspect for this analysis is that they limit the bank's lending capacity but do not constrain sovereign bond holdings due to positive risk weights for the former and zero risk weights for the latter. Consequently, capital regulation is one factor that explains why banks purchase fairly priced sovereign bonds in equilibrium. Such bond holdings provide a richer characterization of the bank-sovereign nexus: While the two main channels of bank-sovereign contagion - government guarantees and taxation - persist in such an allocation, a scenario with adverse feedback loops may occur as well. This happens if banks fail or are considerably more vulnerable because of a sovereign default. Besides such a case, banks can also become sensitive to fiscal fundamentals like public debt or tax capacity because the bond return, which reflects the risk of a sovereign default, becomes a critical determinant of bank risk.

### 4.5.1 Banks

Due to capital requirements, banks need to finance a fraction of their loans by equity whereas sovereign bonds have a risk weight of zero and do not require any equity funding. Their asset allocation is subject to the regulatory constraint

$$L \leq \mu E, \quad (31)$$

where  $\mu$  denotes the equity multiplier.<sup>20</sup> Given a minimum capital requirement of 8% as in Basel II, loans must not be larger than 12.5 times its equity. Consequently, the bank chooses

<sup>19</sup>This would also alter households' savings choice and make deposits sensitive to sovereign risk.

<sup>20</sup>If the capital requirement is  $k$ , the multiplier equals  $\mu = 1/k$ .

deposits and asset allocation in order to maximize expected profits

$$\max_{L,D} \int_{A^*}^{\bar{A}} ALdF(A) + [1 - \max\{F(A^*), p\}]R(D + E - L) - [1 - F(A^*)]D \quad (32)$$

subject to the regulatory constraint (31). Using a similar logic as in the baseline model, one can derive the corresponding failure threshold  $A^*$  based on its general definition (3): As long as sovereign bonds are repaid, they provide a buffer to absorb loan losses. The bank's failure threshold therefore increases in loans and is at most  $\frac{D-R(D+E-\mu E)}{\mu E}$ . The latter represents the case in which the bank provides the maximum amount of loans possible:  $L = \mu E$ . This scenario is captured by the lower, upward-sloping curve in figure 9. If they are not repaid, however, holding bonds immediately reduces a bank's capacity to absorb loan losses. The failure threshold then decreases in loans, which at the margin yield  $A^*$  while bonds yield zero. It is at least  $\frac{D}{\mu E}$  such that the bank is most stable if it provides the maximum amount of loans,  $L = \mu E$ , and holds as few bonds as possible. The upper, downward-sloping curve in figure 9 illustrates this case. Consequently, if bonds are repaid if the bank fails (i.e., if  $\tilde{R} = R$  at  $A = A^*$ ), the government is necessarily more robust than the least stable bank such that  $\hat{A} = F^{-1}(p) < \frac{D-R(D+E-\mu E)}{\mu E}$  or, equivalently,  $p < F\left(\frac{D-R(D+E-\mu E)}{\mu E}\right) \equiv p_1$ . Otherwise, it would default at  $A = A^*$  and sovereign bonds would not be repaid. Similarly, if bonds are not repaid when the bank fails (i.e., if  $\tilde{R} = 0$  at  $A = A^*$ ), the government is necessarily less robust than the most stable bank such that  $\hat{A} = F^{-1}(p) > \frac{D}{\mu E}$  or, equivalently,  $p > F\left(\frac{D}{\mu E}\right) \equiv p_2$ . In contrast to the baseline model, the cutoffs  $p_1$  and  $p_2$  differ because capital requirements prevent an all-loan bank. Whenever sovereign risk is in this interim region,  $p \in [p_1, p_2]$ , the bank survives if bonds are repaid but fails otherwise such that a sovereign default is the very reason for bank failure.

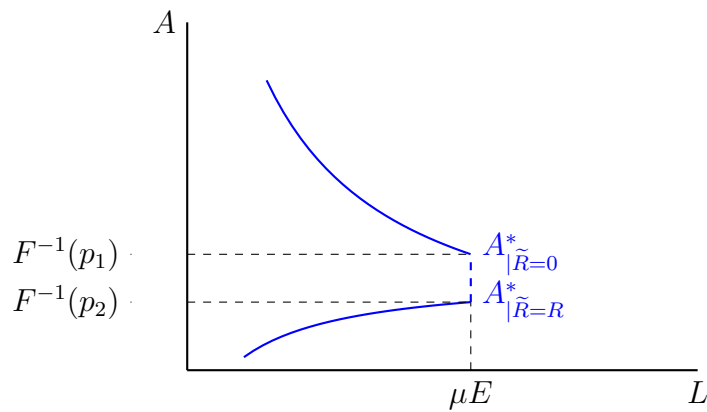


Figure 9: Bank's Failure Threshold

One can summarize the bank's failure threshold as a function of sovereign risk:

$$A^* = \begin{cases} \max \left\{ \frac{D-R(D+E-L)}{L}, F^{-1}(p) \right\}, & \text{if } p < p_1 \\ F^{-1}(p), & \text{if } p \in [p_1, p_2] \\ \min \left\{ \frac{D}{L}, F^{-1}(p) \right\}, & \text{if } p > p_2 \end{cases} \quad (33)$$

We solve for the bank's optimal asset allocation using this definition of the default threshold. Again, the bank's optimization problem is convex or linear in  $L$  and  $D$  such that a corner solution emerges. Hence, the demand for deposit is indeterminate and perfectly elastic at the risk-free interest rate; any amount of deposits supplied by households is accepted. Regarding the asset allocation, the bank chooses between two options: It either provides as much loans as possible and invests the remainder in sovereign bonds,  $L = \mu E$  and  $G = D + E - \mu E$ ; or it only purchases sovereign bonds,  $L = 0$  and  $G = D + E$ . As in the baseline model, the bank chooses the former if this allocation promises higher expected profits, that is, if  $\pi(\mu E) \geq \pi(0)$ . The results are summarized as follows:

**LEMMA 3** *The bank's deposit demand  $D$  is perfectly elastic. Define the cutoff:*

$$R' = \begin{cases} \frac{1}{1-p} \left[ E(A) + \int_0^{\frac{D-R(D+E-\mu E)}{\mu E}} F(A) dA - \frac{p[D-R(D+E-\mu E)]}{\mu E} \right], & \text{if } p < p_1 \\ \frac{1}{1-p} \left[ E(A) + \int_0^{F^{-1}(p)} F(A) dA - pF^{-1}(p) \right], & \text{if } p \in [p_1, p_2] \\ \frac{1}{1-p} \left[ E(A) + \int_0^{\frac{D}{\mu E}} F(A) dA - \frac{pD}{\mu E} \right], & \text{if } p > p_2 \end{cases} \quad (34)$$

$R'$  decreases in the capital requirement if  $p < p_1$ , is unchanged if  $p \in [p_1, p_2]$ , and increases if  $p > p_2$ . The bank's loan volume equals

$$L = \begin{cases} \mu E, & \text{if } R \leq R' \\ 0, & \text{if } R > R' \end{cases} \quad (35)$$

and its sovereign bond holdings are  $G = D + E - L$ . The bank's failure threshold is either

$$A^* = \begin{cases} \frac{D-R(D+E-\mu E)}{\mu E}, & \text{if } p < p_1 \\ F^{-1}(p), & \text{if } p \in [p_1, p_2] \\ \frac{D}{\mu E}, & \text{if } p > p_2 \end{cases} \quad (36)$$

if  $R \leq R'$  or  $A^* = F^{-1}(p)$  if  $R > R'$ .

