Bankers' Bonuses and Biased Beliefs: Three Essays on Risk-Taking under Limited Liability

Daniel Gietl

Munich 2019

Bankers' Bonuses and Biased Beliefs: Three Essays on Risk-Taking under Limited Liability

Daniel Gietl

Inaugural-Dissertation
zur Erlangung des Grades
Doctor oeconomiae publicae (Dr. oec. publ.)

an der Volkswirtschaftlichen Fakultät der
Ludwig-Maximilians-Universität München

vorgelegt von
Daniel Gietl

2019

Referent: Prof. Dr. Andreas Haufler

Korreferent: Prof. Dr. Florian Englmaier

Promotionsabschlussberatung: 24. Juli 2019

Berichterstatter: Prof. Dr. Andreas Haufler, Prof. Dr. Florian Englmaier und Prof. Dr. Dominika Langenmayr

Datum der mündlichen Prüfung: 15. Juli 2019

Acknowledgements

First and foremost, I want to thank my supervisor, Andreas Haufler. As a co-author of my first chapter, he provided me with a jump start into theoretical research that shaped my economic and analytical thinking. Since then, his open door policy allowed me to seek his valuable guidance and help whenever I needed it. Thank you for your insightful and constructive comments that have benefited all parts of this thesis, and for the great work atmosphere at the Seminar for Economic Policy. I am also grateful to my second advisor, Florian Englmaier, for his valuable comments that improved, in particular, my single-authored paper. Moreover, I want to thank Dominika Langenmayr for taking the time and joining my thesis commitee.

Thanks also go to my co-authors of the third chapter, Ciril Bosch-Rosa and Frank Heinemann. The work with Ciril and Frank was always exciting and I am thankful that they taught me a lot about experimental economics in the process. With respect to the third project, I am especially grateful to Ulrich Glogowsky for his altruistic support. He invested a lot of time discussing the project with me, provided great ideas, and constructive comments.

Many colleagues and friends enriched my life at the chair. Thanks go to Florian Loipersberger for being a fun and inspiring office mate despite his daily S-Bahn troubles, and to Franz Reiter for his never-ending ironic comments. I will fondly remember the many interesting discussions with Tobias Hauck and Renate Schwirtz (and her inspiring love for economic research) as well as the great times spent with Ulrich Glogowsky, Ulf Maier, Miriam Müting, Hirofumi Okoshi, and Davide Suverato. I am very thankful to Renate Schwirtz and André Schreiber for their great expertise and readiness to help regarding all kinds of administrative tasks. Special thanks go to the research assistants Grete Bukauskaite, Lucas Coronel, Lisa Essbaumer, Bernhard Kassner, and Theresa Koch, who all added to the productive and nice working atmosphere at the chair.

My time at LMU Munich would not have been the same without all the coffee breaks and extracurricular activities. Thank you Miriam Breckner, Carsten Feuerbaum, Stefan Grimm, Sebastian Horn, Felix Klimm, Marie Lechler, Jakub Rybicki, Susanne Wildgruber, and many others for the great moments and memories. I also want to thank the German Research Foundation (DFG) for the generous financial support, which – among other things – enabled me to present at many interesting conferences. I am also grateful to the library of the European University Institute at Badia Fiesolana in Florence. A substantial part of this thesis has been written there with the indefatigable support of the local baristas.

Last but not least, I would like to give special thanks to my family. I am grateful to my sister Katja, my brother Christoph, and Sissi for the nice weekends and holidays we shared in Wiesenbach. Thank you, Maria and Heinrich, for always being there for me. Your support is invaluable. My greatest gratitude goes to Nona. Writing a dissertation is not always easy. You helped me to rediscover optimism and motivation in bad times, and made the good times all the better. Thank you.

Daniel Gietl

Munich, March 2019

To my parents

Contents

List of Figures

List of Tables

Introduction and Summary

When a business firm fails, stakeholders face direct negative consequences and the firm is usually quickly resolved. When a systemically important financial institution is close to bankruptcy, however, things are often a little different. Just as the investment bank Bear Stearns was on the brink of default in 2008, the Federal Reserve of New York agreed to take on up to \$30 billion worth of its assets. While this bailout has led to public resentment and criticism, Ben Bernanke (2008a) stated that this intervention was imperative. He argued that a bankruptcy of Bear Stearns would have troubled other financial institutions and "the adverse impact of a default would not have been confined to the financial system but would have been felt broadly in the real economy through its effects on asset values and credit availability" (Bernanke, 2008b).

Indeed, the financial crisis of 2007 - 2009 has made us aware of the negative externalities that an ailing financial sector imposes on the real economy. The crisis worsened the credit conditions for corporate borrowers, reduced consumer lending, and lowered investments in the real sector (Campello et al., 2011; Gorton and Metrick, 2012; Santos, 2011). In the United States alone, nearly 9 million jobs were lost during 2008 and 2009 (Greenbaum et al., 2015). The loss of total wealth in the United States is estimated to amount to \$15 - \$30 trillion, which corresponds to 100% - 190% of 2007 U.S. GDP (Atkinson et al., 2013).

The large collateral damage caused by failures of systemically important financial institutions can force governments to bail out these corporations. The fiscal costs of helping troubled banks in the financial crisis amounted to roughly 4.5 % of GDP in the United States, 8.8% of GDP in the United Kingdom, and 3.9% of GDP in the Euro Area (Laeven and Valencia, 2012). In the United States, for example, substantial amounts of taxpayer money have been spent on large financial institutions via the Troubled Asset Relief Program, the bailouts of AIG, Fannie Mae, and Freddie Mac, and several subsidies that assisted private acquisitions of ailing banks (DeYoung et al., 2013). In addition to these implicit guarantees that arise from the expectation to receive government assistance in case of failure, banks also obtain explicit guarantees in the form of deposit insurances. Deposit insurance schemes exist in virtually all developed countries (see Barth et al., 2006, for an overview) and aim to rule out socially harmful bank run equilibria (cf. Diamond and Dybvig, 1983). The implicit and explicit government guarantees erode market discipline as bank creditors' incentives to price in banks' risk-taking are weakened. This leads to a situation where shareholders of protected banks have an incentive to induce their employees to take on socially excessive risks.

Indeed, one of the potential reasons for the recent financial crisis is that steep incentive schemes caused bankers to engage in overly risky investments.[1] Following the Financial Services Modernization Act of 1999, contractual risk-taking incentives in U.S. commercial banks increased substantially in the early 2000s (DeYoung et al., 2013).[2] Moreover, empirical evidence illustrates that pre-crisis risk-taking incentives in the U.S. (Bhagat and Bolton, 2014) and several European countries (Efing et al., 2015) contributed to excessive risk-taking in the banking sector. Efing et al. (2015) show that bankers' bonuses were too high to maximize the net present value of trading income, indicating that shareholders have aimed to capitalize on their limited liability.[3]

In the wake of the financial crisis, bankers' bonuses have not only caught the eye of researchers but also received increased media attention. Banker pay became a source of public resentment as the very bankers that governed troubled financial institutions received large paychecks while the economy plummeted. In the year 2008, nine U.S. banks which received government aid (including Goldman Sachs and Citigroup) paid

[1] The manyfold causes of the financial crisis are discussed in Thakor (2015).

[2] The Financial Services Modernization Act of 1999 (also known as the Gramm-Leach-Bliley Act) repealed parts of the Glass-Steagall Act of 1933. Among other things, it allowed commercial banks and investment banks to consolidate.

[3] In addition to these efficiency issues, the economics literature has recently shown that bankers' bonuses play a significant role in the rising inequality of incomes in many developed countries. For example, the increase in bankers' bonuses accounts for two-thirds of the rise in the share of the top 1% of the income distribution in the United Kingdom since 1999 (Bell and Van Reenen, 2014). More generally, Boustanifar et al. (2017) show that wages in the financial sector contribute to the growing wedge between the wages of skilled and unskilled workers in many developed economies. Relative to its size in employment, finance contributes overproportionately to the skill premium and is thus a driver of inequality.

out a total of \$32.6 billion in bonuses (Wall Street Journal, 2009a). Banker pay became subject of a lively – and at times populist – public debate, which featured several heads of state questioning whether the size of bankers' bonuses is economically and morally justifiable.[4] Barack Obama, for example, proclaimed: "I did not run for office to be helping out a bunch of fat cat bankers on Wall Street. [...] They're still puzzled why is it that people are mad at the banks. Well, let's see. You guys are drawing down 10, 20 million dollar bonuses after America went through the worst economic year that it's gone through in decades, and you guys caused the problem" (Wall Street Journal, 2009b).

In order to appease the public and to tackle the efficiency concerns related to bankers' compensation, many countries have intervened into banker pay. The European Union has introduced a bonus cap, which, as of 2014, limits the ratio of variable to fixed pay for senior bankers to 100% (200% with shareholder approval). The United States have implemented say-on-pay rules for executive compensation and golden parachutes.[5] The United Kingdom has imposed that at least 40% of the variable pay of material risk takers has to be deferred for a minimum of three years. In addition, the U.K. also instituted clawback rules that can reach back up to one decade. Besides these regulatory interventions into banker pay, several countries have introduced banker bonus taxation.[6] For example, the United Kingdom imposed, for the tax year 2009/2010, a 50% levy on banker bonuses exceeding £25,000.[7] A similar temporary tax of 50% on bonuses exceeding €27,500 was implemented in France in 2010.

[4] In 2009, Angela Merkel stated that "(i)t is incomprehensible that banks helped out by the state in many cases pay out huge sums in bonuses" (Spiegel, 2009). David Cameron declared at an EU summit that "(b)ankers have to realise that the British public helped to bail out the banks and it is very galling when they see bankers pay themselves unjustified bonuses. The banks have got to think about their social responsibilities" (BBC, 2010).

[5] In 2016, U.S. president Barack Obama was urging regulators to finalize rules on restricting bankers' bonuses, which included bonus deferrals and clawbacks. The efforts to finish these rules, however, came to a halt under the Trump administration (Wall Street Journal, 2017).

[6] Since April 2010, Greece charges a tax rate between 50% and 90% on bank executives' bonuses. In January 2011, Ireland adopted a 90% tax on executives' bonuses in banks that obtained government support. Since May 2010, Italy levies a 10% bonus tax for the banking sector if variable pay is more than three times as high as fixed compensation.

[7] von Ehrlich and Radulescu (2017) show that this temporary tax reduced net cash bonuses, but neither affected total compensation nor banks' risk-taking.

While many governments taxed and regulated banker compensation after the crisis, we actually know surprisingly little about how to optimally intervene into banker pay. This dissertation aims to shed light on this issue. To do so, Chapter 1 and 2 incorporate recent empirical evidence on banker characteristics into principal-agent models of the banking industry, and Chapter 3 provides empirical evidence on individual risk-taking. More precisely, Chapter 1 sets up a model that investigates the international competition in bonus taxation when bankers are mobile across countries. Chapter 2 analyzes theoretically how regulation and bonus taxation have to adapt when bankers are not fully rational but overconfident. Chapter 3 experimentally tests how individual risk-taking responds to the incentives provided by limited liability and investigates the role of motivated beliefs for risk-taking.

Chapter 2 and 3 thus both analyze biased beliefs – a potential driver of excessive risk-taking in the build-up to the financial crisis. Managerial overconfidence, which is analyzed in Chapter 2, has been shown to increase banks' pre-crisis risk-taking behavior (Ma, 2015; Niu, 2010; Ho et al., 2016) and lately also caught the attention of regulators.[8] Additionally, a recent literature argues that motivated beliefs contributed to excessive pre-crisis risk-taking. Bankers may have manipulated their beliefs about excessively risky investments prior to the financial crisis in order to keep a positive self-image. Motivated beliefs, which we investigate in Chapter 3, are thus a potential explanation why bankers built up a large exposure to subprime loans and subprime-linked securities in the pre-crisis period (Barberis, 2013).

At the core of all three chapters are the risk-taking incentives in the presence of limited liability. In the first two chapters, the banks' limited liability interacts crucially with government guarantees. These guarantees mitigate the bank creditors' incentives to price in the risk-taking of banks. As banks are not fully liable in case of failure, the government guarantees thus create an incentive for banks to shift downside risks to the government. The banks' risk-shifting incentives are then reflected in the bankers' contracts, which are too steep relative to the social optimum. In Chapter 3, we focus on how risk-taking decisions are affected when an individual, rather than a bank, is only partly liable for his actions. To do so, we exogenously vary the degree of liability in different contexts of our experiment and investigate the implications of limited liability

[8] Andrew Bailey, the CEO of the Financial Conduct Authority, stated: "We talk often about credit risk, market risk, liquidity risk, conduct risk in its several forms. You can add to that, hubris risk, the risk of blinding overconfidence" (Guardian, 2016).

for subjects' beliefs and investment behaviour.

In the following, I will briefly put the single chapters into the context of the broader literature, and outline an overview of the lines of argument and the results found in each chapter. All chapters are based on stand-alone papers and can be read independently.

Chapter 1: Bonus Taxes and International Competition for Bank Managers

Chapter 1 builds upon the empirical evidence that bankers are internationally mobile (Greve et al., 2009, 2015; Staples, 2008). High wages in finance attract skilled workers across borders (Boustanifar et al., 2017) and highly skilled workers are likely to move countries when they face high income taxes (Kleven et al., 2014). Yet, almost all theoretical papers related to the taxation and regulation of bankers' bonuses use a closed-economy framework.[9] Hence, we know very little about how the international mobility of bankers affects the compensation contracts set by banks, and how governments' incentives change when bankers' location reacts to interventions into banker pay.

In Chapter 1 of this thesis, Prof. Dr. Andreas Haufler (University of Munich) and I aim to fill this gap. We analyze the international competition in bonus taxation when banks compensate their managers by means of fixed and incentive pay and bankers are internationally mobile. In the model, banks endogenously choose bonus payments that induce excessive managerial risk-taking to maximize their private benefits of existing government bailout guarantees. In this setting the international competition in bonus taxes may feature a 'race to the bottom' or a 'race to the top', depending on whether bankers are a source of net positive tax revenue or inflict net fiscal losses on taxpayers as a result of incentive pay.[10] A 'race to the top' becomes more likely when governments

[9] To the best of my knowledge, Radulescu (2012) is the only exception. This paper, however, is not directly applicable to the banking industry and its optimal regulation. The paper does neither incorporate risk-taking nor government guarantees, and it assumes bonus taxation and regulation to be exogeneous.

[10] A 'race to the bottom' constitutes a situation in which the equilibrium bonus taxes chosen by non-cooperating governments are lower than the equilibrium bonus taxes chosen by cooperating governments. In the case of a 'race to the top', the bonus taxes in the competitive equilibrium exceed the cooperatively set bonus taxes.

impose only lax capital requirements on banks, whereas a 'race to the bottom' is more likely when bank losses are partly collectivized in a banking union.

The analysis in Chapter 1 thus contributes to the literature investigating the effects of public policies towards bonus pay. This literature has, for example, investigated how to optimally set bonus taxes (Besley and Ghatak, 2013), bonus caps (Hakenes and Schnabel, 2014), and clawback rules (Thanassoulis and Tanaka, 2018) in the presence of government guarantees.[11] While all these papers investigate public policies towards banker compensation in a closed-economy setup, we add to this literature by analyzing an open-economy framework. Chapter 1 also relates to the research on income tax competition in the presence of mobile high-income earners (see e.g. Lehmann et al., 2014; Simula and Trannoy, 2010). This strand of literature shows that policy competition in general leads to a 'race to the bottom' in income taxation for highly skilled individuals. We illustrate, however, that the direction of tax competition may change when the competition is for bankers, who may inflict fiscal losses on their home governments through overly risky investment choices. Chapter 1 is a marginally edited version of Gietl and Haufler (2018), which is published in the *European Economic Review*.

Chapter 2: Overconfidence and Bailouts

Chapter 2 builds upon empirical findings in the psychology and behavioral finance literature that investigate the effects of managerial overconfidence. Overconfident managers overestimate the expected return on risky investments, which induces them to take on more risk (see e.g. Hirshleifer et al., 2012; Malmendier and Tate, 2008). Banks with overconfident CEOs have shown greater stock price volatility (Niu, 2010) and higher real estate loan growth (Ma, 2015) prior to the financial crisis of 2007 - 2009. During the crisis years they experienced larger declines of stock return performances and a higher likelihood of failure compared to banks governed by non-overconfident

[11] Hakenes and Schnabel (2014) show that banker bonus caps are welfare-maximizing when bailout expectations are sufficiently large, because the caps are able to curb socially excessive risk-taking. Besley and Ghatak (2013) derive the optimal taxation of bonus pay when bankers endogeneously choose effort and risk-taking. They find that the optimal bonus taxation is progressive in the level of government guarantees that a bank receives. Thanassoulis and Tanaka (2018) show that a combination of clawback rules and restrictions on the curvature of pay can tackle the risk-shifting incentives arising from government guarantees.

CEOs (Ho et al., 2016). Despite the prevalence and importance of managerial overconfidence, however, it is not clear how taxation and regulation of banker pay should be adjusted when bankers are not fully rational but overconfident.

I shed light on this issue by incorporating managerial overconfidence and limited liability into a principal-agent model of the banking industry. As in Chapter 1, I assume that banks receive government guarantees in case of default. The second key component of the analysis is managerial overconfidence. As overconfident agents overestimate their skills and talents, overconfidence is modelled as an overestimation of the returns to effort and risk-taking. Chapter 2 delivers three main results. First, I find that managerial overconfidence necessitates an intervention into banker pay. This is due to the bank's exploitation of the manager's overvaluation of bonuses, which causes excessive risk-taking in equilibrium. Second, I show that the optimal bonus tax always rises in overconfidence, if risk-shifting incentives are sufficiently large. Finally, I find that overconfident managers match according to the regulatory environment faced by banks, and are more likely to be found in banks with large government guarantees, low bonus taxes, and lax capital requirements.

Chapter 2 relates to three main bodies of research. First, it contributes to the literature on the effects of public policies towards banker pay by investigating how managerial overconfidence affects the optimal taxation and regulation of bonuses. Second, Chapter 2 relates to the burgeoning literature on the effects of managerial overconfidence (see Malmendier and Tate, 2015, for an overview). Many papers have investigated the positive (e.g. Englmaier, 2010) and negative (e.g. Malmendier and Tate, 2008) aspects of managerial overconfidence. While this literature focuses on the impact of overconfidence on corporate outcomes, Chapter 2 shows how managerial overconfidence relates to government policies. Third, the analysis contributes to the literature investigating the matching between overconfident managers and firms. Gervais et al. (2011) show theoretically that overconfident managers match with risky, undiversified growth firms in equilibrium. Hirshleifer et al. (2012) provide empirical evidence that firms in innovative industries are more likely to be governed by overconfident CEOs. The findings in Chapter 2 suggest that the matching with overconfident managers is also influenced by government instruments and regulatory policies. Chapter 2 is a marginally edited version of the CRC TRR 190 Discussion Paper Gietl (2018).

Chapter 3: Risk-Taking under Limited Liability – The Role of Motivated Beliefs

Chapter 3 investigates the role of motivated beliefs for risk-taking under limited liability. A broad theoretical and empirical literature (e.g. Bénabou, 2015; Dana et al., 2007) suggests that "people often act as 'motivated Bayesians' - while they gather and process information before and during the decision-making process, they tend to do so in a way that is predictably biased toward helping them to feel that their behavior is moral, honest, or fair, while still pursuing their self-interest" (Gino et al., 2016). These self-serving judgements have also been discussed as a possible driver of excessive risk-taking in the banking industry. Besides bad incentives and faulty risk models, motivated beliefs are a possible reason why bankers built up large exposure to risky subprime assets in the pre-crisis period (Barberis, 2013).

Together with PhD Ciril Bosch-Rosa (Colegio Universitario de Estudios Financieros and Technical University of Berlin) and Prof. Dr. Frank Heinemann (Technical University of Berlin), we set up a laboratory experiment to test whether limited liability affects risk-taking through motivated beliefs. In the experiment, subjects - who we henceforth call "investors" - receive a noisy signal which indicates whether a risky asset will be successful and return a gain, or fail and realize a loss. Given the noisy signal, subjects form subjective beliefs about the success probability of the risky asset and decide how much to invest in it. Between three treatments (*Baseline*, *Matched*, *Diffusion*), we vary how losses are distributed among subjects. In *Baseline*, the investor bears all losses, while in the limited liability treatments (*Matched* and *Diffusion*) the investor only covers 25% of all losses. The other 75% of losses are borne by a single passive subject (*Matched*) or split up equally among many passive subjects (*Diffusion*).

We find that investors invest significantly more in both limited liability treatments than in the *Baseline* treatment. More importantly, using a mediator analysis (Imai et al., 2011, 2013) we isolate the causal effect of limited liability that works through the shift in beliefs from all other effects of limited liability (e.g. the direct effect of changed incentives). We show that the motivated beliefs caused by limited liability have a positive and statistically significant effect on risk-taking. For a given signal, investors evaluate a higher expected success probability for investments under limited liability, and these motivated beliefs lead to higher investments in the limited liability treatments. Additionally, we compare the two limited liability treatments, *Matched* and *Diffusion*. Here we hypothesize that risk-taking in *Diffusion* might be higher, as the concerns for the agents covering the losses get diluted, so that an individual passive subject is not heavily affected by the banker's decision. Yet, we find the investment levels of investors to be similar in both treatments and cannot reject the null hypothesis that they are indeed identical.

Chapter 3 relates to two main bodies of research. The first one investigates the role of risk-taking on behalf of others (see Eriksen et al., 2017, for an overview). Most closely we relate to the experiments in this literature that involve substantial monetary conflicts between investors and other subjects (Andersson et al., 2013; Ahrens and Bosch-Rosa, 2018). We add to this line of research by investigating how motivated beliefs as well as diffused liability affect the risk-taking on behalf of others. A second important strand of literature studies moral reasoning and motivated beliefs (Hastorf and Cantril, 1954; Messick and Sentis, 1979; Kunda, 1990). In many decisions, individuals face a trade-off between personal benefits and feeling moral. There is substantial empirical evidence that individuals resolve this trade-off by using self-serving judgements and beliefs in order to act selfishly while maintaining a positive self-image (see Gino et al., 2016, for an overview). We contribute to this literature by showing that motivated beliefs are a driver of risk-taking under limited liability.

Chapter 1

Bonus Taxes and International Competition for Bank Managers[1]

1.1 Introduction

Bankers' bonuses have been the cause of much debate, and resentment, in recent years. Steep incentive schemes for bank managers have been identified as one of the root causes for the global financial crisis of 2008, as bonuses are believed to be responsible for excessive risk-taking in the banking sector.[2] Empirical studies confirm that incentive pay has been positively correlated with risk-taking in the pre-crisis period (Bhagat and Bolton, 2014). Moreover, there is evidence that the bonus incentives offered by banks in the pre-crisis period have been too strong to be compatible with the risk-adjusted maximization of banks' asset values, suggesting that shareholders have exploited their limited liability (Efing et al., 2015). Against this background, taxing banks' bonus payments promises a twofold return to governments. It ensures some contribution of the banking sector to the fiscal costs of bailouts that occurred during the crisis (International Monetary Fund, 2010), and it provides a Pigouvian mechanism to correct the incentives for overly high risk-taking that result from limited liability in the financial sector.[3]

[1]This chapter is based on joint work with Andreas Haufler (Gietl and Haufler, 2018).

[2]See e.g. Alan Blinder's commentary "Crazy compensation and the crisis" (Wall Street Journal, 2009c).

[3]A further political economy argument for taxing bonuses arises from the high total compensation of bank managers. Bell and Van Reenen (2014) estimate that rising bonuses paid to bankers

In the immediate aftermath of the financial crisis, several countries have indeed introduced bonus taxes. The UK introduced a one-time 50% withholding tax on banker bonuses that exceeded GBP 25,000 and were paid between December 2009 and April 2010.[4] France followed with a similar, temporary bonus tax of 50% in 2010. In the United States, the House of Representatives approved, in 2009, a 90% bonus tax for institutions that were saved with taxpayer money, but this bill was blocked in the U.S. Senate. Since 2010, Italy levies a permanent, 10% additional bonus tax for the banking sector, if variable compensation exceeds three times the fixed salary. In parallel to these national bonus taxes, the European Union has introduced, as of 2014, a regulation that limits bonuses paid to high-level managers in the financial sector to 100% of their fixed salary (200% with shareholder approval).

Given the massive side effects of bonuses in the pre-crisis period, it is surprising, however, that bonus taxation has not become more common, or more persistent. One critical argument for why bankers' bonuses are not taxed more is that top bankers might leave a country that taxes their bonuses severely, and work instead for a bank abroad. Indeed, there is ample evidence that bank managers are mobile across countries. The largest German bank, the Deutsche Bank, for example, has been consecutively governed by three non-German CEOs from 2002-2018.[5] More generally, there is a substantial literature indicating that the international mobility of top managers has grown substantially over the past two decades (e.g. Greve et al., 2015). Focusing specifically on the finance industry, Greve et al. (2009) investigate the nationality of board executives in 41 large European firms in the banking and insurance industry and find that 26% of all executives in the sample are non-nationals. Similarly, Staples (2008) finds that among the 48 largest commercial banks in the world close to 70% have at least one non-national board member.

account for two-thirds of the increase in the share of the top 1% of the income distribution in the United Kingdom since 1999. For the United States, Philippon and Reshef (2012) find that, from the mid-1990s to 2006, chief executive officers (CEOs) in the finance industry have earned a 250% premium relative to CEOs in other sectors of the economy.

[4] The UK bonus tax has been empirically analyzed by von Ehrlich and Radulescu (2017). The authors find that the introduction of the bonus tax has led to a 40% fall in bonus payments. However, other components of executive pay have simultaneously been raised so as to largely compensate bank managers for the reduction in their bonuses.

[5] The CEOs were Josef Ackermann (Switzerland, 2002-2012), Anshuman Jain (UK, 2012-2015), and John Cryan (UK, 2015-2018).

Despite the conclusive evidence for the international mobility of bank managers, almost all theoretical papers investigating the impact of banker bonus taxation and regulation use a closed-economy framework (see our literature review below). In this chapter we aim to fill this gap by analyzing the non-cooperative setting of bonus taxes in a two-country model with one bank in each country and mobility of bankers between the two banks. Our model incorporates governments, banks, and bank managers that all behave optimally, given their incentives. The model has four stages. In Stage 1, the two symmetric countries non-cooperatively set bonus taxes to maximize expected net revenues, which result as the difference between expected bonus tax revenues and the expected costs to taxpayers of bailing out banks in the case of default. In Stage 2, the two banks endogenously choose the managers' compensation structure, which consists of bonus payments and a fixed wage component. The contracts set in this stage determine where managers choose to work in Stage 3. Finally, in Stage 4, bank managers take simultaneous effort and risk-taking decisions in the country in which they work.

At the core of our analysis are two principal-agent problems. The first is between a bank's shareholders and its managers. Managers have private effort and risk-taking costs and thus choose lower effort and less risk-taking than would be optimal for shareholders. Second, there is a principal-agent problem between the banks' shareholders and taxpayers in the bank's home country, if shareholders anticipate that their bank is (partly) bailed out by the government in case of failure. Therefore, shareholders incentivize bank managers to take on "excessive" risk, relative to what would be optimal for the country as a whole. Governments therefore choose bonus taxes for a double reason, to collect tax revenues and to make bonuses a more costly instrument from the bank's perspective. Both banks and governments compete with their respective counterparts in the foreign country.

Our main result is that there can be either a 'race to the bottom' or a 'race to the top' with respect to the bonus taxes chosen in the non-cooperative tax equilibrium. Which result is obtained depends on the *fiscal value* of a bank manager, which equals the expected bonus tax income minus the expected bailout costs for the government. A 'race to the top' is more likely to occur if the risks of bank failures are large, and if taxpayers are heavily exposed to downside risks as a result of low capital requirements for banks. In this case governments regard each banker as a fiscal liability and optimally set bonus taxes in excess of those that are globally optimal, in order to shift risks from domestic to foreign taxpayers. A 'race to the top' becomes less likely when bank profits also enter the government's objective function, or when bailout costs for banks are collectivized. The latter occurs, for example, in the European Union's newly established banking union. Together these results may explain why several countries levied high bonus tax rates in the immediate aftermath of the financial crises, but abolished these taxes later, as the perceived risks to taxpayers fell while bank profits resumed.

Our analysis is related to two strands in the literature. A first strand analyzes the effects of public policies towards bonus schemes.[6] Besley and Ghatak (2013) analyze the optimal bonus taxation of managers when bankers can choose both effort and risk-taking. Hakenes and Schnabel (2014) study how bailout expectations affect both the optimal bonus contract offered by the bank and the imposition of bonus caps by welfare-maximizing governments. Thanassoulis (2012) derives the role of bonus caps in a setting where the competition for bankers increases their compensation, which in turn drives up banks' default risk. All these studies analyze policies towards bonus pay in a closed economy setting. Radulescu (2012) is the only study of bonus taxation in an open economy of which we are aware. This paper does not incorporate risk-taking decisions by bank managers, however, and bonus taxes are exogenous to the model.

A second related literature analyzes policy competition in the presence of cross-country externalities. There is an established literature on international tax competition (see Keen and Konrad, 2013, for a recent survey) that has recently been applied to study non-linear income tax competition in the presence of mobile high-income earners (Simula and Trannoy, 2010; Bierbrauer et al., 2013; Lehmann et al., 2014; Lipatov and Weichenrieder, 2015). These models generally find a 'race to the bottom' in income taxation, as a result of policy competition for mobile individuals.[7] However, the mobile rich take no risks in these models, and they are always a source of positive tax revenue for the competing governments. As we show in this chapter, the direction of tax competition may change when the competition is for bank managers, who may inflict fiscal losses on their home governments through overly risky investment choices.

This chapter is structured as follows. Section 1.2 introduces the basic setup of our

[6]The incentive effects of bonus schemes are themselves the subject of a large literature. See e.g. Bannier et al. (2013) and Acharya et al. (2016) for recent analyses of bonus pay in the competition for managerial talent.

[7]Similar 'race to the bottom' results have been obtained for regulatory policies towards profitable banks that export part of their services to the foreign country. See e.g. Acharya (2003), Sinn (2003) and Dell'Ariccia and Marquez (2006).

analysis. Section 1.3 analyzes the decisions of bank managers. Section 1.4 turns to the banks' choice of optimal managerial compensation. Section 1.5 derives the tax competition equilibrium between the two governments. Section 1.6 analyzes several model extensions and Section 1.7 concludes.

1.2 Model Setup and Roadmap

We consider a region of two symmetric open economies $i \in (1, 2)$. In each of the two countries there is one bank of variable size, where bank size corresponds to the number of identical divisions within the bank. Running a division requires the specific knowledge of a bank manager. Hence each bank employs exactly one manager per division and the number of managers a bank hires equals the number of its divisions.

The banks in our model are financial intermediaries, which collect savings from depositors and invest them into assets.[8] The two banks are fully integrated into world capital markets and, irrespective of their number of divisions, are too small to affect world prices. Hence banks compete in the world capital market to attract deposits and equity, taking both the deposit rate and the cost of equity as exogenously given. Similarly, the two banks engage in risky investments, but they cannot influence the (stochastic) gross returns from these investments.