**Proof:** See Appendix 4.A.1.

The bank's portfolio consists of both loans and sovereign bonds as long as the bond return is small enough such that expected bank profits from investing in a combined portfolio of loans and bonds are higher than in case of a bonds-only portfolio. Note that - although defined in a piecewise manner - the cutoff return  $R'$  exhibits no discrete jumps and is increasing in  $p$ . Tighter regulation induces banks to favor the safer portfolio.

### 4.5.2 Equilibrium

The choices of the households and the government are similar to those in the baseline model. Focusing on the case of banks with the combined portfolio (see discussion in Appendix 4.A.1), these results and lemma 3 establish:

**PROPOSITION 3** *The equilibrium allocation  $\{A^*, \hat{A}, D, G, L, p, R, R'\}$  is characterized by conditions (2), (10) - (12), (20), and (34) - (36). Using (20), define the sovereign default threshold for  $L = \mu E$ :*

$$\hat{A}_{|L=\mu E} = \begin{cases} \frac{D-R(D+E-\mu E)}{\mu E} + \max \left\{ \frac{BR-\bar{\tau}(D+W_2)}{\mu E}, \frac{BR-\bar{\tau}(D+W_2)}{\bar{\tau}\mu E} \right\}, & \text{if } R \leq R_2 \\ \bar{A}, & \text{if } R > R_2 \end{cases} \quad (37)$$

$R_2$  equals  $\frac{\bar{\tau}(W_2+\bar{A}\mu E)}{(1-\omega\bar{\tau})B}$ . Two types of equilibria may exist:

- The 'good' equilibrium with  $p_g < 1$  and  $R_g < R_2$  exists if  $\exists R \in [1, R_2)$  such that  $F[\hat{A}_{|L=\mu E}(R)] < 1 - \frac{1}{R}$ .
- The 'bad' equilibrium with  $p_b = 1$  and  $R \rightarrow \infty$  always exists.

In each type of equilibrium, banks hold a combination of loans and sovereign bonds: They provide the maximum amount of loans  $L = \mu E$  and invest the remainder in sovereign bonds,  $G = D + E - \mu E$ . The bank failure threshold is

$$A^* = \begin{cases} \frac{D-R(D+E-\mu E)}{\mu E}, & \text{if } R \leq R_0 \\ \min \left\{ \frac{D-R(D+E-\mu E)}{\mu E} + \frac{BR-\bar{\tau}(D+W_2)}{\bar{\tau}\mu E}, \frac{D}{\mu E} \right\}, & \text{if } R > R_0 \end{cases}$$

and the government's default threshold equals  $\hat{A} = \hat{A}_{|L=\mu E}$ .

**Proof:** See Appendix 4.A.1.

The preferential treatment of sovereign bonds, which are subject to zero risk weights, is one reason why banks invest in fairly priced bonds. Without regulation, they do not purchase any bonds at all because fair pricing makes them less attractive than loans. Hence, banks are

sensitive to sovereign risk through bond return and repayment, and a scenario with adverse feedback loops is possible.

### 4.5.3 Comparative Statics

Three cases with fundamentally different channels of bank-sovereign contagion (see summary in Appendix 4.A.2) are possible: First, the banks are less stable than the government (i.e.,  $A^* > \hat{A}$ ) whenever the bond return is low. Bank-sovereign contagion may thus occur because of government guarantees. Second, they are at least as stable as the government (i.e.,  $A^* < \hat{A}$ ), which is the case if the bond return exceeds the cutoff  $R_0$ . Hence, the tax capacity is small compared to the level of public debt such that quite a large taxable income from bank owners (i.e., a high realization of  $A$ ) is necessary to raise sufficient revenue. In reality, this describes highly indebted countries with a small tax base. Contagion thus occurs even without bank failure in the first place simply due to a small dividend income of bank owners that leads to an erosion of the tax base. Third, an adverse feedback may occur in the latter scenario whenever the bank fails because sovereign bonds are not repaid.

#### Sovereign Risk

The sovereign default threshold is given by (37), which means that the default probability  $p = F(\hat{A})$  and the bond return  $R$  react to changes in the fiscal and regulatory environment as follows:

**COROLLARY 3** *In the 'good' equilibrium, the sovereign default probability satisfies  $\frac{\partial p}{\partial \bar{\tau}} < 0$  and  $\frac{\partial p}{\partial B} > 0$ , which implies  $\frac{\partial R}{\partial \bar{\tau}} < 0$  and  $\frac{\partial R}{\partial B} > 0$ . The sensitivities of  $p$  and  $R$  to the regulatory multiplier  $\mu$  are positive as long as  $R \leq R_0$  but can be of either sign for  $R > R_0$ .*

**Proof:** See Appendix 4.A.1.

A fiscally sound country characterized by low public debt and a high tax capacity generally features a reduced probability of sovereign default, which translates into relatively small bond returns. A more fragile country, however, is more likely to default and thus borrows at higher interest rates.

The impact of capital requirements on sovereign risk is more subtle: If a government is less likely to default than banks (i.e., if  $\hat{A} \leq A^*$  or, equivalently,  $R \leq R_0$ ), tighter capital requirements reduce sovereign risk, as banks are less exposed to loan risk and absorb a larger amount of potential losses. This, in turn, lowers the cost of deposit insurance that might ultimately trigger its own default. Hence, tighter capital regulation clearly improves fiscal stability. If the government is more vulnerable in equilibrium (i.e., if  $\hat{A} > A^*$  or, equivalently,  $R > R_0$ ),



however, this effect can be ambiguous. Recall that a sovereign default occurs in this case because the tax base is so small that the government cannot raise sufficient revenue. The impact of regulation on bank profits is therefore critical: Tighter capital requirements effectively force banks to reallocate assets from loans to sovereign bonds. This may increase the realized bank profit as long as the return of bonds exceeds that of loans at the sovereign default threshold (i.e., as long as  $R > \hat{A}$ ) such that tighter regulation, due to its impact on taxable date 2 income, still reduces sovereign risk. If the sovereign default threshold  $\hat{A}$  is very high, however, bank profits and the tax base increase if banks are allowed to hold more loans. These still perform very well at the default threshold and yield a larger (taxable) payoff than sovereign bonds (i.e.,  $\hat{A} > R$ ). This is the reason why a tighter regulatory stance might even weaken fiscal stability in these countries characterized by high sovereign risk and high interest rates in equilibrium. For capital regulation to increase sovereign risk, the default threshold and the bond return need to be very high, which is a rather unlikely scenario for the 'good' equilibrium, however.<sup>21</sup> Under such circumstances, it appears more likely that the 'good' equilibrium ceases to exist such that only the 'bad' equilibrium remains. Apart from this special case, tighter capital requirements reduce sovereign risk. This also implies that the government is more stable and benefits from lower interest rates in an allocation where banks hold both loans and sovereign bonds than in the unconstrained equilibrium (proposition 1).