The banks' investment may be either at home or abroad. In the established terminology of international trade, the banks in our model are thus exporters of financial services. In our benchmark model, we assume that each bank operates only from its home market, and does not set up an affiliate in the respective other country. In the extensions (Section 1.6.3) we lift this restriction and allow banks to engage in foreign direct investment (FDI).[9]

While the two banks are small in world capital markets, they are large players in the regional market for bank managers. This is a plausible setting in a European context, for example, where the market for bank managers is largely a European one, whereas

[8] For brevity and concreteness, we refer to these units as banks, but our model equally applies to non-bank financial institutions. See e.g. Niepmann (2015, p. 249) for a similar approach.

[9] For the example of Germany, Buch et al. (2011, Table 2) document that more than 95% of German banks fall in the category of being exporters of financial services, whereas less than 3% have branches or subsidiaries abroad.

capital market integration is worldwide. The total number of managers in our regional economy is thus fixed, and all managers are employed in one of the two countries in equilibrium. Managers differ in their individual attachment to the two countries and therefore are imperfectly mobile between the two countries. Apart from their location preferences, all managers are identical in our benchmark model.[10] Banks compete for the imperfectly mobile managers by means of a compensation package, which consists of both a bonus payment and a fixed wage. Managerial compensation is chosen so as to maximize the bank's after-tax profits, which is the product of the number of divisions within the bank, and the net expected profit per division.[11]

The bank's portfolio: Each division of a bank in country i has a total amount of fixed assets equal to one, which is lent in the world market. Lending operations are risky. To incorporate meaningful roles of both managerial effort and risk-taking, we assume that there are three possible returns for the bank, which can be high, medium, or low. The portfolio realizes a high return Y^h with probability $p^h > 0$, a medium return $Y^m < Y^h$ with probability $p^m > 0$ and a low return $Y^l = 0$ with probability $p^l = 1 - p^h - p^m > 0$. Since all returns are fixed from the bank's perspective, a bank has constant returns to scale in our setting.

Our specification of a division's return structure follows Besley and Ghatak (2013). Assuming a technology that is separable in risk-taking and effort, the probabilities for the different returns are linear functions of each manager's effort e and risk-taking r:[12]

$$\begin{aligned} p^h &= \alpha e + \beta r, \\ p^m &= p_0^m - r, \\ p^l &= p_0^l - \alpha e + (1-\beta) r, \end{aligned} \tag{1.1}$$

where $p^h + p^m + p^l = p_0^m + p_0^l \equiv 1$. The exogenous 'baseline' probability of a low state, p_0^l, can be interpreted as reflecting general business conditions in the banking sector. With the specification (1.1), a high return Y^h can only be obtained when managers

[10] In the extensions (Section 1.6.4), we analyze the case where managers additionally differ in their location-specific productivities.

[11] An alternative setting would have national banking sectors that consist of a variable number of identical, small banks. In such a setting it is difficult, however, to model a meaningful principal-agent problem between the owner and the manager of each bank.

[12] Since managers are identical, manager-specific indices are omitted from all variables in our benchmark model.

either exert effort or take risk. More generally, the manager's effort e shifts probability mass from p^l to p^h and thereby increases the mean return of the division's portfolio. Risk-taking r instead shifts probability mass from the intermediate state to the high and the low states, thereby increasing the variance of the division's returns.

The manager's remuneration structure: To align the interests of each division manager and the bank's shareholders, the bank in country i pays a bonus, if the return for the bank division is high (Y^h). Beyond the bonus payment, the manager also receives an endogenous wage that is paid independently of the realized return. The bonus payment will induce bank managers to increase both effort and risk-taking, relative to a situation where they receive only the fixed pay. The higher risk-taking will, however, also increase the probability that the low return $Y^l = 0$ occurs. In this case the division fails. For analytical tractability, we assume that the returns of the different divisions of a bank are perfectly correlated. Hence, if one division of a bank fails, so do all the others. Therefore, the bank as a whole fails with probability p^l.[13]

If the bank in country i fails, the external creditors of the bank will be bailed out by country i's government. We take the bank's external funds to be deposits and assume that the share of deposit financing is exogenously fixed, for example by a binding minimum capital requirement. In this case the bailout occurs through deposit insurance, which exists in virtually all developed countries.[14] With these government guarantees, the bank does not face the full cost of failure. It therefore has an incentive to induce excessive risk-taking by its managers, as compared to the social optimum.[15]

[13]If the returns of different divisions were imperfectly correlated, cross-subsidization between divisions within the bank would be possible. In this case a failure for the entire bank would still arise with a positive probability, but this probability would be a complex function of the correlation coefficient, the number of divisions, and the profitability of each division.

[14]Barth et al. (2006) give an overview of deposit insurance schemes around the world, and discuss their benefits and costs. A more detailed model would motivate deposit insurance endogenously in a framework where banks transform illiquid assets into liquid liabilities and liquidity shortages can arise in a bank run equilibrium (Diamond and Dybvig, 1983). We follow the simpler approach that is dominant in the literature on regulatory competition (see e.g. Dell'Ariccia and Marquez, 2006) and take the existence of deposit insurance as exogenously given.

[15]This argument also makes clear why the bank pays a bonus only in the high state. A bonus in the intermediate state m would not change effort and decrease risk-taking, thereby reducing the amount of loss-shifting to taxpayers [see eq. (1.1)]. Hence it would tend to reduce expected profits from the bank's perspective.

Banks are owned by risk-neutral shareholders who choose a remuneration scheme for managers that maximizes total bank profits.[16] By choosing the remuneration scheme, banks simultaneously influence the effort and risk-taking choices of their managers, and try to attract managers from abroad through their overall level of managerial pay. Since effort and risk-taking choices can only be affected by the bonus, this instrument will always be part of the optimal compensation package. Whether the fixed wage will also be used in the bank's optimum then depends on which of the two compensation elements is more cost-effective in attracting additional managers from abroad. We focus here on the more common and more general regime in which both bonuses and fixed wages are optimally used by the banks in equilibrium.[17]

The government: Governments are aware of the moral hazard problem caused by their bailout policies and use bonus taxation to counteract the distorted incentives. Bonus taxes therefore have a corrective role in our setting, in addition to their objective of raising government revenue. In our benchmark model, we assume that the government maximizes its net tax revenue, which is given by total expected bonus tax revenue minus the expected bailout costs.[18] This focus on tax revenue maximization corresponds to the declared objective of many governments to collect a 'fair and substantial contribution' from the financial sector for the fiscal cost this sector has caused during the financial crisis (International Monetary Fund, 2010). More generally, as long as the weight of government tax revenues exceeds that of private sector incomes, a bonus tax dominates the alternative policy instrument of a regulatory cap on bonus payments. This is because the latter has the same corrective role as the bonus tax, but it does not collect tax revenue (cf. Keen, 2011). Therefore, we confine our analysis of policy instruments to a bonus tax.

Finally, we assume that the two governments hosting the banks choose their tax policies non-cooperatively. This implies that governments are subject to similar competitive forces, arising from the international mobility of bank managers, as the national banking sectors are. However, the incentive structures of banks and governments are different. While attracting additional managers is always privately profitable for banks,

[16] Assuming risk neutrality is a frequent assumption in the literature, as shareholders will optimally divide their investment among many activities, and hence diversify their risk.

[17] See our working paper version (Gietl and Haufler, 2017) for an analysis of the case in which only the bonus is paid under the optimized compensation scheme.

[18] This government objective will be generalized in Section 1.6.1 by incorporating bank profits.

governments may lose from an increased size of their national banking sector when the expected bailout costs exceed bonus tax revenue. For analytical tractability, our analysis focuses on fully symmetric countries. The symmetry assumption allows us, in particular, to directly compare the policies chosen under international tax competition to those that are Pareto optimal for the region as a whole.

We structure our analysis as a sequential four-stage game. In the first stage, governments non-cooperatively choose their bonus taxes, anticipating the responses of both banks and their managers to these taxes. In the second stage, banks choose their profit-maximizing remuneration scheme, taking as given the bonus taxes that governments have set in the first stage. In the third stage, managers decide in which country to work, on the basis of the remuneration schemes offered to them by the two banks. Finally, in the fourth stage, managers' choose their levels of effort provision and risk-taking, in the country (and hence bank) of their choice. We thus model a strict hierarchy of decisions where optimizing governments behave as first movers towards banks, whereas banks behave as first-movers vis-à-vis managers. As usual, we proceed by backward induction in order to obtain the subgame perfect Nash equilibrium.

1.3 Decisions of Bank Managers

1.3.1 Effort- and Risk-Taking Choices

In Stage 4, managers choose their effort and risk-taking levels. All managers respond in the same way to a given remuneration scheme. Taking effort and risk involves private, nonmonetary costs for the manager.[19] For analytical tractability, we assume that these cost functions are quadratic and given by $c^e(e) = \eta e^2/2$ and $c^r(r) = \mu r^2/2$. Due to these private costs, managers will neither exert enough effort nor take enough risk from the point of view of bank owners. Effort and risk-taking decisions are not observable. However, bank owners can mitigate the principal-agent problem by a bonus payment z_i in the high return state, which occurs with higher probability p^h when effort and risk-taking are increased.

[19] As in Besley and Ghatak (2013), private costs of risk taking can be seen as the (psychological) costs of seeking out risk-taking opportunities above a 'natural' or benchmark level. This natural risk is here normalized to zero, but it could equally be set at a positive level without affecting any results.

Managers located in country i maximize their location-specific utility u_i, which is the excess of expected bonus and fixed wage payments over the private costs of effort and risk-taking. Using (1.1) gives

$$u_i = p_i^h z_i + w_i - c^e(e_i) - c^r(r_i) = (\alpha e_i + \beta r_i) z_i + w_i - \frac{\eta e_i^2}{2} - \frac{\mu r_i^2}{2}. \tag{1.2}$$

Maximizing (1.2) with respect to the managers' choice variables e_i and r_i yields

$$e_i = \frac{\alpha z_i}{\eta}, \qquad r_i = \frac{\beta z_i}{\mu}. \tag{1.3}$$

Hence the managers' effort level e_i depends positively on the bonus payment z_i, and negatively on the effort cost parameter η. Analogously, the risk choice r_i is increasing in the bonus payment z_i and falling in the risk cost parameter μ. The fixed wage w_i does not affect managers' optimal effort or risk-taking decisions.

Using (1.3) in (1.1), we can derive the equilibrium probabilities of the states $\{h, m, l\}$:

$$p_i^{h*} = \alpha e_i + \beta r_i = \left[\frac{\alpha^2}{\eta} + \frac{\beta^2}{\mu}\right] z_i \equiv \gamma z_i, \tag{1.4}$$

$$p_i^{m*} = p_0^m - \frac{\beta}{\mu} z_i, \tag{1.5}$$

$$p_i^{l*} = p_0^l + \left[\frac{\beta}{\mu} - \gamma\right] z_i \equiv p_0^l + \delta z_i. \tag{1.6}$$

In eq. (1.4), we have introduced the parameter $\gamma > 0$ to summarize the marginal effect of the bonus payment on the probability of a high return. This consists of two effects. A higher bonus leads to more effort and to more risk-taking, which both increase p^h. Similarly, in eq. (1.6) the parameter δ summarizes the marginal effect of the bonus on the low return probability p^l. The sign of δ is ambiguous, in general. On the one hand, a higher bonus leads to more risk-taking, which increases p^l. On the other hand, a higher bonus payment induces more effort and this reduces p^l. In our following analysis we assume that $\delta \geq 0$, implying that the effect of the bonus on managers' risk-taking (weakly) dominates the effect on managerial effort. Thus a higher bonus increases the probability of a low return.[20] Finally, the effect of the bonus on the medium return in (1.5) is unambiguously negative.

[20] Siegert (2014) shows that bonuses may have non-monotonic effects on the probability of managers to choose actions that are detrimental to their employer, with sufficiently high bonuses reducing the probability of managers to 'misbehave'. Empirically, however, higher-powered incentives for bank managers are generally found to be positively correlated with the probability of losses (see e.g. Cheng et al., 2015).

Substituting (1.3) in (1.2) gives the location-specific utilities of managers working in country i. These are increased by both a higher bonus and a higher fixed wage:

$$u_i^* = \left[\frac{\alpha^2}{\eta} + \frac{\beta^2}{\mu}\right] \frac{z_i^2}{2} + w_i \equiv \frac{\gamma z_i^2}{2} + w_i. \tag{1.7}$$

1.3.2 Migration Decision

In Stage 3 managers take the bonuses z_i and fixed wages w_i as given and choose whether to work in country 1 or in country 2. Managers maximize their gross utility, which consists of the location-specific utility in (1.7), and the non-monetary attachment to a particular country. There are a total of $2\bar{N}$ managers in the region, which are all employed in one of the two countries. Hence $N_1 + N_2 = 2\bar{N}$, where N_i is the number of managers working in country i in equilibrium.

Managers differ in their country preferences. More precisely, managers are of type k, where k is the relative attachment to country 1 and we assume that k is distributed uniformly along $[-\bar{N}, +\bar{N}]$. Other things equal, all managers with $k > 0$ prefer to work in country 1, whereas managers with $k < 0$ prefer to work in country 2. A common interpretation is that country 1 is the home country for all managers with $k > 0$, whereas country 2 is the home country for all managers with $k < 0$. We scale the location preference parameter k by the constant a. This constant captures the cultural, institutional and geographical distances between the two countries, where a large parameter a stands for large cross-country differences.[21] The gross utility U_i of a manager of type k in country i is then

$$U_1(z_1, w_1, k) = u_1^*(z_1, w_1) + ak, \qquad U_2(z_2, w_2) = u_2^*(z_2, w_2). \tag{1.8}$$

All managers choose to work in the country that gives them the higher gross utility. We characterize the manager that is just indifferent between working in country 1 or in country 2 by the location preference $\hat{k}$. Equating U_1 and U_2 in (1.8) and using (1.7), we derive $\hat{k}$ as a function of differences in bonus payments and fixed wages between

[21] Van Veen et al. (2014) give empirical evidence that a higher cultural and geographical distance between a manager's nationality and a company's country of origin makes it less likely that the manager is employed by that company. Moreover, the parameter a is generally affected by economic integration. Trade integration between countries will typically reduce a, whereas financial integration may indeed increase it (see von Ehrlich and Seidel, 2015).

the two countries:

$$\hat{k} = \frac{1}{a}\left[\frac{\gamma}{2}(z_2^2 - z_1^2) + (w_2 - w_1)\right]. \tag{1.9}$$

Managers with $k \in [\hat{k}, \bar{N}]$ work in country 1 and managers with $k \in [-\bar{N}, \hat{k}]$ work in country 2. Given the uniform distribution of k, there will be $\bar{N} - \hat{k}$ managers in country 1 and $\bar{N} + \hat{k}$ managers in country 2. Using (1.9) then determines the number of managers in country i as a function of the differences in bonus payments and wages:

$$N_i = \bar{N} + \frac{1}{a}\left[\frac{\gamma}{2}(z_i^2 - z_j^2) + (w_i - w_j)\right] \qquad \forall\, i,j \in \{1,2\},\ i \neq j. \tag{1.10}$$

The larger is the bonus of country i, relative to that of country j, the more managers will work in country i in equilibrium. The same holds for the fixed wage. To quantify the managers' response, we introduce the semi-elasticity of migration with respect to the fixed wage:

$$\varepsilon \equiv \frac{\partial N_i}{\partial w_i}\frac{1}{N_i} = \frac{1}{aN_i}\ . \tag{1.11}$$

The semi-elasticity ε is the higher, the weaker is the managers' attachment to a particular country (the lower is the parameter a).[22] Moreover, the migration elasticity falls in our model when the total number of managers in the country rises.

1.4 Banks' Compensation Choices

1.4.1 Banks' Division Profits

In Stage 2, we turn to the remuneration decisions made by the owners of the single bank in each country. The bank in country i sets the bonus z_i and the fixed wage w_i to maximize its expected after-tax profits (which accrue to its shareholders). The expected after-tax profit of the bank in country i is

$$\Pi_i = N_i \pi_i^D, \tag{1.12}$$

where the number of divisions N_i, which equals the number of managers, is in (1.10). The expected profit of each division, π_i^D, is determined by the division's exogenous financing structure, its endogenous investment decision, and the endogenous work

[22]Kleven et al. (2014) empirically estimate the migration elasticity of foreign high income earners in Denmark with respect to the after-tax wage factor, and find it to lie between 1.5 and 2.0.

contract. Each division finances its unit investment by a combination of deposits and equity, where the shares of deposits and equity in total liabilities are s and $(1 - s)$, respectively. These shares are determined by minimum capital requirements in each country, which are exogenous to our analysis. Since government guarantees are confined to external funds (i.e., deposits), banks will always exhaust the permissible level of external funds. Therefore, the share s of deposit finance is directly fixed by each country's capital requirement. Insured depositors face no risk and receive a risk-free interest rate d. Given the assumption that banks and countries are small players in world capital markets in our model, the deposit rate d is fixed exogenously.[23]

With this specification, and recalling that the division's gross return is zero in the low state, the expected profit of each division is

$$\pi_i^D = p_i^{h*}[Y^h - sd - z_i(1 + t_i)] + p_i^{m*}[Y^m - sd] - w_i - (1 - s)d. \tag{1.13}$$

The first two terms in (1.13) give the division's profits for the high and the intermediate return, respectively. When the representative division realizes Y^h (with probability p_i^{h*}), it pays sd to its depositors. Moreover, in state h the bank pays the net bonus z_i to its manager and the proportional bonus tax $t_i z_i$ to country i's government. In state m, the division receives a portfolio return of Y^m and pays back sd to its depositors. Bonuses are not paid in this state.

If a division obtains the low return $Y^l = 0$, then it is unable to pay back its depositors, and so is the entire bank, due to the perfect correlation between the divisional returns (see Section 1.2). In this case the payments to depositors (sd) are covered by deposit insurance, and thus eventually by the taxpayers in country i. Hence, in state l, these payments do not enter the division's profit in (1.13).

However, the manager's fixed wage w_i is paid by the division in all states, implying that the bank's shareholders realize a loss, with a corresponding reduction in the value of

[23]If the two banks were large in world capital markets, opening up new divisions would bid up the world deposit rate (i.e., the return to savings). This would increase the marginal cost of a new division, in addition to the costs of attracting additional managers. In equilibrium, the mobility of managers would therefore be lower in a setting where the two banks affect the world deposit rate. Modelling the international market for deposits would, however, significantly complicate our analysis without changing its qualitative results.

their equity, if the low state occurs.[24] We thus assume that taxpayer-financed deposit insurance schemes are available to the bank in the low state l, before the bank's equity is wiped out completely. Finally, the last term in (1.13) gives the opportunity costs of the bank's equity $(1-s)$, which is valued at the risk-free interest rate d for notational simplicity. Incorporating this last term implies that division profits represent excess profits beyond the normal return to equity.

1.4.2 Bonus Payment and Fixed Wage

Our analysis focuses on the case where the remuneration of bank managers is composed of both success-related bonus payments and a positive fixed wage w_i.[25] Maximizing the bank's profits in (1.12) with respect to the bonus z_i, and using (1.13) and (1.4)–(1.5) gives

$$\frac{\partial \Pi_i}{\partial z_i} = \frac{\gamma z_i}{a}\,\pi_i^D + N_i\left[\gamma(Y^h - sd) - \frac{\beta}{\mu}(Y^m - sd) - 2\gamma z_i(1+t_i)\right] = 0. \tag{1.14}$$

The first effect in eq. (1.14) is unambiguously positive. A higher bonus z_i enables the bank to attract more managers and thereby run more divisions. This increases bank profits for any given expected profit per division. In an interior optimum, the second effect in (1.14) must therefore be negative, implying that the (after-tax) profit per division falls when the bonus is increased. This occurs by increasing the bonus until its effect on the expected gross return of the division (the first two terms in the squared bracket) is less than the bank's gross-of-tax cost of the bonus (the last term in the squared bracket).

Maximizing bank profits in (1.12) and (1.13) with respect to the fixed wage gives

$$\frac{\partial \Pi_i}{\partial w_i} = \frac{\pi_i^D}{a} - N_i = \frac{1}{a}\left[\pi_i^D - \frac{1}{\varepsilon}\right] \leq 0 \quad \forall\, i, \tag{1.15}$$

[24] We assume that fixed wage payments are less than the value of the bank's equity, $w_i < (1-s)d$. Having the manager participate in the losses of the low state would require a more complex, dynamic model in which managers face an increased risk of dismissal, or a lower wage in future wage contracts, when their investments have failed.

[25] In the European Union, for example, the employees of credit institutions and investment firms identified as having a material impact on the institution's risk profile had a ratio of variable over fixed remuneration of 65% in 2014. The highest ratios of variable over fixed pay are found in asset management (100%) and in investment banking (89%). See European Banking Authority (2016).

where the second step has used the migration (semi-) elasticity in (1.11). Eq. (1.15) holds with equality, and the fixed wage is used as a component of managerial compensation, when the division profit π_i^D (i.e., the gain from attracting an additional manager) is high, or when the migration elasticity of managers is high ($1/\varepsilon$ is low). In this case, a small positive wage attracts a large number of additional managers to the bank, relative to the number of division managers to whom the higher wage must be paid. If a small fixed wage has a positive effect on firm profits, then the wage rate will be further increased, lowering division profits in (1.13) until the first-order condition (1.15) is met with equality.

In the following, we assume that these conditions are met and $w_i > 0$ in the bank's optimum. This implies $\pi_i^D/a = N_i$ from the complementary slackness condition (1.15). Substituting this into (1.14) and collecting terms, the optimal bonus is given by

$$z_i^* = \frac{\Omega}{1+2t_i} \quad \forall\, i, \qquad \Omega \equiv (Y^h - sd) - \frac{\beta}{\mu\gamma}(Y^m - sd) > 0, \tag{1.16}$$

where the term Ω summarizes the marginal effects of the bonus (via the managers' effort and risk-taking choices) on a division's expected gross return. Clearly, this term must be positive for the bank to choose a positive bonus in equilibrium. Note, moreover, that the increase in a division's expected gross profit exceeds the social return to the induced changes in managerial behavior, because the social cost of a higher failure probability induced by the bonus are not incorporated in Ω.[26] Since the bonus is rising in Ω, bonus incentives set by the bank will therefore be 'excessive' from a social welfare perspective, as a result of the government's guarantees.[27] Finally note that the banks' optimal bonus payment is unaffected by the international mobility of bank managers, as reflected in the parameter a.[28]

In Appendix A.1, we use equations (1.15) and (1.16) for both countries to derive the

[26]If these costs were incorporated, the term $\delta sd/\gamma$ would have to be subtracted from Ω in (1.16).

[27]See Laeven and Levine (2009) for empirical evidence that government guarantees provide banks with an incentive to increase risk-taking and Adams (2012) for evidence that banks with a higher performance pay for CEOs were more likely to receive government support in the financial crisis.

[28]Note, however, that this does *not* imply that the bonus simply maximizes the profits of a representative division (π_i^D). This is because a higher bonus still has a positive effect on attracting mobile managers in equilibrium. Analytically, this is reflected in the first term in (1.14) being positive in the bank's optimum, whereas it would be zero if division profits were maximized.

optimal fixed wage, as a function of both countries' tax rates. This is given by

$$w_i^* = p_0^m(Y^m - sd) - (1-s)d + \frac{1}{6}\gamma\Omega^2\left[\frac{4t_i - 1}{(1+2t_i)^2} + \frac{1}{(1+2t_j)}\right] - \bar{N}a. \qquad (1.17)$$

The last term in (1.17) shows that an increase in manager mobility (i.e., a decrease in a) increases the fixed wage. This reflects that the fixed wage is the banks' marginal instrument to attract mobile workers in our analysis. We summarize our results in:

Proposition 1.1 *For given bonus taxes* (t_i, t_j)*, an increase in the mobility of bank managers (a fall in* a*) increases their fixed wage but leaves the bonus payment unchanged.*

Proposition 1.1 implies that increasing international mobility will lead to a higher overall compensation of managers (the sum of fixed wages and bonuses) in equilibrium. A higher international mobility of managers in recent decades (see Greve et al., 2015) can thus provide a possible explanation for the concurrent increase in total banker compensation. This argument complements the one given in the existing literature, which has focused on increased competition in national banking sectors as an explanation for the rise in managerial pay (Thanassoulis, 2012; Bannier et al., 2013). The interesting result in Proposition 1.1 is, however, that the higher overall remuneration is reflected in the fixed wage, rather than in the bonus payment. A direct implication of this result is that the higher international mobility of managers has *no* repercussions on the risk-taking choices of managers in equilibrium.[29]

1.4.3 Effects of Bonus Taxes on Managerial Remuneration

Before turning to governments' non-cooperative tax choices, we derive the effects that bonus taxes in each of the two countries have on managerial remuneration, and on the equilibrium number of managers working in each country.

A bonus tax in country i not only affects the bonus payment in this country, but it also changes the fixed wage in both banks. For the bonus payment, we get from (1.16):

$$\frac{\partial z_i}{\partial t_i} = \frac{-2\Omega_i}{(1+2t_i)^2} < 0, \qquad \frac{\partial z_i}{\partial t_j} = 0 \qquad i \neq j. \qquad (1.18)$$

[29]This result is changed when the bonus is the only remuneration instrument of banks. In this case, a higher mobility of managers increases the bonus payment of banks, and it therefore also raises risk-taking by managers in equilibrium. See our working paper version (Gietl and Haufler, 2017, Sec.4).

A higher bonus tax in country i makes bonus compensation more expensive for the bank in country i and thus reduces the optimal bonus payment z_i.[30] Country j's bonus tax t_j has no impact on the optimal bonus payment in bank i. This is because bonuses are used only to affect bankers' effort and risk-taking choices, whereas the competition for internationally mobile bank managers occurs via the fixed wage.

The effects of bonus taxes in both countries on bank i's fixed wage w_i are derived from (1.17):

$$\frac{\partial w_i}{\partial t_i} = \frac{4\gamma\Omega_i^2}{3}\left[\frac{(1-t_i)}{(1+2t_i)^3}\right], \qquad \frac{\partial w_i}{\partial t_j} = \frac{-\gamma\Omega^2}{3(1+2t_j)^2} < 0 \qquad i \neq j. \tag{1.19}$$

As long as $t_i < 1$, a higher bonus tax in country i will increase the fixed wage paid by bank i. Effectively, bank i shifts the compensation of its managers away from the more expensive bonus payment [see (1.18)] and towards the fixed wage, which is not covered by the additional tax.[31] When $t_i > 1$, however, the effect is turned around and a higher bonus tax reduces the fixed wage. Intuitively, in this case the high bonus tax makes it so costly to incentivize managers that banks reduce both the bonus pay and the fixed wage. In contrast, an increase in country j's bonus tax will always decrease bank i's fixed wage. The higher bonus tax in j drives managers to country i. This increases the marginal cost of the wage w_i, which has to be paid to more managers, but it does not change the number of additional managers that a marginal increase in w_i can attract.

These results can be used to derive the change in the equilibrium number of managers N_i caused by the bonus tax. Differentiating (1.10) with respect to t_i leads to

$$\frac{\partial N_i}{\partial t_i} = \frac{1}{a}\left[\gamma z_i \frac{\partial z_i}{\partial t_i} + \frac{\partial w_i}{\partial t_i} - \frac{\partial w_j}{\partial t_i}\right] = \frac{-\gamma\Omega^2}{3a(1+2t_i)^2} < 0, \tag{1.20}$$

where the second step follows from substituting in (1.18) and (1.19). In sum, the negative effect of a bonus tax in i on the bonus compensation of country i's managers dominates the changes in fixed wages in both countries. Therefore, a higher bonus tax in country i causes an outflow of managers.

[30] This effect might differ, if bank managers are strongly risk averse. Dietl et al. (2013) show that a bonus tax can increase the bonus payment in this case, because the tax has an insurance effect that counteracts the higher costs of the bonus. However, the empirical evidence on the risk preferences of bank managers suggests that they are risk-neutral, or only mildly risk-averse (see Thanassoulis, 2012).

[31] Our benchmark analysis abstracts from general income taxes that would fall, at a uniform rate, on all forms of managerial compensation. In Section 1.6.1 we discuss how our results are affected when an additional income tax on managers' overall compensation is introduced.

1.5 International Competition in Bonus Taxes

1.5.1 Governments' Bonus Tax Decisions

In Stage 1, governments set the bonus tax t_i that maximizes their net tax revenue W_i. In our model, net tax revenues are given by the expected bonus tax revenues minus expected bailout costs. Expected bonus tax revenue is collected from N_i managers in the domestic bank, multiplied by the expected bonus tax revenue per manager $p_i^h t_i z_i$. Bailout costs arise from compensating all depositors of the domestic bank in the event that the bank fails.[32] They are obtained by multiplying the number of divisions N_i of the domestic bank with the expected bailout costs per division, $p_i^l sd$.

We introduce F_i as the *net fiscal value* of a manager in country i, which equals expected tax income minus expected bailout costs per division. The government's net tax revenue is then given by

$$W_i = N_i F_i, \qquad F_i \equiv p_i^{h*} t_i z_i - p_i^{l*} sd. \tag{1.21}$$

Importantly for our analysis, the fiscal value of a manager can be positive or negative. It is positive if, in the government's tax optimum, the revenue from taxing the manager's bonus exceeds the expected bailout costs for the government when the manager's division fails. However, it is also possible that the bailout costs exceed the government's bonus tax revenue and the fiscal value of a manager is negative. Below, we discuss the conditions under which each of these cases holds in equilibrium.

In the case where $W_i < 0$, we assume that there are unmodelled and fixed benefits for the economy from having a domestic banking sector, even though the exact size of the domestic bank does not matter for the real economy.[33] The non-tax benefits of having a domestic bank will then cause each government to accept negative net tax revenues from the banking sector, if fiscal conditions are unfavorable. Therefore, each

[32] Recall that the primary purpose of deposit insurance is to prevent bank runs (cf. footnote 14). Therefore, deposit insurance typically covers all depositors in a bank, no matter whether they are domestic residents or not.

[33] One example that is in line with this assumption arises when the production sector in each country can obtain credit from either the domestic or the foreign bank. In the complete absence of a domestic bank, however, the access to credit is either limited for the domestic economy, or it becomes discretely more expensive as a result of the foreign bank's monopoly power.

government will still solve an interior tax optimization problem, rather than shutting down its domestic banking sector entirely.

Maximizing net tax revenue as given in (1.21) with respect to t_i gives

$$\frac{\partial W_i(t_i,t_j)}{\partial t_i} = N_i(t_i,t_j)\left[z_i^2\gamma + 2\gamma z_i t_i\,\frac{\partial z_i}{\partial t_i} - \delta s d\,\frac{\partial z_i}{\partial t_i}\right] + F_i\,\frac{\partial N_i}{\partial t_i} = 0 \quad \forall\, i \neq j. \tag{1.22}$$

Equation (1.22) implicitly defines each country's best response to the tax rate of the other country, $t_i^*(t_j)$, where the interdependency of tax rates is caused by the equilibrium number of managers $N_i(t_i,t_j)$. To interpret the fundamental trade-off for governments' optimal bonus tax choices, we start with the second term in (1.22). Since bonus taxes cause an outmigration of managers from eq. (1.20), the second term in (1.22) has the opposite sign as the fiscal value of a manager, F_i, which we discuss in detail below. The sign of the first term depends on the sum of three terms in the squared bracket, which give the change in net tax revenue for a representative division ($\partial F_i/\partial t_i$). The first term gives the direct effect of a tax increase at an unchanged tax base and is clearly positive. The second term is negative, because a higher bonus tax reduces bonus payments [see eq. (1.18)], and hence the bonus tax base. The third term is again positive, as the tax induced fall in bonus payments lowers the probability of bank default and thus reduces taxpayer losses when $\delta > 0$.