### Bank Risk

Bank's sovereign bond holdings link bank and sovereign risks through bond return and repayment, which creates the possibility of an adverse feedback. Recall that the failure threshold of banks considerably varies depending on the equilibrium bond return

$$A^* = \begin{cases} \frac{D-R(D+E-\mu E)}{\mu E}, & \text{if } R \leq R_0 \\ \frac{D-R(D+E-\mu E)}{\mu E} + \frac{BR-\bar{\tau}(D+W_2)}{\bar{\tau}\mu E}, & \text{if } R \in (R_0, R_1) \\ \frac{D}{\mu E}, & \text{if } R \geq R_1 \end{cases} \quad (38)$$

where the cutoffs  $R_0$  and  $R_1$  follow from (18) and (19). Recall figure 5: As long as the equilibrium bond return is small ( $R \leq R_0$ ) such that the government is more stable than banks, bonds provide a cushion to absorb loan losses. If, however, the bond return is large ( $R \geq R_1$ ) due to a substantial debt burden, in which case the government is less stable than the bank, bond holdings directly translate into losses at the bank failure threshold  $A^*$ ; this uses up equity and weakens banks' resilience. In an intermediate case  $R \in (R_0, R_1)$ , the bank's failure is conditional upon non-repayment of bonds: It would survive for an even worse loan

<sup>21</sup>This is only feasible if the maximum loan return  $\bar{A}$  is large enough such that  $R_2 > \frac{\bar{\tau}W_2}{B-\bar{\tau}(D+E)}$ .

performance if bonds were repaid but it cannot absorb losses on both assets. As a result, the sovereign default is the very reason for bank failure and both thresholds ( $A^*$  and  $\hat{A}$ ) just coincide. This case reflects the negative feedback loop as a poor loan performance itself does not push banks into bankruptcy but triggers a sovereign default, which immediately leads to bank failure. Using the bond return's sensitivities from corollary 3, differentiating (38) yields:

**COROLLARY 4** *The sensitivities of bank risk,  $F(A^*)$ , differ between three cases:*

- *If  $R \leq R_0$ , bank risk increases in the tax capacity,  $\frac{\partial A^*}{\partial \bar{\tau}} > 0$ , and decreases in public debt,  $\frac{\partial A^*}{\partial B} < 0$ , whereas capital requirements have an ambiguous effect,  $\frac{\partial A^*}{\partial \mu}$ .*
- *If  $R \in (R_0, R_1)$ , bank risk decreases in the tax capacity,  $\frac{\partial A^*}{\partial \bar{\tau}} < 0$ , and increases in public debt,  $\frac{\partial A^*}{\partial B} > 0$ , whereas the effect of capital requirements can be of either sign,  $\frac{\partial A^*}{\partial \mu}$ .*
- *If  $R \geq R_1$ , bank risk does not directly depend on fiscal fundamentals,  $\frac{\partial A^*}{\partial \bar{\tau}} = \frac{\partial A^*}{\partial B} = 0$ , and decreases in the regulatory multiplier  $\frac{\partial A^*}{\partial \mu} < 0$ .*

**Proof:** See Appendix 4.A.1.

Bank risk exhibits significant differences depending on the equilibrium bond return. In the first case,  $R \leq R_0$ , bonds are always repaid as long as the bank survives. Hence, they reduce banks' exposure to loan risk and generate profits that may serve as a buffer to absorb loan losses. The bond return plays a prominent role as it reduces bank risk by generating higher profits and links it to fiscal fundamentals. Since a higher public debt level,  $B$ , and a lower tax capacity,  $\bar{\tau}$ , raise the bond return as shown in corollary 3, they even enhance banks' resilience. Therefore, slightly increasing sovereign risk in a country that is still fiscally sound (i.e., pays a relatively low bond return in equilibrium) may reduce bank risk because higher bond returns raise profits and (final-period) equity. The impact of the regulatory multiplier  $\mu$  is, in principle, ambiguous in such a scenario because of two countervailing effects: On the one hand, tighter regulation directly lowers the bank's exposure to risky loans thereby making it more resilient. On the other hand, it reduces sovereign risk as shown in corollary 3 such that bond returns fall; the latter, in turn, reduces bank profits and thus its capacity to withstand a poor loan performance. However, it is likely that the positive direct effect prevails. The effects associated with the bond return are of course expected to be less pronounced in reality where banks hold diversified portfolios of sovereign bonds and may, in fact, substitute foreign for domestic bonds if the latter become riskier. However, banks' sovereign exposures are also characterized by a significant home bias that is empirically well documented.

In the second case,  $R \in (R_0, R_1)$ , a bank failure is triggered by the non-repayment of government bonds such that sovereign and bank risk are similar and their default thresholds coincide. In

other words, banks fail because of an adverse feedback. As a result, increases in sovereign risk imply higher bank risk. Weaker fiscal fundamentals ( $B$  and  $\bar{\tau}$ ), therefore, increase bank risk, whereas the effects of tighter capital regulation are generally ambiguous but likely positive as discussed in section 4.5.3.

In the third case,  $R \geq R_1$ , banks are more stable than the government, and do not immediately fail if bonds are not repaid. Put differently, sovereign risk is so high that the government defaults even though bank loans perform well. This case also captures bank risk in the 'bad' equilibrium, in which the country experiences a sovereign debt crisis and defaults irrespective of the banking sector's loan performance. Bank risk then only depends on bank characteristics and is disconnected from fiscal fundamentals in the sense that they have no direct impact on failure threshold and probability. Although there is no scope for any immediate feedback like in the second case, the sovereign default weakens banks' resilience. Interestingly, relaxing capital requirements (i.e., raising the regulatory multiplier) reduces bank risk in this scenario: The intuition is that banks hold more loans, which are worth  $A^*$  at the margin, and fewer sovereign bonds, which are worth zero.

The interaction between bank and sovereign risks is a key feature of this model. In fiscally sound countries that pay a low bond return, there is a tension between bank and sovereign risks because holding bonds only yields small profits due to low returns such that banks' loss-absorbing capacity is limited. This means that bank risk is *ceteris paribus* higher in a risk-free country ( $R = 1$ ) than in a still solid country with a positive default probability (i.e., if  $R$  is close to  $R_0$ ). As soon as sovereign risk and the corresponding bond return increase above a cutoff, the relation between bank and sovereign risks is reversed because bank failure crucially depends on bond repayment. Improving fiscal fundamentals then makes bond repayment more and a bank failure less likely. If bond return and debt burden are so large that a sovereign default occurs even though bank loans perform relatively well, for instance, in a 'bad' equilibrium, the bank can absorb the bond losses and its own risk only depends on leverage and loan performance. Hence, bank risk does not directly depend on fiscal fundamentals but is higher as a result of a sovereign default.

## 4.6 Conclusion

We present a model of the bank-sovereign nexus, which has been a prominent feature in the ongoing European banking and debt crisis. In order to study contagion between banks and sovereigns and to analyze the impact of government guarantees for stability and welfare, the model uniquely combines financial fragility with sovereign debt fragility in the form of multiple equilibria and self-fulfilling debt crises. Unlike in most other papers on that topic, risks originate

in the banking sector, more precisely, from the banks' asset side. A poor loan performance directly hits the bank but may also cause a sovereign default. This is because the fate of the two is tied together by deposit insurance cost and taxation. Importantly, the provision of deposit insurance can either trigger or prevent a sovereign default. The outcome depends crucially on the liquidation value of the bank's assets: A government safeguards its own stability whenever its intervention prevents high cost of a disorderly bank liquidation but may jeopardize it otherwise. The provision of deposit insurance lifts domestic consumption levels as well as welfare as it avoids significant bankruptcy cost and may effectively shift the debt burden onto foreign bondholders. This is a key difference to other contributions on sovereign debt crises, in which default is the result of a strategic decision.

Banks in this model only purchase fairly priced bonds due to their preferential regulatory treatment, that is, because no equity has to be held against them. Bond holdings make them sensitive to the fiscal state and cause the unhealthy symbiosis between the banking sector and the sovereign. Therefore, it is possible that banks only fail because of sovereign default. Adverse feedback loops of that sort were the source of major problems in recent years. The model is able to rationalize both the Irish case, in which banks stood at the heart of the problem, and, to a lesser extent, the Greek scenario, in which a sudden loss of confidence in the government was the decisive trigger. The interplay between the risks of banks and sovereigns reveals a number of interesting interdependencies. We find, for instance, that financial and fiscal stability may not always work in the same direction in the sense that higher bond returns, which are the result of weaker fiscal fundamentals, provide a buffer to absorb loan losses to the bank and thus stabilize the latter. While this is true for fiscally sound countries, the effect reverses for banks located in unstable regions. Stricter capital requirements tend to enhance the resilience of both banks and sovereigns, but also raise awareness of potentially countervailing effects. The novel findings of this analysis clarify the fundamental mechanisms of contagion between governments and banks and outline possible consequences of the policy options at hand. They also rationalize important implications of deposit insurance, potential welfare benefits of sovereign default, as well as consequences of tighter capital requirements.

Bank-sovereign contagion and adverse feedback effects are at the core of our analysis. Motivated by recent crises in Ireland and Spain, the focus of our paper is clearly on risks originating in the banking sector. In further research, one may also include other sources of risk such as political or macroeconomic shocks to study this aspect of sovereign-bank contagion. Moreover, our analysis provides one explanation for why banks hold fairly priced domestic sovereign bonds; namely, that they receive preferential treatment in the current regulatory framework. Further motivations for bond holdings, such as their role as a collateral in the interbank market, and their effect on the relation between bank stability and sovereign risks may be explored as

well. Our paper studies systemic crises (i.e., correlated risks), the consequences of which can be particularly disastrous. An extension, however, could analyze which mechanisms of the interplay between bank and sovereign risks prevail in case of imperfect correlation and how deposit insurance schemes would affect welfare in such an environment.

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## 4.A Appendix

### 4.A.1 Proofs and Derivations

**Proof of Lemma 1:** We distinguish between two cases: Suppose first  $p \leq \bar{p}$  such that bonds are repaid for the realization of  $A$  at which the bank fails and  $\max\{F(A^*), p\} = F(A^*)$ . Integrating the term  $\int_{A^*}^{\bar{A}} dF(A)$  yields the expected bank profit:

$$\pi = \left[ \bar{A} - F(A^*)A^* - \int_{A^*}^{\bar{A}} F(A)dA \right] L + [1 - F(A^*)][R(D + E - L) - D]$$

where by (5), its failure threshold is  $A^* = \max\left\{\frac{D-R(D+E-L)}{L}, F^{-1}(p)\right\}$ .<sup>22</sup> The first-order condition w.r.t.  $D$  is nonnegative due to  $R \geq 1$ :

$$\frac{\partial \pi}{\partial D} = [1 - F(A^*)](R - 1) \geq 0$$

Hence, the bank always raises the maximum amount of deposits households are willing to supply at the risk-free interest rate. The first-order condition w.r.t.  $L$  is

$$\frac{\partial \pi}{\partial L} = \bar{A} - F(A^*)A^* - \int_{A^*}^{\bar{A}} F(A)dA - [1 - F(A^*)]R$$

The objective function is linear or convex in  $L$  as the second-order condition is nonnegative

$$\frac{\partial^2 \pi}{\partial L^2} = f(A^*)(R - A^*) \frac{\partial A^*}{\partial L} \geq 0$$

because of  $\frac{\partial A^*}{\partial L} = \frac{R(D+E)-D}{L^2} > 0$  if  $A^* > F^{-1}(p)$  and  $\frac{\partial A^*}{\partial L} = 0$  if  $A^* = F^{-1}(p)$ .<sup>23</sup> Note that (5) implies  $R \geq A^*$ . Therefore, the optimal choice is determined by the corner solution  $L = \{D + E, 0\}$ . The bank chooses  $L = D + E$  and  $G = 0$  if  $\pi(D + E) \geq \pi(0)$ :

$$\left[ \bar{A} - \frac{\bar{p}D}{D + E} - \int_{D/(D+E)}^{\bar{A}} F(A)dA \right] (D + E) - (1 - \bar{p})D \geq (1 - p)[R(D + E) - D]$$

which uses  $A^* = \frac{D}{D+E}$  if  $L = D + E$  and  $A^* = F^{-1}(p)$  if  $L = 0$ . Otherwise, the bank purchases sovereign bonds only ( $L = 0$  and  $G = D + E$ ). Rearranging yields

$$\bar{A} - \int_{D/(D+E)}^{\bar{A}} F(A)dA \geq (1 - p)R + \frac{pD}{D + E} \quad (39)$$

<sup>22</sup>The threshold is  $[D - R(D + E - L)]/L$  if  $L \geq [R(D + E) - D]/[R - F^{-1}(p)]$  and  $F^{-1}(p)$  else.

<sup>23</sup>Note that the objective function  $\pi$  is linear for  $L < [R(D + E) - D]/[R - F^{-1}(p)]$  and convex for larger  $L$ ; there is no discrete jump of  $\pi$  at  $L = [R(D + E) - D]/[R - F^{-1}(p)]$ .

where the l.h.s. equals  $E(A) + \int_0^{D/(D+E)} F(A)dA$ . This gives the maximum bond return  $R'$ . Second, suppose instead that  $p > \bar{p}$ . Bonds are then not repaid for the realization of  $A$  at which the bank fails and  $\max\{F(A^*), p\} = p$ . Hence, the bank's expected profit is:

$$\pi = \left[ \bar{A} - F(A^*)A^* - \int_{A^*}^{\bar{A}} F(A)dA \right] L + (1-p)R(D+E-L) - [1-F(A^*)]D$$

The default threshold is  $A^* = \min\left\{\frac{D}{L}, F^{-1}(p)\right\}$  by (5).<sup>24</sup> The first-order condition w.r.t.  $D$  is

$$\frac{\partial \pi}{\partial D} = (1-p)R - [1-F(A^*)]$$

In equilibrium, bonds are priced such that this condition is nonnegative and the bank raises the maximum amount of deposits supplied by households. The first-order condition w.r.t.  $L$  is

$$\frac{\partial \pi}{\partial L} = \bar{A} - F(A^*)A^* - \int_{A^*}^{\bar{A}} F(A)dA - (1-p)R$$