Two cases can then be distinguished. If the fiscal value of a manager, F_i, is positive in equilibrium, then the outmigration of managers caused by the tax increase leads to a negative second effect. In an interior optimum, the first term in (1.22) must therefore be positive, on net. This requires that the negative second term in the squared bracket is small, implying a 'low' bonus tax rate t_i^* in equilibrium. In the opposite case where $F_i < 0$ holds in equilibrium, the second term in (1.22) is instead positive. In this case the increase in the bonus tax rate must therefore reduce the net revenue obtained from each division in an interior tax optimum, and the first term in (1.22) must be negative. This requires that the negative second term in the squared bracket is large, implying a 'high' bonus tax rate t_i^* in the non-cooperative tax equilibrium.

A *Nash equilibrium* is defined as a combination of tax rates t_1^*, t_2^* that, for equilibrium values of manager compensation (z_i, w_i), satisfy (1.22) for both countries simultaneously. Given that countries are perfectly symmetric in our model, we focus only on symmetric Nash equilibria in the following, where endogenous variables are equal in all countries and $\hat{k} = 0$ in eq. (1.9).[34] Substituting optimal bonus payments in (1.16) along with the effects of taxes on bonus payments and the equilibrium number of managers [eqs. (1.18) and (1.20)], and setting $t_i = t_j$ in the symmetric equilibrium, the first-order condition for optimal bonus taxes (1.22) can be rewritten as

$$\begin{aligned}\frac{\partial W_i}{\partial t_i} =& \frac{\gamma\Omega^2}{3a(1+2t)^2}\left[p_0^l sd - \frac{\gamma t\Omega^2}{(1+2t)^2} + \frac{\delta\Omega sd}{(1+2t)}\right] \\ &+ \frac{\bar{N}\Omega}{(1+2t)^2}\left[\frac{\gamma\Omega(1-2t)}{(1+2t)} + 2\delta sd\right] = 0. \end{aligned} \tag{1.23}$$

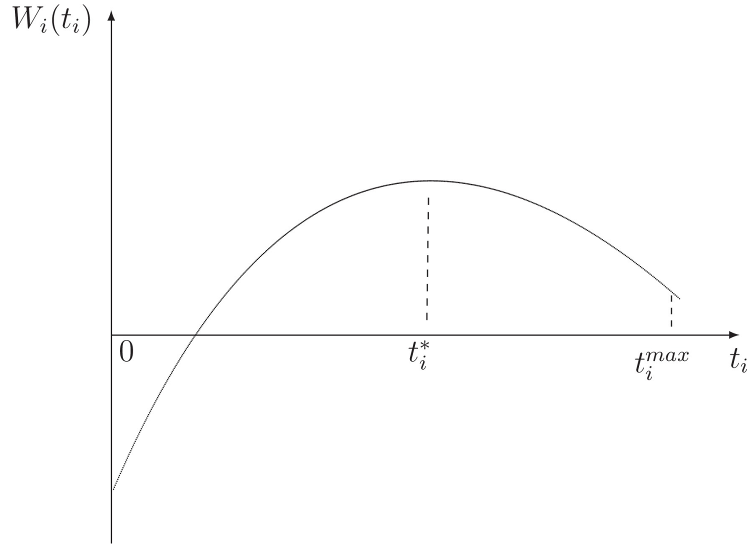
A symmetric Nash equilibrium exists, if the objective function $W_i = N_i(t_i, t_j) \times F_i(t_i)$ is continuous in both t_i and t_j, and strictly quasi-concave in t_i. Continuity is guaranteed in our setting because N_i and F_i are continuous in t_i and t_j [see eqs. (1.10) and (1.21)]. It remains to show that $W_i(t_i)$ is quasi-concave in t_i, i.e., that the second-order condition for the governments' optimal choice of bonus taxes holds. This second-order condition is derived and discussed in Appendix A.2. As is common in tax competition models, it is not possible to sign the second-order condition without any ambiguity. However, Appendix A.2 gives a concrete numerical example to show that it holds for a wide range of parameter values. In the following, we assume that $W_i(t_i)$ is indeed quasi-concave in t_i and a symmetric Nash equilibrium in tax rates will therefore exist.

The next question concerns the properties of the symmetric Nash equilibrium. In particular, we are interested in the conditions under which an *interior* Nash equilibrium with $0 < t_1^* = t_2^* < \infty$ exists. Finite equilibrium tax rates are particularly relevant for the case where the fiscal value of a manager is negative in equilibrium, $F_i(t_i^*) < 0$, as in this case it seems possible that both governments choose tax rates that are approaching infinity, in order to discourage all bonus payments in equilibrium. In the following, we derive conditions under which W_i is rising in t_i at $t_i = 0$, but falling in t_i as $t_i \to \infty$. As is shown in Figure 1.1, this combination must imply an interior Nash equilibrium (t_i^*), since W_i is continuous and quasi-concave in t_i.[35]

[34]We cannot exclude that additional, asymmetric Nash equilibria also exist in our model. However, if they exist, they have no obvious economic interpretation in a fully symmetric setup.

[35]Figure 1.1 is drawn for the case where $F_i(t_i^*) > 0$ in equilibrium, which implies that $W_i(t_i)$ is positive in the tax optimum. If instead $F_i(t_i^*) < 0$, then the entire graph of $W_i(t_i)$ is below the zero net revenue line. The shape of $W_i(t_i)$ is the same as in Figure 1.1, however, and our argument for an interior tax equilibrium is also unchanged.

Figure 1.1: Existence of an Interior Nash Equilibrium



The conditions for an interior Nash equilibrium are summarized in:

Proposition 1.2 *A symmetric Nash equilbrium with interior tax rates* $0 < t^* < \infty$ *exists, if the following condition holds:*

$$\gamma\Omega\left(1 - \frac{\varepsilon p_0^l sd}{3}\right) - 2\delta sd > 0.$$

Proof: See Appendix A.3.

Intuitively, the government's bonus tax revenue per division, $\gamma t_i z_i^2$, is unambiguously concave in the bonus tax rate, and has an interior maximum at $t_i = 0.5$. Therefore, a first condition for an interior Nash equilibrium is that the effect of the tax rate change on divisional bonus tax revenue dominates the effect on the divisional bailout costs. This will be the case if the marginal effect of the bonus on the probability of the high return state (which incorporates the parameter $\gamma > 0$) dominates the marginal effect of the bonus on the probability of the low state (with the parameter $\delta \geq 0$).[36] The second condition ensuring an interior solution is that the tax-induced net revenue changes resulting from the changed incentives of existing managers in a country dominate the revenue changes resulting from the inflow or outflow of managers. This condition will

[36]Recall from our discussion in Section 1.3.1 [eqs. (1.4)–(1.6)] that γ is unambiguously positive from both the effort and risk-taking choices of bank managers. In contrast, the effects of effort and risk taking on the parameter δ are mutually offsetting.

be met when the migration elasticity of managers, ε, is not too large.[37] In the following we assume that the condition stated in Proposition 1.2 is met and both countries choose an interior tax rate t_i^* in the symmetric Nash equilibrium.

Finally, we analyze in more detail the fiscal value of a manager, F_i, which plays a critical role in our analysis. In a first step, we substitute the equilibrium probabilities (1.4) and (1.6) along with the optimal bonus payment (1.16) into the expression for F_i in (1.21). This yields an expressions for F_i that depends only on exogenous parameters, and on the tax rate t_i:

$$F_i(t_i) \equiv p_i^{h*} t_i z_i - p_i^{l*} sd = \frac{\gamma t_i \Omega^2}{(1+2t_i)^2} - \left(p_0^l + \frac{\delta\Omega}{(1+2t_i)}\right) sd, \tag{1.24}$$

where Ω is given in (1.16). Evaluating F_i at the optimal tax rate t_i^*, implicitly defined in (1.23), gives the equilibrium fiscal value of a manager, denoted in the following by F_i^*. We can then calculate the total response of F_i^* to an exogenous parameter χ, using the implicit function theorem in (1.23) to derive the effect of χ on t_i^*:

$$\frac{dF_i^*}{d\chi} = \frac{\partial F_i^*}{\partial \chi} + \frac{\partial F_i^*}{\partial t_i}\frac{dt_i^*}{d\chi}, \qquad \frac{dt_i^*}{d\chi} = -\frac{\partial^2 W_i/\partial t_i \partial \chi}{\partial^2 W_i/\partial t_i^2} \; . \tag{1.25}$$

We are mainly interested in how F_i^* is affected by the exogenous 'baseline' probability of a low state (p_0^l), and by the (insured) deposit share s. The effects of these two parameters on $F_i^*(p_0^l, s)$ are summarized in:

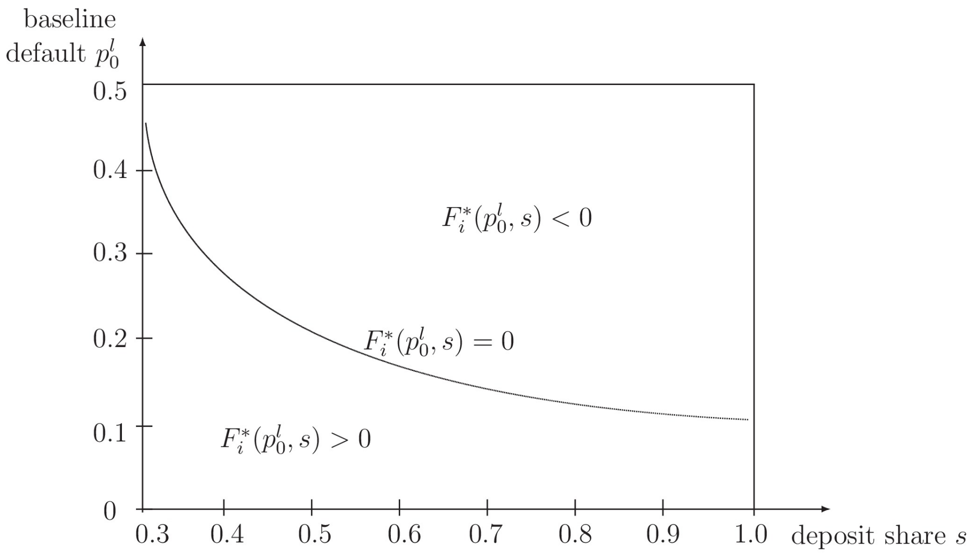
Proposition 1.3 *(i) In equilibrium, the fiscal value of a manager F_i^* is unambiguously falling in the 'baseline' probability of a low state, p_0^l.*
(ii) If $\delta = 0$, the fiscal value of a manager F_i^* is falling in the deposit share s.

Proof: See Appendix A.4.

It is seen from (1.24) that an increase in the 'baseline' probability of the default state, p_0^l, lowers the fiscal value F_i^* by the direct effect. At the same time, an increase in p_0^l raises the optimal tax rate t_i^* in the Nash equilibrium (see Appendix A.4). Appendix A.4 proves that this indirect effect can never overcompensate the direct effect, and the overall effect of p_0^l on F_i^* is thus always negative. For the deposit share s, the analysis

[37] Note that moderate migration elasticities required for an interior tax equilibrium do not preclude an equilibrium where fixed wages are part of managerial compensation [see eq. (1.15)]. In particular, when the division profits π_i^D are sufficiently high due to a high exogenous return Y^h, then even moderate migration elasticities will ensure that (1.15) holds with equality.

Figure 1.2: Equilibrium Regions for the Fiscal Value of Managers $F_i^*(p_0^l, s)$



Parameters: $\gamma = 0.5$; $\delta = 0$; $\bar{N} = 10$, $a = 0.05$, $Y^h = 3.5$, $Y^m = 2$, $d = 1$

is more complicated, in general, because the composite parameter Ω depends on s. However, in the special case where $\delta = 0$, it is straightforward to show that the negative direct effect in (1.24) once again dominates the indirect effect operating through the change in the equilibrium tax rate, and the overall effect of s on F_i^* is negative.

From Proposition 1.3, and assuming δ to be sufficiently small, the fiscal value of a manager $F_i^*(p_0^l, s)$ is a falling function of both the baseline probability of default p_0^l, and of the deposit share s. Figure 1.2 shows how different pairs of parameters (p_0^l, s) then lead to either positive or negative fiscal values of managers in equilibrium, for given parameter values of the remaining exogenous model parameters. In the figure, the downward sloping curve $F_i^*(p_0^l, s) = 0$ defines the locus of all combinations of p_0^l and s for which the fiscal value of a manager is zero in the non-cooperative tax equilibrium. Combinations of p_0^l and s that lie to the right and above this curve lead to a negative fiscal value of managers in equilibrium ($F_i^* < 0$), whereas the region below and to the left of the curve is characterized by positive fiscal values of managers ($F_i^* > 0$). From our discussion of the governments' optimal bonus tax choice in eq. (1.22), we furthermore know that the region characterized by $F_i^* > 0$ is associated with lower bonus tax rates as compared to the region where $F_i^* < 0$ holds.

1.5.2 Are Non-Cooperative Bonus Taxes too High or too Low?

The next step is to compare the optimal bonus taxes chosen by non-cooperating governments to the bonus tax rates that would be optimal from a regional welfare perspective. We start from an interior, symmetric Nash equilibrium where $\partial W_i/\partial t_i = 0$ holds for both countries $i \in \{1,2\}$. Since countries are symmetric, we can define regional welfare as the sum of national welfare levels

$$W_W = W_i + W_j \quad \forall\, i,j \in \{1,2\}, i \neq j, \tag{1.26}$$

where W_i is given in eq. (1.21). Choosing t_i so as to maximize regional welfare would imply $\partial W_W/\partial t_i = 0$ in eq. (1.26). The nationally optimal bonus taxes derived in the previous section are instead chosen so that $\partial W_i/\partial t_i = 0$ holds [see eq. (1.22)]. Hence, any divergence between nationally and globally optimal bonus taxes is shown by the effect of country i's policy variable t_i on the welfare of country j. If $\partial W_j/\partial t_i > 0$, bonus taxes chosen at the national level are 'too low' from a global welfare perspective, as an increase in t_i would generate a positive externality on the welfare of country j. The reverse holds if $\partial W_j/\partial t_i < 0$. In this case the externality on the foreign country is negative and nationally chosen bonus taxes are 'too high' from a regional welfare perspective.

Using this argument and employing symmetry, which implies $\partial W_j/\partial t_i = \partial W_i/\partial t_j$, we differentiate (1.21) with respect to the foreign tax rate t_j.[38] This gives

$$\frac{\partial W_i}{\partial t_j} = F_i \frac{\partial N_i}{\partial t_j} = \left[\frac{\gamma \Omega^2 t_i}{(1+2t_i)^2} - \left(p_0^l + \frac{\delta \Omega}{1+2t_i}\right) sd\right] \left[\frac{\gamma \Omega}{3a(1+2t_j)^2}\right]. \tag{1.27}$$

Equation (1.27) shows that the fiscal externality is driven by the migration decision of managers. A rise in t_j decreases the bonus in country j and thus reduces the attractiveness of the entire compensation package offered to managers in country j. This drives managers to country i and increases the number of managers, N_i, there. Therefore, the sign of the fiscal externality is always equal to the sign of F_i^* in equilibrium.

If the fiscal value of managers $F_i^*(p_0^l, s)$ is positive in equilibrium, a bonus tax increase in country j benefits country i through the immigration of managers, who are net

[38] Recall that the foreign tax rate t_j does not affect the domestic bonus z_i [see eq. (1.18)]. Hence t_j does not affect the fiscal value per manager F_i.

contributors to tax revenues. In this case the net fiscal externality is positive, implying that bonus taxes set in the non-cooperative equilibrium are lower than the bonus taxes that would be chosen under policy coordination. This is the conventional case of a 'race to the bottom' in the setting of bonus taxes. Drawing on Figure 1.2 illustrates that this case arises for parameter combinations where the deposit share s (and hence the implicit level of government guarantees) and the baseline probability of default p_0^l are both low.