The objective function is linear or convex in  $L$  as the second-order condition is again nonnegative

$$\frac{\partial^2 \pi}{\partial L^2} = -f(A^*)A^* \frac{\partial A^*}{\partial L} \geq 0$$

because of  $\frac{\partial A^*}{\partial L} = -\frac{D}{L^2} < 0$  if  $A^* > F^{-1}(p)$  and  $\frac{\partial A^*}{\partial L} = 0$  if  $A^* = F^{-1}(p)$ .<sup>25</sup> The bank chooses  $L = D + E$  and  $G = 0$  if  $\pi(D + E) \geq \pi(0)$ :

$$\left[ \bar{A} - \frac{\bar{p}D}{D+E} - \int_{D/(D+E)}^{\bar{A}} F(A)dA \right] (D+E) - (1-\bar{p})D \geq (1-p)[R(D+E) - D]$$

Rearranging yields the cutoff  $R'$ . Finally, one obtains the sensitivity of  $R'$  by totally differentiating (39):

$$\frac{\partial R'}{\partial E} = \frac{D}{(D+E)^2} \frac{p-\bar{p}}{1-p}$$

such that  $\frac{\partial R'}{\partial E} < 0$  if  $p < \bar{p}$  and  $\frac{\partial R'}{\partial E} > 0$  if  $p > \bar{p}$ . *Q.E.D.*

**Proof of Proposition 1:** The 'bad' equilibrium always exists, as for  $R \rightarrow \infty$ ,  $\hat{A} = \bar{A}$ , and  $p = 1$ . The bond return is determined by (11) which means that a default with certainty implies that  $R \rightarrow \infty$  is indeed justified. Since  $R' \rightarrow \infty$ , the bank prefers holding loans only,

<sup>24</sup>More precisely, the default threshold is  $D/L$  if  $L \geq D/F^{-1}(p)$  and  $F^{-1}(p)$  else.

<sup>25</sup>The objective function is linear for  $L < D/F^{-1}(p)$  and convex for larger  $L$ ; there is no discrete jump of  $\pi$  at  $L = D/F^{-1}(p)$ .



$L = D + E$ . To prove the existence of the 'good' equilibrium, we proceed in two steps: First, suppose  $L = D + E$  such that  $\hat{A} = \hat{A}|_{L=D+E}$ . Given that a bond return  $R \in [1, R_2)$  with  $F[\hat{A}|_{L=D+E}(R^*)] \leq 1 - \frac{1}{R}$  exists, the continuity<sup>26</sup> of both  $F(A)$  and  $\hat{A}|_{L=D+E}$ , which implies that  $F[\hat{A}|_{L=D+E}(R)]$  is non-decreasing in  $R$ , together with  $F[\hat{A}|_{L=D+E}(1)] \geq 0 = 1 - \frac{1}{1}$  ensure the existence of the 'good' equilibrium with  $R_g \leq R$ . Graphically, bond pricing and default curve intersect. Hence, one can identify an equilibrium candidate; for it to be a true equilibrium, one needs to show that  $R_g \leq R'$  is satisfied such that the bank is indeed willing to hold loans only: Substituting  $R_g = \frac{1}{1-p}$  from the bond pricing condition into (6) implies:

$$p \leq \frac{D+E}{D} \left[ E(A) + \int_0^{\frac{D}{D+E}} F(A) dA - 1 \right] \quad (40)$$

This means that the default probability implied by  $R_g$ ,  $p_g = F[\hat{A}|_{L=D+E}(R_g)]$ , needs to satisfy the above condition. If condition (40) is violated for all potential values of  $R^*$ , implying that the bank would prefer to hold sovereign bonds only, the candidate identified above is no equilibrium. Therefore, only the 'bad' equilibrium exists in this case. In general, a bank holding sovereign bonds only cannot be an equilibrium outcome: The government's default probability is then either zero or one and, by (11), the bond return is either one or infinity. These values, in turn, are smaller than the cutoff  $R'$ ; the bank would then prefer loans over bonds. Since  $L = D+E$  in each type of equilibrium,  $A^* = \frac{D}{D+E}$  and  $\hat{A} = \hat{A}|_{L=D+E}$  immediately follow. *Q.E.D*

**Proof of Corollary 1:** The systems (11) and (24) jointly determine  $\hat{A}$  and  $R$ . Since  $R < R'$  in the 'good' equilibrium, the system is

$$J^1 = \hat{A} - \frac{D}{D+E} - \max \left\{ \frac{BR - \tau(D+W_2)}{D+E}, \frac{BR - \tau(D+W_2)}{\bar{\tau}(D+E)} \right\} = 0$$

$$J^2 = [1 - F(\hat{A})]R - 1 = 0$$

Provided that in equilibrium  $R \leq R_0$ , the Jacobian matrix is

$$J = \begin{bmatrix} 1 & -\frac{B}{D+E} \\ -f(\hat{A})R & 1 - F(\hat{A}) \end{bmatrix}$$

Denote the Jacobian determinant by  $\nabla$ :

$$\nabla = 1 - F(\hat{A}) - \frac{f(\hat{A})BR}{D+E} > 0 \quad (41)$$

<sup>26</sup>Note that  $\hat{A}|_{L=D+E}(R)$  has two kinks at  $R = R_0$  and  $R = R_2$  but no jumps.

The sign is derived using a specific property of the equilibrium, which follows from the intersection of the default threshold and the bond pricing equation: In the 'good' equilibrium, the bond pricing curve is steeper than the default threshold (i.e.,  $1/R^2 > f(\hat{A})d\hat{A}/dR$ ). This property is necessary for the existence of the equilibrium since, for  $R = 1$ ,  $F[\hat{A}(1)] \geq 0 = p(1)$ .<sup>27</sup> substituting  $1 - F(\hat{A}) = 1/R$ , which holds in equilibrium, into (41) implies that  $\nabla > 0$  in the 'good' equilibrium. Cramer's rule yields:

$$\begin{aligned}\frac{\partial R}{\partial B} &= \frac{1}{\nabla} \frac{f(\hat{A})R^2}{D+E} > 0, & \frac{\partial \hat{A}}{\partial B} &= \frac{1}{\nabla} \frac{(1-F(\hat{A}))R}{D+E} > 0 \\ \frac{\partial R}{\partial \bar{\tau}} &= -\frac{1}{\nabla} \frac{f(\hat{A})(D+W_2)R}{D+E} < 0, & \frac{\partial \hat{A}}{\partial \bar{\tau}} &= -\frac{1}{\nabla} \frac{(1-F(\hat{A}))(D+W_2)}{D+E} < 0 \\ \frac{\partial R}{\partial E} &= -\frac{1}{\nabla} \frac{f(\hat{A})R(BR - \bar{\tau}W_2 + (1-\bar{\tau})D)}{(D+E)^2} < 0, & \frac{\partial \hat{A}}{\partial E} &= -\frac{1}{\nabla} \frac{(1-F(\hat{A}))(BR - \bar{\tau}W_2 + (1-\bar{\tau})D)}{(D+E)^2} < 0\end{aligned}$$