Conversely, if $F_i^*(p_0^l, s)$ is negative in equilibrium, the fiscal externality in eq. (1.27) is also negative. Non-cooperatively set bonus taxes are then unambiguously higher than those in the coordinated equilibrium and there is a 'race to the top' in bonus taxation. Intuitively, managers are unwanted by governments in this case, as the expected bailout costs for the government dominate the revenue potential from bonus taxation. Hence each country attempts to drive bank managers to the other country by means of a high bonus tax, thus shifting fiscal risks from domestic to foreign taxpayers. Figure 1.2 shows that this case is associated with unfavorable conditions in the banking sector (p_0^l is high), and large government guarantees (the deposit share s is high). We summarize our results in this section in:

Proposition 1.4 *In a symmetric, interior tax equilibrium, the following holds:*

(i) If the fiscal value of a manager, $F_i^*(p_0^l, s)$, is positive in equilibrium, non-coordinated bonus taxes are below their globally optimal levels, and a 'race to the bottom' occurs.

(ii) If the fiscal value of a manager, $F_i^*(p_0^l, s)$, is negative in equilibrium, non-coordinated bonus taxes are above their globally optimal levels, and a 'race to the top' occurs.

1.5.3 Discussion

Our results in Proposition 1.4 incorporate two different settings. When the equilibrium fiscal value of managers is positive, governments undertax bonuses, relative to the globally efficient level, in an attempt to attract more 'fiscally valuable' bank managers. In this case, therefore, governments will not fully correct the distortion arising from the excessive bonus incentives set by banks as a result of their limited liability. When the fiscal value of bank managers is negative, however, governments' incentives to correct for the banks' limited liability and their strategic incentive to reduce bank size are mutually reinforcing. Hence, each country overtaxes bonuses in this case, in order to drive 'fiscally harmful' managers to the other country.

The case where bonus taxes are below their efficient levels corresponds to the setting that is well known from the tax competition literature (see Keen and Konrad, 2013, for a survey). The recent literature has generalized this result to non-linear income tax competition between governments pursuing a redistributive objective (Lehmann et al., 2014; Lipatov and Weichenrieder, 2015), and it has shown that tax competition may even eliminate all taxes on the high-skilled when they are perfectly mobile across countries (Bierbrauer et al., 2013). More generally, the conclusion of Sinn (1997) applies in this setting that governments in competition will be unable to fully correct the externalities that arise from (allocative or distributional) market failures.

The opposite setting with inefficiently high bonus taxes rarely occurs in the tax competition literature, which typically excludes risk-taking decisions, and hence the possibility of negative returns. This setting has some similarities with the NIMBY (Not In My Backyard) scenario, however, that is known from the taxation of environmentally hazardous plants or products (e.g. Markusen et al., 1995). The main difference to this scenario is that the negative externalities in our case are fiscal ones: High bonus taxes are used by each country to shift the fiscal risks associated with bailout guarantees from domestic to foreign taxpayers.

The ambiguity about the direction of tax competition is particularly relevant in the banking sector, due to the possibility that bank managers cause fiscal losses for taxpayers. In our model, governments use price signals (i.e., taxes) to change the behavior of banks and, via the change in bonus payments, the behavior of managers in the direction of lower risk-taking. Similar effects can also be obtained by forcing banks to hold more equity capital by means of minimum capital requirements. A small literature has studied regulatory competition in capital standards and has typically found that this competition leads to a 'race to the bottom' in capital standards when governments focus primarily on maximizing domestic bank profits (Acharya, 2003; Sinn, 2003; Dell'Ariccia and Marquez, 2006). Recently, Haufler and Maier (2016) have shown, however, that regulatory competition in capital standards will instead lead to a 'race to the top' when the governments' objective function is broadened and also includes fiscal risks as well as consumer surplus, which is affected by the overall availability of credit. In sum, therefore, the direction of regulatory competition is ambiguous in this literature, similar to our results for bonus taxation.

1.6 Extensions

In the following we extend our model in various directions. In Section 1.6.1 we incorporate bank profits into the welfare functions of governments. Section 1.6.2 then investigates the situation in a banking union, where the two symmetric countries internalize a share of each other's bailout costs. Our focus in both sections lies on the fiscal externalities that are added to our benchmark analysis, and how these affect the direction of bonus tax competition. In Section 1.6.3 we consider the additional effects that arise when each bank can open up a subsidiary in the other country (i.e., engage in FDI). Finally, Section 1.6.4 investigates the international competition for bank managers when bankers differ not only in their country preferences, but also have individual, location-specific productivities.

1.6.1 Bank Profits in the Government's Objective

So far we have included only bonus tax revenue and bailout costs in the welfare functions of governments. We now analyze the case where each government additionally takes into account a share θ of the domestic bank profits Π_i. The objective function thus changes to:

$$\bar{W}_i = N_i F_i + \theta N_i \pi_i^D. \tag{1.28}$$

The new second term on the right-hand side gives the income that domestic capital owners derive from the profits of the domestic banking sector. The welfare weight θ thus jointly reflects the share of the domestic banking sector that is owned by domestic residents, and the relative valuation of this profit income in the government's objective.

Differentiating (1.28) gives

$$\frac{\partial \bar{W}_i}{\partial t_j} = F_i \frac{\partial N_i}{\partial t_j} + \theta \pi_i^D \frac{\partial N_i}{\partial t_j} \ . \tag{1.29}$$

The first term in (1.29) corresponds to the fiscal externality in our benchmark model. The additional term on bank profits in country i results again from the changed bank size in country i following the increase in t_j. This effect is positive from eq. (1.20). The simultaneous change in w_i caused by a rise in t_j has no first-order welfare effect on country i, because w_i is optimally chosen by country i's bank [eq. (1.15)].

In sum, adding bank profits to the government's objective adds a positive term to the fiscal externalities. In Figure 1.2, the frontier dividing the regions where a 'race to the bottom' or a 'race to the top' occurs will then no longer coincide with the frontier where the fiscal value of a manager F_i^* is zero. Instead, the regime frontier is shifted up and to the right, implying that a 'race to the bottom' now occurs for a wider set of parameter values (p_0^l, s). Intuitively, by increasing its tax rate, the government of country j causes some bank managers to move to country i. This will increase bank profits in country i, even when the net contribution of bank managers to country i's tax revenues is negative.

A related extension is to add a general income tax, levied at an exogenous rate, that bank managers have to pay on all their income (i.e., the fixed wage and the bonus). Incorporating income taxes does not add an additional component to the government's objective, as in (1.29). However, it adds a positive revenue term to the equilibrium fiscal value of managers F_i^*, thus rendering the single externality in (1.29) positive for a larger parameter range. In this case, the regime frontier in Figure 1.2 corresponds again to the $F_i^* = 0$ curve, but this frontier is shifted up, relative to our benchmark setting. Hence, a 'race to the bottom' in bonus taxation occurs again for a wider range of parameter combinations (p_0^l, s).

1.6.2 Joint Liability of Bailout Costs

Another relevant extension of our benchmark model is to incorporate joint liability of the two countries in the case of individual bank failures. In the Euro area, such a scheme has been introduced by the so-called 'Single Resolution Mechanism' (SRM) within the EU's banking union. To be sure, the SRM has simultaneously introduced a number of safeguards against a direct collectivization of bank losses. In particular, a principle of 'bail-in' has been set up, according to which shareholders and non-insured creditors of the bank should be the first to bear bank losses. This 'bail-in' component must cover at least 8% of a bank's assets, before collective revenue sources can be used. In the case of large bank failures it seems likely, however, that these funds will not suffice to cover all losses. Additional funds will then come from two sources: (i) an EU-wide 'resolution fund', financed by levies on member states' banks, for which a collectivization has already been agreed upon, and (*ii*) national deposit insurance systems, whose collectivization is currently a major policy issue in the EU.

In the following we therefore analyze the effects of a partial collectivization of bailout costs. We take ρ to be the share that taxpayers in country i pay for the expected losses of bank failures in country j, whereas $(1-\rho)$ is the share of losses that taxpayers in each country pay for the bank losses in their own country. Joint liability of bailout costs then implies

$$\hat{W}_i = N_i \left[T_i - (1-\rho)B_i\right] - \rho N_j B_j \quad \forall\, i \neq j, \tag{1.30}$$

where T_i is the tax revenue per manager and B_i is the bailout cost per manager in i:

$$T_i \equiv p_i^{h*} t_i z_i, \qquad B_i \equiv p_i^{l*} sd \quad \forall\; i.$$

To analyze the fiscal externalities associated with bonus taxation, we differentiate (1.30) with respect to t_j. This gives

$$\frac{\partial \hat{W}_i}{\partial t_j} = \frac{\partial N_i}{\partial t_j}\left[T_i - (1-\rho)B_i\right] + N_i \left[\frac{\partial T_i}{\partial t_j} - (1-\rho)\frac{\partial B_i}{\partial t_j}\right] - \rho \left[B_j \,\frac{\partial N_j}{\partial t_j} + N_j \,\frac{\partial B_j}{\partial t_j}\right]. \tag{1.31}$$

To see how the fiscal externalities change with respect to the collectivization of bailout costs, we differentiate (1.31) with respect to ρ. This gives, after using symmetry and summarizing terms

$$\frac{\partial \hat{W}_i/\partial t_j}{\partial \rho} = 2B_i \frac{\partial N_i}{\partial t_j} - N_i \delta sd \frac{\partial z_j}{\partial t_j} > 0. \tag{1.32}$$

The first term in (1.32) is always positive, since $\partial N_i/\partial t_j > 0$. This effect captures that the negative externality from shifting bailout costs abroad via manager migration becomes smaller when the degree of collectivizing bailout costs is increased (ρ rises). The second term in (1.32) is also positive when $\delta > 0$. This is because an increase in t_j reduces the bonus in country j, thus reducing risk-taking and hence the expected losses arising in country j's banking sector. For a higher level of ρ a larger part of this net revenue gain is transferred to country i. In sum, the right-hand side in (1.32) is thus unambiguously positive, implying that a higher degree of collectivizing bailout costs (a rise in ρ) increases the value of the net externality $\partial \hat{W}_i/\partial t_j$. In Figure 1.2, this extension once again corresponds to an upward shift in the frontier dividing the two regimes, thus increasing the range of parameter combinations (p_0^l, s) for which a 'race to the bottom' occurs. We summarize our results in the first two extensions of this section in:

Proposition 1.5 *A 'race to the bottom' in bonus taxes occurs for a wider set of parameter values* (p_0^l, s)*, if*

(i) *domestic bank profits receive a higher weight in the welfare function of governments* (θ *is increased), or if*

(ii) *bailout costs are more strongly collectivized between countries* (ρ *rises).*

Proposition 1.5 (i) can be used to rationalize the development of bonus taxation in the recent past. In the period immediately following the 2008 financial crisis, large-scale bank bailouts occurred in many countries, implying that the net fiscal value per bank manager (F_i) was frequently negative. Given this experience, the protection of national taxpayers was the dominant concern in many countries, relative to the incentive to increase banking sector profits (i.e., θ was low). These conditions may explain why high bonus tax rates were enacted, or at least prepared, in several OECD countries in 2009 and 2010 (see the introduction). In the following years, however, perceived risks for taxpayers fell and banking sector profits resumed, and with it the incentive to attract banking sector profits from abroad (a rise in θ). These developments may have caused the competition via bonus taxes to change directions, moving from a 'race to the top' to a 'race to the bottom', and to the repeal of previously enacted bonus taxes.

Moreover, from Proposition 1.5 (ii), partially collectivizing the costs of bank restructuring in the European banking union may further contribute to a 'race to the bottom' in bonus taxation when bonus taxes are set unilaterally and non-cooperatively. Setting a lower bound on bonus taxes or, alternatively, limiting bonus payments by regulatory means may thus be a desirable coordination measure complementing the banking union. And indeed, the latter occurred with the coordinated 2014 regulation limiting bonus payments in the EU to 100% of bankers' fixed salary.

1.6.3 Multinational Banks and Multiple Banks

Our next extension is to allow each bank to open up a subsidiary in the other country. Hence there are now four bank entities, two in each country. We focus on the conceptually simplest case where each entity of a multinational bank is free to choose the bonus and the fixed wage that maximizes the profit of this unit only.[39] Hence, the four bank affiliates effectively behave like four independent banks, with two banks competing in each of the two markets $i \in (1, 2)$. Bonus taxes continue to be paid in the country where a bank unit operates.

The core difference between this scenario and our benchmark analysis is that there is now competition for managers by bank units operating in the *same* country. Since managers have no preferences for individual banks, each bank can attract the entire set of managers that locate in a particular country (in a symmetric equilibrium, this will be $\bar{N}$) by marginally overbidding its rival in that market. Since all bank units are symmetric, banks in each country will overbid each other until all rents are transferred to the managers, and division profits are therefore zero in equilibrium.[40]

The equilibrium compensation structure for managers is then as follows. The fixed wage will be set so high as to reduce the division profit in (1.13) to zero. A zero division profit in turn implies that the first term in the first-order condition for the banks' bonus payment (1.14) is also zero. Hence, different from our benchmark model, the optimal bonus simply maximizes the profit of a representative division. The optimal bonus is

$$\tilde{z}_i^* = \frac{\Omega}{2(1+t_i)}, \qquad \Omega \equiv (Y^h - sd) - \frac{\beta}{\mu\gamma}(Y^m - sd) > 0, \tag{1.33}$$

which is lower than in our benchmark model because the bonus is not used to attract additional managers (cf. footnote 28). Substituting (1.33) in (1.13) and setting the division profit equal to zero determines the fixed wage

$$\tilde{w}_i^* = \Gamma^*(t_i) \equiv p_0^m(Y^m - sd) - (1-s)d + \frac{\gamma\Omega^2}{4(1+t_i)}, \tag{1.34}$$

where $\Gamma^*(t_i)$ is the rent from attracting an additional manager, net of the optimal bonus payment.

It follows from (1.33) and (1.34) that both the bonus and the fixed wage payment of a bank operating in country i are a function only of the bonus tax rate in the host

[39] Assuming instead that the parent bank in the headquarter country chooses the compensation package for both units of the multinational bank leads to a setup where each bank maximizes the sum of its profits in two markets. The results are the same as in the simpler set-up followed here, however, because there are no interdependencies between the compensation choices in the two units of each bank.

[40] This outcome is analogous to that of Bertrand price competition in a symmetric duopoly market.

country i. Since this tax rate is the same for the two banks in a given country i, the compensation packages offered by the two banks in each country will be identical. Within each country, the allocation of managers between the two competing banks is therefore indeterminate.

This indeterminacy is of no concern for our further results, however. What matters from the perspective of country i's government is only the *total* number of managers within its jurisdiction. This number continues to be determined by the combination of location preferences and the compensation packages offered by banks in *different* countries, as summarized in eq. (1.10).