If in equilibrium  $R > R_0$ , the Jacobian matrix is

$$J = \begin{bmatrix} 1 & -\frac{B}{\bar{\tau}(D+E)} \\ -f(\hat{A})R & 1 - F(\hat{A}) \end{bmatrix}$$

The Jacobian determinant is

$$\nabla = 1 - F(\hat{A}) - \frac{f(\hat{A})BR}{\bar{\tau}(D+E)} > 0$$

The sign of  $\nabla$  is derived using the same approach as above; thus, the signs of the sensitivities do not differ from the case  $R \leq R_0$ . Applying Cramer's rule yields:

$$\begin{aligned}\frac{\partial R}{\partial B} &= \frac{1}{\nabla} \frac{f(\hat{A})R^2}{\bar{\tau}(D+E)} > 0, & \frac{\partial \hat{A}}{\partial B} &= \frac{1}{\nabla} \frac{(1-F(\hat{A}))R}{\bar{\tau}(D+E)} > 0 \\ \frac{\partial R}{\partial \bar{\tau}} &= -\frac{1}{\nabla} \frac{f(\hat{A})(D+W_2)R}{\bar{\tau}(D+E)} < 0, & \frac{\partial \hat{A}}{\partial \bar{\tau}} &= -\frac{1}{\nabla} \frac{(1-F(\hat{A}))(D+W_2)}{\bar{\tau}(D+E)} < 0 \\ \frac{\partial R}{\partial E} &= -\frac{1}{\nabla} \frac{f(\hat{A})R(BR - \bar{\tau}W_2 + (1-\bar{\tau})D)}{\bar{\tau}(D+E)^2} < 0, & \frac{\partial \hat{A}}{\partial E} &= -\frac{1}{\nabla} \frac{(1-F(\hat{A}))(BR - \bar{\tau}W_2 + (1-\bar{\tau})D)}{\bar{\tau}(D+E)^2} < 0\end{aligned}$$

The signs of the sensitivities in corollary 1 then follow from  $p = F(\hat{A})$ . *Q.E.D.*

**Proof of Proposition 2:** Given (27), one needs to distinguish between three intervals of the equilibrium bond return  $R$ : First, if  $R \geq R_0$ , the default thresholds  $\hat{A}$  and  $\hat{A}_N$  coincide such that  $p = p_N$  irrespective of  $v$ . Second, if  $R \in [R_0 - \frac{(1-v)\bar{\tau}D}{B}, R_0)$ ,  $\hat{A}_N = \frac{D}{D+E} = A^*$  whereas  $\hat{A} < A^*$  for all  $R < R_0$ , which implies that  $\hat{A}_N > \hat{A}$  and  $p_N > p$ . Consequently,  $\hat{A}_N \geq \hat{A}$  for all

<sup>27</sup>For a graphical exposition, refer to figure 6.

$R \geq R_0 - \frac{(1-v)\bar{\tau}D}{B}$ . Rearranging this condition yields

$$v \leq \frac{BR - \bar{\tau}W_2}{\bar{\tau}D} \quad (42)$$

Third, if  $R < R_0 - \frac{(1-v)\bar{\tau}D}{B}$ ,  $\hat{A}_N = \frac{BR - \bar{\tau}W_2}{v\bar{\tau}(D+E)}$  and  $\hat{A} = \frac{D}{D+E} + \frac{BR - \bar{\tau}(D+W_2)}{D+E}$ . Solving  $\hat{A}_N \geq \hat{A}$  for  $v$  yields

$$v \leq \frac{BR - \bar{\tau}W_2}{\bar{\tau}[BR - \bar{\tau}W_2 + (1 - \bar{\tau})D]} \quad (43)$$

For  $p \geq p_N$ , the equilibrium allocation (i.e., the combination of  $R$  and  $v$ ) needs to satisfy either (42) or (43). Since all combinations that fulfill (43) are also consistent with (42) and since  $v \leq 1$ , condition (28) characterizes all allocations for which deposit insurance does not increase the government's default threshold and vulnerability. *Q.E.D.*

**Proof of Lemma 3:** This proof is similar to the proof of lemma 1: First, it is shown that the bank's objective function is increasing in or independent of  $D$  and either linear or convex in  $L$  such that the bank is willing to accept any amount of deposits and its optimal asset allocation is a corner solution (i.e., the bank either provides no loans at all or the maximum amount possible  $\mu E$ ). Second, we characterize the asset allocation depending on sovereign bond characteristics (i.e.,  $p$  and  $R$ ) by comparing expected profits for the two corner solutions. First, suppose  $p < p_1$ , that is, the government is still solvent for the realization of  $A$  at which the bank fails. The bank's expected profit is:

$$\pi = \left[ \bar{A} - F(A^*)A^* - \int_{A^*}^{\bar{A}} F(A)dA \right] L + [1 - F(A^*)][R(D + E - L) - D]$$

where by (34), its default threshold equals  $A^* = \max \left\{ \frac{D - R(D + E - L)}{L}, F^{-1}(p) \right\}$ .<sup>28</sup> The first-order condition w.r.t.  $L$  is nonnegative due to  $R \geq 1$ :

$$\frac{\partial \pi}{\partial D} = [1 - F(A^*)](R - 1) \geq 0$$

The first-order condition w.r.t.  $L$  is

$$\frac{\partial \pi}{\partial L} = \bar{A} - F(A^*)A^* - \int_{A^*}^{\bar{A}} F(A)dA - [1 - F(A^*)]R$$

The objective function is linear or convex as the second-order condition is nonnegative

$$\frac{\partial^2 \pi}{\partial L^2} = f(A^*)(R - A^*) \frac{\partial A^*}{\partial L} \geq 0$$

<sup>28</sup>More precisely, the default threshold is again  $[D - R(D + E - L)]/L$  if  $L \geq [R(D + E) - D]/[R - F^{-1}(p)]$  and  $F^{-1}(p)$  else.

as  $\frac{\partial A^*}{\partial L} \geq 0$  and  $R \geq A^*$ . Therefore, expected profit is maximized either if  $L = \mu E$  or  $L = 0$ . The bank chooses  $L = \mu E$  as long as it yields a larger expected profit,  $\pi(\mu E) \geq \pi(0)$ :

$$\left[ \bar{A} - p_1 F^{-1}(p_1) - \int_{F^{-1}(p_1)}^{\bar{A}} F(A) dA \right] \mu E + (1-p_1)[R(D+E-\mu E) - D] \geq (1-p)[R(D+E) - D]$$

This inequality uses  $A^* = F^{-1}(p_1) = \frac{D-R(D+E-\mu E)}{\mu E}$  if  $L = \mu E$  and  $A^* = F^{-1}(p)$  if  $L = 0$ . Using these definitions and rearranging yields the first part of (36).