As in the benchmark model, we thus differentiate (1.10) to get the effect of a higher bonus tax t_i on the number of managers in country i. Using (1.33) and (1.34) gives

$$\frac{\partial \tilde{N}_i}{\partial t_i} = \frac{1}{a}\left[\tilde{z}_i \gamma \frac{\partial \tilde{z}_i}{\partial t_i} + \frac{\partial \tilde{w}_i}{\partial t_i}\right] = \frac{-\gamma \Omega^2 (2+t_i)}{4a(1+t)^3}. \tag{1.35}$$

Comparing (1.35) with the corresponding derivative in our benchmark model [eq. (1.20)] shows that the quantitative effects of the bonus tax differ in the two settings, because of the differences in equilibrium bonus and fixed wage payments. Specifically, it is straightforward to show that

$$|\frac{\partial \tilde{N}_i}{\partial t_i}| > |\frac{\partial N_i}{\partial t_i}|.$$

Hence the negative effect of a bonus tax on the equilibrium number of managers is stronger in the multiple-banks framework considered here. This is due primarily to the different responses of the fixed wage. In our benchmark model, a bonus tax increased the fixed wage [for $t_i < 1$; see (1.19)] and this mitigated the outflow of managers in response to the tax. In contrast, in the extension considered here, the bonus tax also reduces the fixed wage [see eq. (1.34)] and this reinforces the outmigration of managers in response to the bonus tax. Intuitively, a higher bonus tax reduces the profitability of each division, and this directly translates into a lower fixed wage in a setting where all rents are transferred to managers.

The higher outmigration of managers from country i following a rise in t_i leads to a correspondingly higher inflow of managers to country j. Hence the externalities arising from bonus taxation [cf. eq. (1.27)] are stronger in a setting with multiple bank units in each country, as compared to our benchmark case. If $F_i^* > 0$ in equilibrium and the fiscal externality is positive, this implies a more severe 'race-to-the-bottom', and hence lower bonus taxes, in comparison to the benchmark case. In contrast, if $F_i^* < 0$ and the fiscal externality is negative, the 'race-to-the-top' is intensified and tax rates are higher than in the benchmark analysis.

1.6.4 Location-Specific Productivities

In this final extension, we investigate the international competition for bank managers when the latter differ in two dimensions, their individual preferences for a specific country, and their individual and location-specific productivities.[41] To isolate the effects of this extension, we return to our assumption that banks do not engage in FDI and there is only one bank unit in each country. Moreover, to keep the analysis easily tractable in the presence of two sources of heterogeneity, we assume that these are positively and monotonously correlated. Hence, agents with a higher location preference for country 1 are also relatively more productive in this country. This is most intuitive when thinking about country preferences as a preference for each manager's home country. It is plausible that each manager will also be relatively more productive in his home country, because he will be more familiar with the legal and institutional work environment there.

We define the location-specific productivity of manager k in country i as x_i^k. This country-specific productivity adds an additively separable term to the division profit in eq. (1.13), giving

$$\pi_i^{D,k} = p_i^{h*}[Y^h - sd - z_i(1+t_i)] + p_i^{m*}[Y^m - sd] - w_i - (1-s)d + x_i^k. \tag{1.36}$$

Both banks know the individual country preferences and the country-specific productivities of each manager k. Hence, each bank is able to set individual bonuses and fixed wages for each manager. The ability to set individualized bonuses implies that the bank now maximizes the expected after-tax profit of a *single* division. This leads to the same bonus choice as in the previous section, given in eq. (1.33). Importantly, the optimal bonus payment of each bank will be independent of the manager type k. Substituting (1.33) into the manager-specific division profit (1.36) gives

$$\pi_i^{D,k} = \Gamma^*(t_i) + x_i^k - w_i^k \geq 0, \tag{1.37}$$

[41] See Burbidge et al. (2006) for a related tax competition analysis when firms have country-specific and heterogeneous productivities.

where the type-independent rent from attracting an additional manager, $\Gamma^*(t_i)$, is given in eq. (1.34) in the previous section. This is augmented by the additional rent x_i^k that the manager- and location-specific productivity creates. Hence the fixed wage w_i^k determines how the total rent $\Gamma^*(t_i) + x_i^k$ is distributed between bank i and manager k.

The fixed manager-specific wage w_i^k is determined by a bidding competition between the two banks. The *maximum* fixed wage offered by the bank in country i for a manager of type k is denoted by $\bar{w}_i^k$. This is obtained by setting (1.37) equal to zero, giving

$$\bar{w}_i^k = \Gamma^*(t_i) + x_i^k.$$

In equilibrium, manager k works for the country that can offer him the largest expected utility. The maximum expected utility that can be offered to manager k in country 1, $\bar{U}_1^k$, is the sum of the maximum fixed wage $\bar{w}_1^k$, the equilibrium bonus payment, net of effort and risk-taking costs, and the relative location preference ak. Corresponding to eqs. (1.7) and (1.8) in our benchmark case, the condition for manager k to work in country 1 in a bidding equilibrium is

$$\bar{U}_1^k = \frac{\gamma z_1^2}{2} + \Gamma^*(t_1) + x_1^k + ak \geq \bar{U}_2^k = \frac{\gamma z_2^2}{2} + \Gamma^*(t_2) + x_2^k. \tag{1.38}$$

If eq. (1.38) holds, then it is optimal for bank 1 to choose the *equilibrium* wage w_1^k just high enough to match the maximum expected utility for manager k in country 2, $\bar{U}_2^k$. Analogously, if the inequality sign in (1.38) is reversed, then w_2^k is determined by the maximum expected utility for manager k in country 1. Hence, the equilibrium fixed wage of manager k depends on his *outside option*, the maximum expected utility in the country where he does not work in equilibrium.

Equation (1.38) also determines how the utility differential $\bar{U}_1^k - \bar{U}_2^k$ changes with the manager of type k. Since bonus payments z_i and rent factors $\Gamma^*(t_i)$ are independent of individual productivities, this is

$$\frac{\partial(\bar{U}_1^k - \bar{U}_2^k)}{\partial k} = a + \frac{\partial(x_1^k - x_2^k)}{k} \equiv \Phi > a. \tag{1.39}$$

This is unambiguously positive as managers with a higher k have both a higher location preference for country 1 and a relatively higher productivity, and wage, in this country.

For the manager of type $\hat{k}$, who is indifferent between the two banks in equilibrium, the equilibrium wage and the maximum wage coincide for both countries, $\bar{w}_i^{\hat{k}} = w_i^{\hat{k}}\ \forall\ i \in \{1, 2\}$. From (1.38) we then obtain the number of managers in country i as

$$N_i^\dagger = \bar{N} - \hat{k} = \bar{N} + \frac{1}{a}\left[\frac{\gamma}{2}(z_i^2 - z_j^2) + \Gamma^*(t_i) - \Gamma^*(t_j) + x_i^{\hat{k}} - x_j^{\hat{k}}\right] \quad i \neq j.$$

Differentiating gives

$$\frac{\partial N_i^\dagger}{\partial t_i} = \left[\tilde{z}_i \gamma \frac{\partial \tilde{z}_i}{\partial t_i} + \frac{\partial \Gamma^*}{\partial t_i} \right] \frac{1}{\Phi} = \frac{-\gamma \Omega^2 (2 + t_i)}{4(1 + t_i)^3} \frac{1}{\Phi}, \tag{1.40}$$

where Φ is given in (1.39) and the derivatives $\partial \tilde{z}_i / \partial t_i$ and $\partial \Gamma^*(t_i)/\partial t_i$ correspond to those in the previous section [eq. (1.35)].

Eq. (1.40) shows that the outmigration of managers differs from our benchmark analysis in eq. (1.20) in two respects. First, since $\Phi > a$, the denominator in (1.40) is increased. Hence the outmigration of managers following a bonus tax increase is reduced by location-specific productivities that are aligned with country preferences. Intuitively, as a bonus tax t_i drives managers out of country i, the remaining managers not only have a higher location preference for country i, but also tend to have a higher location-specific productivity in this country. This tends to reduce the outflow of managers for a given increase in t_i.

The second difference to our benchmark analysis is that the bonus tax has different effects on the bonuses and on the fixed wages chosen by banks. In this respect, the competition for managers with location-specific productivities has similar effects as the competition between multiple banks in the same country in Section 1.6.3. As we have seen there, these effects tend to reinforce the outmigration of managers following a tax increase, because higher bonus taxes not only reduce the bonus payment by banks, but also reduce the rent $\Gamma^*(t_i)$ and hence the fixed wage.

In sum, therefore, the effect of a bonus tax on the equilibrium number of managers, and hence the strength of the fiscal externality, may either be weaker or stronger in eq. (1.40), as compared to the benchmark analysis in eq. (1.20). If the relationship between location-specific productivities and location preferences is sufficiently strong, so that Φ is substantially larger than a from (1.39), then the first effect dominates and tax competition between the two countries is weakened. The bonus tax rates in the non-coooperative equilibrium will then be higher than in the benchmark setting if the 'race to the bottom' scenario applies ($F_i^* > 0$), but they will be lower in the 'race to the top' scenario ($F_i^* < 0$).

1.7 Conclusion

In this chapter we have incorporated international mobility of bank managers into a framework with two principal-agent problems. Banks choose their compensation structure, which consists of a fixed wage and bonus pay, so as to simultaneously induce managers to take the effort and risk choices desired by the principal, and to attract additional managers from abroad. In the event of failure, banks impose negative externalities on taxpayers, due to the existence of government guarantees. This gives rise to excessive bonus payments by banks, relative to those that would be socially optimal. Governments therefore choose bonus taxes to collect tax revenue and to counteract the distorted incentives of banks and their managers. In doing so, governments, like banks, are subject to the international competition arising from bank managers' mobility.

In such a setting non-cooperative levels of bonus taxes can generally be above or below the levels that would be optimal under policy coordination. Therefore there can be a 'race to the bottom' or a 'race to the top' in bonus taxes. The 'race to the top' result arises if bank managers have a negative fiscal value for the jurisdiction in which they work, inflicting expected losses on taxpayers that exceed bonus tax revenues. In this case, governments set bonus taxes above their Pareto efficient levels, in order to shift fiscal risks from domestic to foreign taxpayers.

The 'race to the top' result is specific to highly paid agents that, despite being a source of tax revenue, take risky decisions without bearing the full cost of it. It may explain the wave of very high marginal taxes on bankers' bonuses in the immediate aftermath of the 2008 financial crisis. More recently, however, the perceived risks from bank failures have fallen again, while jobs and profits in the banking sector have gained new importance. This may have changed incentives for governments once more, in the direction of a 'race to the bottom'. In the newly created European banking union the costs of bank defaults are furthermore shared between its member states, strengthening the incentives to adjust bonus taxes downwards. The coordinated cap on bonus payments that EU countries have recently enacted can therefore be seen as a direct complement to the creation of the banking union.

Our analysis can be extended in various directions. A first possible extension is to extend the set of government instruments and endogenize regulatory policies, which have been taken as exogenous in the present analysis. In such a setting it would also be interesting to consider country asymmetries that give rise to different regulatory and tax policies in the Nash equilibrium. A further interesting extension is to consider bank managers that are overconfident (see Ho et al., 2016 for recent evidence) and therefore overvalue the bonus component of their compensation. What does this imply for the banks' optimal compensation structure, and for the tax incentives of governments? We address this issue in Chapter 2.

Chapter 2

Overconfidence and Bailouts[1]

2.1 Introduction

Excessive risk-taking in the banking sector played a crucial role in the financial crisis of 2007-2009. Banks worldwide invested in large stocks of subprime mortgage-backed securities, which resulted in the bursting of the US housing bubble in the fall of 2007 (see e.g. Diamond and Rajan, 2009). Two of the main reasons for excessive risk-taking in the banking sector – which have so far only been considered independently – are government guarantees and managerial overconfidence.

In the part of the finance literature assuming perfectly rational agents, government guarantees are seen as a major cause for excessive risk-taking, as they weaken the incentive for bank creditors to price in banks' risk-taking. This lack of market discipline makes it attractive for shareholders to shift losses to the government. The empirical relevance of this risk-shifting incentive has been shown repeatedly. In the United States, for example, financial institutions that had previously received government assistance under the Troubled Asset Relief Program subsequently shifted to riskier assets (Duchin and Sosyura, 2014). In Germany, savings banks that had their government guarantees removed cut their credit risk substantially afterwards (Gropp et al., 2014).

In the behavioral finance literature, overconfident managers are seen as a core reason for excessive risk-taking.[2] Overconfident managers overestimate the expected return

[1] This chapter is based on Gietl (2018).

[2] Moore and Healy (2008) distinguish three notions of overconfidence: overestimation, overplacement, and overprecision. We focus on overconfidence as the manager's *overestimation* of the

on risky investments, which causes them to take on higher risks (see e.g. Hirshleifer and Luo, 2001; Malmendier and Tate, 2008; Gervais et al., 2011).

Overconfidence is particularly pronounced in complex, high-risk environments with noisy feedback, and thus under conditions that are vividly present in the banking sector.[3] Indeed, there is comprehensive evidence that banks with overconfident CEOs take on more risk. Banks governed by overconfident CEOs were more aggressive in lending before the financial crisis of 2007-2009. During the crisis years, these banks suffered from greater increases in loan defaults, larger declines of stock return performances, and a higher likelihood of failure than banks managed by non-overconfident CEOs (Ho et al., 2016).[4]

It is well established that managerial overconfidence and moral hazard arising from government guarantees are key reasons for excessive risk-taking in the banking industry. Up to this point, however, it has not been analyzed how overconfidence and government guarantees interact. It is thus neither clear how to regulate and tax financial markets that are simultaneously characterized by these two features nor how banks set up contracts in such an environment. We aim to fill these gaps by incorporating managerial overconfidence and limited bank liability into a principal-agent model of the banking sector. In this setting, we allow the government to optimally set a bonus tax in order to correct for the inefficiencies resulting from overconfidence and government guarantees.

Our framework is as follows. The model consists of three stages and three players. In the first stage, the government sets the welfare-maximizing bonus tax. We define welfare as the weighted sum of the bank's profit, the manager's utility, the government's bonus tax revenue and bailout costs. Stage 2 turns to the bank's maximization problem. The bank chooses the performance-related bonus and the fixed wage that maximize

success probability of his investment. Hence we relate to the empirical literature that investigates the effects of overconfidence on firm outcomes by using personal portfolios of top managers as a proxy for overconfidence (see e.g. Malmendier and Tate, 2005; Deshmukh et al., 2013).

[3]While there is substantial evidence that individuals generally overestimate their own abilities and talents (e.g. Taylor and Brown, 1988), there are several reasons why bank managers are supposed to be even more overconfident than the lay population (see Section 2.2.1 for details). Glaser et al. (2005) find that professional traders and investment bankers are indeed more overconfident than students.

[4]In addition, banks with overconfident CEOs generally experience higher stock return volatility (Niu, 2010) and have shown higher real estate loan growth prior to the financial crisis (Ma, 2015).

the bank's expected after tax profit. In the third stage, the manager decides whether to accept the bank's contract. If the manager accepts the contract, he unobservably chooses the level of effort and the risk of the bank's investment.

Based on the work of Besley and Ghatak (2013) and Hakenes and Schnabel (2014), we incorporate two principal-agent problems in our model. The first principal-agent problem arises between the government and the bank because of government guarantees. Government guarantees imply that the government will step in to partly bail out external investors if the bank defaults. External investors, knowing that they are paid even in case of a bank default, do not fully price in the bank's risk. Hence the bank has an incentive to induce excessive risk by means of high bonuses in order to draw on the government guarantees. The second principal-agent problem arises between the bank and the manager.[5] The banker has costs from effort- and risk-taking and thus does not provide as much effort and risk as desired by the bank. Since the bonus increases effort- and risk-taking, the bank can use it to influence both principal-agent problems to its own advantage.

The other key feature of our model – besides the moral hazard resulting from government guarantees – is managerial overconfidence. Seminal findings in the psychology literature show that individuals overestimate the probabilities of advantageous events, especially if the individuals believe to have control over the probabilities of those events (e.g. Langer, 1975) and if they are highly committed to the outcome (e.g. Weinstein, 1980). We incorporate these findings by modeling overconfidence as an overestimation of the returns to effort and risk-taking.[6] This implies that an overconfident manager exerts greater effort and risk, increases effort and risk more strongly for a marginal increase in the bonus, and overvalues the expected utility that he obtains from the bonus.