Second, suppose that  $p \in [p_1, p_2]$ , the expected bank profit is

$$\pi = \left[ \bar{A} - p F^{-1}(p) - \int_{F^{-1}(p)}^{\bar{A}} F(A) dA \right] L + (1-p)[R(D+E-L) - D]$$

where  $A^* = F^{-1}(p)$  irrespective of  $D$  and  $L$ . Obviously, the objective function is linear. While it is non-decreasing in  $D$  such that the bank accepts any amount of deposits, the asset allocation is determined by comparing the corner solutions: The bank chooses  $L = \mu E$  as long as

$$\left[ \bar{A} - p F^{-1}(p) - \int_{F^{-1}(p)}^{\bar{A}} F(A) dA \right] \mu E + (1-p)[R(D+E-\mu E) - D] \geq (1-p)[R(D+E) - D]$$

and  $L = 0$  otherwise. Rearranging yields the second part of (36).

Eventually, suppose  $p > p_2$ . The government defaults for the realization of  $A$  at which the bank fails. Hence, the bank's expected profit is:

$$\pi = \left[ \bar{A} - F(A^*)A^* - \int_{A^*}^{\bar{A}} F(A) dA \right] L + (1-p)R(D+E-L) - [1-F(A^*)]D$$

The default threshold equals  $A^* = \min \left\{ \frac{D}{L}, F^{-1}(p) \right\}$ .<sup>29</sup> The first-order condition w.r.t.  $D$  is

$$\frac{\partial \pi}{\partial D} = (1-p)R - [1-F(A^*)]$$

In equilibrium, bonds are priced such that this condition is nonnegative and the bank raises any amount of deposits supplied by households. The first-order condition w.r.t.  $L$  is

$$\frac{d\pi}{dL} = \bar{A} - F(A^*)A^* - \int_{A^*}^{\bar{A}} F(A) dA - (1-p)R$$

The objective function is again linear or convex in  $L$  due to

$$\frac{\partial^2 \pi}{\partial L^2} = -f(A^*)A^* \frac{\partial A^*}{\partial L} \geq 0$$

<sup>29</sup>More precisely, it is  $D/L$  if  $L \geq D/F^{-1}(p)$  and  $F^{-1}(p)$  else.

as  $\frac{\partial A^*}{\partial L} \leq 0$ . The bank chooses  $L = \mu E$  if

$$\left[ \bar{A} - \frac{p_2 D}{\mu E} - \int_{D/\mu E}^{\bar{A}} F(A) dA \right] \mu E + (1-p)R(D+E-\mu E) - (1-p_2)D \geq (1-p)[R(D+E) - D]$$

This inequality uses  $A^* = F^{-1}(p_2) = \frac{D}{\mu E}$  if  $L = \mu E$  and  $A^* = F^{-1}(p)$  if  $L = 0$ . Applying these definitions and rearranging yields the third part of (36). *Q.E.D.*

**Proof of Proposition 3:** In the extension, we focus on the scenario where the bond return implied by fair bond pricing (11) never exceeds the cutoff  $R'$  given by (34) such that the bank always holds  $L = \mu E$  and  $G = D + E - \mu E$  if bonds are fairly priced. This requires

$$E(A) + \int_0^{\frac{D}{\mu E}} F(A) dA - \frac{D}{\mu E} \geq 1 \quad (44)$$

If this relation is satisfied,  $R \leq R'$  for all  $p \in [0, 1]$ . Since any equilibrium requires fairly priced bonds, only the asset allocation  $L = \mu E$  and  $G = D + E - \mu E$  is consistent with equilibrium. The bond return is determined by (11). A default with certainty therefore implies that  $R \rightarrow \infty$  is indeed justified. Since  $R' \rightarrow \infty$ , the bank prefers to hold a combination of loans and bonds with  $L = \mu E$  and  $G = D + E - \mu E$ . The 'good' equilibrium exists whenever there exists a bond return  $R \in (1, R_2)$  such that  $F[\hat{A}_{|L=\mu E}(R)] < 1 - \frac{1}{R}$ : Since  $F[\hat{A}_{|L=\mu E}(1)] \geq 0 = 1 - \frac{1}{1}$ , the continuity<sup>30</sup> of  $F(A)$  and  $\hat{A}_{|L=\mu E}(R)$ , which also means that  $F[\hat{A}_{|L=\mu E}(R)]$  is increasing in  $R$ , ensures that the 'good' equilibrium with  $R_g \leq R$  exists. Note that the equilibrium asset allocation  $L = \mu E$  and  $G = D + E - \mu E$  is ensured by the additional condition (44) which implies  $\hat{A} = \hat{A}_{|L=\mu E}$  and that the existence of  $R$  is sufficient for the existence of the equilibrium. *Q.E.D.*

**Proof of Corollary 3:** The system (11) and (37) jointly determines  $\hat{A}$  and  $R$ . Since  $R < R'$  in the 'good' equilibrium, the system is

$$J^1 = \hat{A} - \frac{D - R(D + E - \mu E)}{\mu E} - \max \left\{ \frac{BR - \tau(D + W_2)}{\mu E}, \frac{BR - \tau(D + W_2)}{\bar{\tau} \mu E} \right\} = 0$$

$$J^2 = [1 - F(\hat{A})]R - 1 = 0$$

Provided that in equilibrium  $R \leq R_0$ , the Jacobian matrix is

$$J = \begin{bmatrix} 1 & -\frac{(1-\omega)B}{\mu E} \\ -f(\hat{A})R & 1 - F(\hat{A}) \end{bmatrix}$$

<sup>30</sup>Note that  $\hat{A}_{|L=\mu E}(R)$  has two kinks at  $R = R_0$  and  $R = R_2$  but no jumps.

The Jacobian determinant is

$$\nabla = 1 - F(\hat{A}) - \frac{f(\hat{A})(1 - \omega)BR}{\mu E} > 0$$

The sign of the Jacobian determinant again follows from the property of the 'good' equilibrium that the bond pricing curve is steeper than the default threshold (i.e.,  $1/R^2 > f(\hat{A})d\hat{A}/dR$ ). Substituting  $1 - F(\hat{A}) = 1/R$  implies  $\nabla > 0$  such that Cramer's rule yields:

$$\begin{aligned} \frac{\partial R}{\partial B} &= \frac{1}{\nabla} \frac{f(\hat{A})R^2}{\mu E} > 0, & \frac{\partial \hat{A}}{\partial B} &= \frac{1}{\nabla} \frac{(1 - F(\hat{A}))R}{\mu E} > 0 \\ \frac{\partial R}{\partial \bar{\tau}} &= -\frac{1}{\nabla} \frac{f(\hat{A})R(D + W_2)}{\mu E} < 0, & \frac{\partial \hat{A}}{\partial \bar{\tau}} &= -\frac{1}{\nabla} \frac{(1 - F(\hat{A}))(D + W_2)}{\mu E} < 0 \\ \frac{\partial R}{\partial \mu} &= \frac{1}{\nabla} \frac{f(\hat{A})R[R(D + E) - D - (BR - \bar{\tau}(W_2 + D))]}{\mu^2 E} > 0 \\ \frac{\partial \hat{A}}{\partial \mu} &= \frac{1}{\nabla} \frac{(1 - F(\hat{A}))[R(D + E) - D - (BR - \bar{\tau}(W_2 + D))]}{\mu^2 E} > 0 \end{aligned}$$

If in equilibrium  $R > R_0$ , the Jacobian matrix is

$$J = \begin{bmatrix} 1 & -\frac{(1 - \omega\bar{\tau})B}{\bar{\tau}\mu E} \\ -f(\hat{A})R & 1 - F(\hat{A}) \end{bmatrix}$$

By the same argument as above, it can be shown that the Jacobian determinant is positive:

$$\nabla = 1 - F(\hat{A}) - \frac{f(\hat{A})(1 - \omega\bar{\tau})BR}{\bar{\tau}\mu E} > 0$$

Using Cramer's rule yields:

$$\begin{aligned} \frac{\partial R}{\partial B} &= \frac{1}{\nabla} \frac{f(\hat{A})R^2}{\bar{\tau}\mu E} > 0, & \frac{\partial \hat{A}}{\partial B} &= \frac{1}{\nabla} \frac{(1 - F(\hat{A}))R}{\bar{\tau}\mu E} > 0 \\ \frac{\partial R}{\partial \bar{\tau}} &= -\frac{1}{\nabla} \frac{f(\hat{A})R(D + W_2)}{\bar{\tau}\mu E} < 0, & \frac{\partial \hat{A}}{\partial \bar{\tau}} &= -\frac{1}{\nabla} \frac{(1 - F(\hat{A}))(D + W_2)}{\bar{\tau}\mu E} < 0 \\ \frac{\partial R}{\partial \mu} &= \frac{1}{\nabla} \frac{f(\hat{A})R[\bar{\tau}W_2 - R(B - \bar{\tau}(D + E))]}{\bar{\tau}\mu^2 E}, & \frac{\partial \hat{A}}{\partial \mu} &= \frac{1}{\nabla} \frac{(1 - F(\hat{A}))[\bar{\tau}W_2 - R(B - \bar{\tau}(D + E))]}{\bar{\tau}\mu^2 E} \end{aligned}$$

The sensitivities  $\frac{\partial R}{\partial \mu}$  and  $\frac{\partial \hat{A}}{\partial \mu}$  are positive as long as  $\bar{\tau}[R(D + E) + W_2] > BR$  or, equivalently,  $R < \frac{\bar{\tau}W_2}{B - \bar{\tau}(D + E)}$ .<sup>31</sup> Rearranging yields  $\hat{A} < R$ , that is, as long as the sovereign default threshold is smaller than the equilibrium bond return, sovereign risk increases in the regulatory multiplier. As soon as  $\hat{A} > R$ , sovereign risk decreases in the multiplier. The signs of the sensitivities in corollary 3 then follow from  $p = F(\hat{A})$ . *Q.E.D.*

<sup>31</sup>Note that  $R_0 < \frac{\bar{\tau}W_2}{B - \bar{\tau}(D + E)}$  such that a positive sign of these sensitivities is, in principle, feasible if the equilibrium bond return exceeds  $R_0$ .

**Proof of Corollary 4:** If  $R \leq R_0$  in equilibrium,  $A^* = \frac{D-R(D+E-\mu E)}{\mu E}$  with partial derivatives:

$$\begin{aligned}\frac{\partial A^*}{\partial B} &= -\frac{D+E-\mu E}{\mu E} \frac{\partial R}{\partial B} < 0 \\ \frac{\partial A^*}{\partial \bar{\tau}} &= -\frac{D+E-\mu E}{\mu E} \frac{\partial R}{\partial \bar{\tau}} > 0 \\ \frac{\partial A^*}{\partial \mu} &= \frac{R(D+E)-D}{\mu^2 E} - \frac{D+E-\mu E}{\mu E} \frac{\partial R}{\partial \mu}\end{aligned}$$

The signs of  $\frac{\partial A^*}{\partial B}$  and  $\frac{\partial A^*}{\partial \bar{\tau}}$  follow directly from the sensitivities of  $R$  summarized in corollary 3. The sign of  $\frac{\partial A^*}{\partial \mu}$  is unclear given that  $R$  increases in  $\mu$ . If  $R \in (R_0, R_1)$ , the bank and sovereign default threshold coincide such that  $\frac{\partial A^*}{\partial B} > 0$  and  $\frac{\partial A^*}{\partial \bar{\tau}} < 0$  and  $\frac{\partial A^*}{\partial \mu}$  is ambiguous. If  $R \geq R_1$ ,  $A^* = \frac{D}{\mu E}$  is independent of the bond return, which implies that  $\frac{\partial A^*}{\partial B} = \frac{\partial A^*}{\partial \bar{\tau}} = 0$  and  $\frac{\partial A^*}{\partial \mu} < 0$ . *Q.E.D.*

## 4.A.2 Summary

	(1)	(2)	(3)
Outcome	Banks less stable than government ( $A^* \geq \hat{A}$ )	Banks more stable than government ( $A^* \leq \hat{A}$ )	Banks equally stable than government ( $A^* = \hat{A}$ )
Bond return	$R \leq R_0$	$R \geq R_1$	$R \in (R_0, R_1)$
Channel of bank-sovereign contagion	Deposit Insurance Cost	Taxation	Taxation
Adverse feedback	None	Sovereign default weakens banks	Sovereign default triggers bank failure
Equilibrium type	'Good'	'Good', 'bad'	'Good', 'bad'
Existence in baseline model	Yes	Yes	No (requires sov. bond holdings)
Existence under cap. regulation	Yes	Yes	Yes

Table 1: *Overview: Three Scenarios*





## Curriculum Vitae

Born on February 7, 1988 in Luzern, Switzerland

### Education

Sept. 2007 - Sept. 2016: University of St. Gallen

Feb. 2012 - Sept. 2016: Ph.D. in Economics and Finance

Dissertation: *Essays on the Regulation and Taxation of Banks*

Thesis Committee: Christian Keuschnigg (St. Gallen),

Gyöngyi Lóránth (Vienna), Reto Föllmi (St. Gallen)

Sept. 2010 - Mar. 2012: M.A. in Economics

Master's Thesis: *Investment, Finance and the Labor Market*

Sept. 2007 - Mar. 2011: B.A. in Economics

Aug. 2001 - June 2007: Kantonsschule Alpenquai Luzern (June 2007: Matura)

### Employment

Since Jan. 2012: University of St.Gallen, Institute of Economics (FGN-HSG)

Since Jan. 2012: Research Assistant (Chair Prof. Dr. Christian Keuschnigg)

Since Feb. 2013: Teaching Assistant for Economics

### Conferences and Seminars

Swiss Institute of Banking and Finance, Brown Bag Seminar 03/13, Ruhr Graduate School of Economics, 7th Doctoral Conference in Economics, Dortmund 02/14, Warsaw International Economic Meeting (WIEM) 07/14, Ruhr Graduate School of Economics, 8th Doctoral Conference in Economics, Essen 02/15, Oxford University - Centre of Business Taxation, Doctoral Meeting, Oxford 09/15, RES Annual Conference, Brighton 03/16, EFMA 25th Annual Conference, Basel 06/16, Ifo Institute, Public Economics Research Seminar, Munich 07/16