Our analysis delivers three main results. First, we derive the optimal bonus tax and find that it always increases in overconfidence, if risk-shifting incentives are strong. Gov-

[5]Caprio and Levine (2002) highlight two features that differentiate banks from nonfinancial firms. First, the greater safety net that accompanies banks. And second, the opaqueness of banks, which amplifies agency problems.

[6]De la Rosa (2011) gives an overview of the literature which indicates that agents overestimate their return to effort. Our assumption that overconfident managers overestimate the return to risk-taking is backed up by several finance studies that suggest overconfident CEOs have a higher tendency to undertake risky projects (e.g. Hirshleifer et al., 2012; Ho et al., 2016; Niu, 2010).

ernment guarantees create an externality of the bank's behavior on taxpayers, which is especially attractive for the bank to exploit when the manager is overconfident. In systemically important financial institutions, it is thus optimal to curb the social implications of overconfidence with a large bonus tax. In banks that receive a low level of government guarantees, however, the optimal bonus tax can decrease in overconfidence. This is because overconfident managers react more elastically to changes in the bonus and reduce their effort more strongly than rational managers when bonuses are taxed.

Second, we find that managerial overconfidence always necessitates an intervention into banker pay, even if shareholders fully internalize the externalities of their risk-taking. Overconfidence creates an incentive for the bank to increase its bonus in order to save compensation costs, because an overconfident manager overvalues the utility derived from bonuses. This incentive drives up bonuses and thus causes socially excessive risk-taking, even if shareholders have no incentive to draw on government guarantees. Unlike instruments regulating shareholders risk-taking incentives (e.g. capital requirements), a direct intervention into banker pay (e.g. via bonus taxes or bonus caps) can implement the socially desirable bonus, because these instruments additionally tackle the inefficiencies arising from the manager's overvaluation of the bonus.

Third, we find that overconfident bankers and banks with large government guarantees match in equilibrium. As banks with larger government guarantees benefit more from inducing excessive risk-taking by the manager, these banks also benefit more from hiring an overconfident manager. The selection of overconfident managers into banks that receive large bailout subsidies has substantial implications for taxpayers. It leads to a high default risk of these banks and causes large expected bailout costs for taxpayers. We argue that direct interventions into banker pay (e.g. a bonus tax or cap) are particularly suited to avoid the matching between overconfident managers and banks with large government guarantees. This is because banker pay interventions not only tackle risk-shifting incentives but also make it more costly for shareholders to exploit managerial overvaluation. Taken as a whole, the three main results of this chapter suggest that the presence of managerial overconfidence calls for bonus taxes in systemically important financial institutions. Bonus taxation can curb the bank's risk-shifting incentives, deter the exploitation of managerial overvaluation, and avoid the selection of overconfident managers into systemically important financial institutions.

This chapter relates to the literature on the optimal taxation and regulation of banker compensation. Besley and Ghatak (2013) examine the optimal tax-scheme for banker compensation in financial markets that are characterized by government guarantees. They find that this optimal tax-scheme is progressive in the size of the government guarantee and can increase both equity and efficiency. Investigating the international competition for bank managers, Gietl and Haufler (2018) find that there can be either a 'race to the bottom' or a 'race to the top' in bonus taxation when managers are mobile across countries and banks are protected by government guarantees. Hakenes and Schnabel (2014) and Thanassoulis and Tanaka (2018) investigate non-tax regulatory measures. Hakenes and Schnabel (2014) find that bonus caps are welfare-increasing for sufficiently large bailout expectations, because they curb the ability for banks to induce excessive risk. Thanassoulis and Tanaka (2018) show that a combination of clawback rules and restrictions on the curvature of pay can induce an executive to implement socially optimal risk choices. While these papers look at the optimal taxation and regulation, respectively, of compensation in the presence of government guarantees, they do assume fully rational bankers. This chapter contributes to this strand of literature by investigating how taxation and regulation have to adapt when bankers are not fully rational but overconfident.

A second important strand of literature concerns the effects of managerial overconfidence. Following the seminal paper of Malmendier and Tate (2005), an influential literature investigating the effects of managerial overconfidence on firm outcomes has emerged.[7] Empirical evidence shows that firms can benefit from CEO overconfidence, for example because overconfident CEOs capitalize on innovative growth opportunities better (Hirshleifer et al., 2012) and because firms can exploit the managerial overvaluation of incentive pay to lower compensation costs (Humphery-Jenner et al., 2016).[8] Overconfident CEOs, however, can also reduce shareholder value by engaging in value destroying investments and mergers (Malmendier and Tate, 2008). While this literature focuses on the impact of overconfidence on firm outcomes, we show how managerial overconfidence affects government policies.

We also contribute to the literature on the matching between overconfident managers and firm characteristics. Gervais et al. (2011) analyze how compensation contracts

[7] See Malmendier and Tate (2015) for an overview.

[8] De la Rosa (2011) and Gervais et al. (2011) show theoretically that firms have an incentive to exploit the managerial overvaluation of incentive pay.

optimally adapt to managerial overconfidence.[9] The authors find that, in equilibrium, overconfident managers are selected into risky, undiversified growth firms. Graham et al. (2013) show empirically that there is indeed a positive relationship between CEO overconfidence and growth firms. Beyond that, Hirshleifer et al. (2012) find that firms in innovative industries are more likely to be run by overconfident CEOs. This chapter shows that overconfident managers may also match according to the regulatory environment faced by banks, and are more likely to be found in banks with large government guarantees, low bonus taxes, and lax capital requirements.

This chapter is structured as follows. Section 2.2 introduces the basic setup of our three-stage model. Section 2.3 analyzes the effort- and risk-taking decisions of rational and overconfident managers. Section 2.4 investigates the maximization problem of the bank as well as the bank's optimal contract for the manager. Section 2.5 sets up our welfare function and derives the optimal bonus tax. Section 2.6 shows why overconfidence necessitates an intervention into banker pay. Section 2.7 investigates the competition for overconfident managers. Section 2.8 discusses several policy implications before Section 2.9 concludes.

2.2 Setup

The bank in our model is a financial intermediary, which is financed through equity and deposits.[10] We assume that the share of deposit financing is exogenously determined, for example by binding capital requirements. The depositors demand a fixed expected return for their deposits. In case of a bank default they are partly insured by the government (see below).

Assets: The bank's assets are normalized to 1 and consist of a risky portfolio. This portfolio can realize a high, a medium, or a low return ($Y^h > Y^m > Y^l = 0$). These investment returns are exogenous and publicly observable. The corresponding probabilities of the returns ($p^h > 0$, $p^m > 0$, and $p^l = 1 - p^h - p^m > 0$), however, are

[9] There is empirical evidence that firms adjust their contracts to managerial overconfidence. For instance, Humphery-Jenner et al. (2016) find that overconfident executives and non-executives receive incentive-heavier compensation contracts.

[10] For brevity, we call these units banks. However, our model generally also applies to non-bank financial intermediaries which are characterized by government guarantees and strong agency problems.

endogenously determined by the unobservable decisions of the manager on effort e and risk-taking b.

Following Hakenes and Schnabel (2014), we assume that the probabilities of the exogenous returns are linear functions of the manager's effort and risk-taking choices:

$$\begin{aligned} p^h &= \alpha e + \beta b, \\ p^m &= p_0^m - b, \\ p^l &= p_0^l - \alpha e + (1-\beta) b. \end{aligned} \tag{2.1}$$

Effort e increases the mean return of the portfolio as it shifts probability mass from p^l to p^h. Risk-taking b is modelled as a mean-preserving spread. It shifts probability mass from p^m to both p^l and p^h. Taking effort and risk involves private, non-monetary costs for the manager.[11] For simplicity, we assume that these cost functions are quadratic. The private effort and risk-taking costs of a manager are given by

$$c^e(e) = \frac{\eta e^2}{2} \qquad \text{and} \qquad c^b(b) = \frac{\mu b^2}{2}. \tag{2.2}$$

These private costs, along with non-observable effort and risk-taking choices by the manager, cause moral hazard problems between the manager and the bank. Specifically, the manager exerts less effort and risk-taking than desired by the bank. The bank can mitigate this principal-agent problem by paying a bonus z if the high return Y^h is realized, which incentivizes the manager to increase effort and risk. In addition to the bonus payment z, the bank can pay a fixed wage F that is independent of the realized return.

Government guarantees: As deposits are partly insured, a second principal agent problem arises between the government and the bank. In the case of bank default, Y^l, the government partly bails out depositors. This assumption is motivated by the

[11] As in Hakenes and Schnabel (2014), $b = 0$ can be interpreted as the natural risk-level. Raising risk beyond this natural risk-level (i.e., choosing $b > 0$) causes private costs as the manager has to actively search for riskier investments or to move into new asset classes. Hence the parameter b can be seen as the effort to increase the risk level beyond its natural level, whereas the parameter e can be interpreted as the productive effort that increases the mean return of the portfolio.

presence of deposit insurance in essentially all developed countries.[12] The partially insured investors do not fully price in the default probability of the bank, which enables the bank to shift losses to the government. Hence, the bank has an incentive to use the bonus z to incentivize the manager to take on excessive risk at the expense of the government.[13]

The government is aware of this risk-shifting problem and uses bonus taxation to correct the bank's distorted incentives. Our baseline model focuses on this policy instrument, as the bonus tax not only acts as a Pigovian tax, but also redistributes from the financial sector to taxpayers. This redistributive aspect reflects the goal of many governments to get the financial sector to "make a fair and substantial contribution toward paying for any burden associated with government interventions to repair the banking system" (International Monetary Fund, 2010). A bonus cap, as an alternative measure to intervene in banker pay, will be discussed in Section 2.6.1.

2.2.1 Overconfidence

As managerial overconfidence is an integral part of our analysis, this subsection motivates and explains our modelling of overconfidence. In our model, an overconfident manager overestimates his skills and thus overestimates the returns to effort and risk-taking. The psychology literature shows that individuals generally overestimate their own abilities and talents (see Taylor and Brown, 1988, for a review) and the probabilities of advantageous events (e.g. Langer, 1975). As Taylor and Brown (1988) conclude: "A great deal of research in social, personality, clinical, and developmental psychology documents that normal individuals possess unrealistically positive views of themselves [and] an exaggerated belief in their ability to control the environment".

There are several reasons why top bank managers are likely to be more overconfident

[12]Barth et al. (2006) provide an overview of deposit insurance schemes and discuss their welfare effects. A more complex model would motivate the existence of deposit insurance as a means to avoid bank runs when banks engage in maturity transformation (cf. Diamond and Dybvig, 1983). We, however, focus on the principal agent problems that characterize the banking industry and thus follow the dominant approach in the literature (e.g. Besley and Ghatak, 2013; Hakenes and Schnabel, 2014) and assume government guarantees to be exogenously given.

[13]This argument illustrates why the bank does not pay a bonus in the medium state, Y_m. A bonus in the medium state would reduce the manager's risk-taking incentives and thus lower the bank's profits derived from the government guarantee.

than the lay population. First, successful bankers are likely to become overconfident due to the self-attribution bias. Top bankers have experienced success in their careers. As individuals generally overestimate the extent to which they have contributed to their own success (Langer, 1975), successful bankers and traders are especially prone to becoming overconfident (see e.g. Daniel et al., 1998; Gervais and Odean, 2001).[14] Second, selection effects may imply that overconfident individuals are more likely to become top bankers than non-overconfident people. For example, overconfident individuals overestimate the expected value of performance pay and thus self select into jobs with high performance pay such as banking. Finally, Goel and Thakor (2008) show that if firms promote based on the best performances, then overconfident managers are more likely to be promoted as they take on larger risks.[15]

Due to the manager overestimating the returns to effort and risk-taking, the probabilities as perceived by an overconfident manager differ from the actual probabilities. We denote parameters as perceived by an overconfident manager with a hat. The probabilities as considered by the manager are given by

$$\begin{aligned} \hat{p}^h &= (1+\ \theta)(\alpha e + \beta b), \\ \hat{p}^m &= p_0^m - b, \\ \hat{p}^l &= p_0^l - (1+\ \theta)\alpha e + b[1 - \beta(1+\ \theta)], \end{aligned} \tag{2.3}$$

The parameter θ in eq. (2.3) measures the level of overconfidence. For $\theta = 0$ the manager is rational and evaluates the probabilities correctly as in eq. (2.1). For $\theta > 0$, however, the manager overestimates the probability of the high state ($\hat{p}^h > p^h$) and underestimates the default probability ($\hat{p}^l < p^l$). Our analysis will show that overconfidence affects the bank's optimal bonus and fixed wage, and thus critically influences the principal-agent problems both between the bank and the manager, and between the government and the bank.

In the following sections we analyze our sequential three-stage model. In Stage 1, the

[14] If agents receive *negative* (but unbiased) noisy feedback on their own performance, however, then they attribute the negative feedback to being unlucky (i.e., they think their feedback underrepresents their individual performance), as shown by Grossman and Owens (2012).

[15] First evidence confirms that top bankers are indeed more overconfident than the general population. Using questionnaires and experiments, Glaser et al. (2005) find that professional traders and investment bankers are more overconfident than students. Graham et al. (2013) examine psychometric tests and conclude that CEOs are more optimistic than the general population.

government sets its welfare-maximizing bonus tax t. In Stage 2, the bank chooses the profit-maximizing bonus z and fixed wage F. Stage 3 analyzes the decisions of the manager. The manager chooses whether to accept the bank's contract based on his *perceived* expected utility. If the manager accepts the contract, he decides on the levels of effort and risk. We proceed to solve our model by backward induction.

2.3 Stage 3: Manager's Choices and Perceived Utility

In Stage 3, the government has set its bonus tax t and the bank has chosen the manager's contract (z and F). Given his contract, the manager maximizes his *perceived* expected utility. For an overconfident manager the perceived expected utility deviates from his actual expected utility as he misjudges the probabilities of the exogenous returns.

The risk-neutral manager receives the bonus z if and only if state h occurs.[16] On top of that, he obtains the fixed wage F in any state. The perceived expected utility is given by

$$\hat{u} = (1+\theta)(\alpha e + \beta b)z + F - \frac{\mu b^2}{2} - \frac{\eta e^2}{2}. \tag{2.4}$$

Eq. (2.4) shows that the perceived expected utility depends positively on the manager's estimate of the success probability $[\hat{p}^h = (\alpha e + \beta b)(1+\theta)]$, the bonus z, and the fixed wage F. The perceived expected utility decreases in the risk-taking costs, $\frac{\mu b^2}{2}$, and the effort-taking costs, $\frac{\eta e^2}{2}$.

Maximizing (2.4) with respect to e and b, we obtain

$$e^* = \frac{(1+\theta)\alpha z}{\eta}, \tag{2.5}$$

$$b^* = \frac{(1+\theta)\beta z}{\mu}. \tag{2.6}$$

Hence both the manager's effort level e and the risk level b increase in the level of overconfidence θ and the bonus payment z. Note that the manager's optimal effort and risk level do not depend on the fixed wage F.

[16] Thanassoulis (2012) reviews the literature on risk preferences of bankers and finds that bankers are risk neutral or very mildly risk averse.

Using (2.5) and (2.6) in (2.1), we can derive the equilibrium probabilities of the different returns:

$$
\begin{aligned}
p^{h*} &= \left[\frac{\alpha^2}{\eta} + \frac{\beta^2}{\mu}\right] z(1+\theta) \equiv \gamma z(1+\theta), \\
p^{m*} &= p_0^m - \frac{\beta}{\mu} z(1+\theta), \\
p^{l*} &= p_0^l + \left[(1-\beta)\frac{\beta}{\mu} - \frac{\alpha^2}{\eta}\right] z(1+\theta) \equiv p_0^l + \delta z(1+\theta).
\end{aligned}
\tag{2.7}
$$

A higher bonus leads to more effort and risk-taking, which both unambiguously increase p^h. The sign of δ in eq. (2.7) determines whether the marginal effect of the bonus on the low return probability p^l is positive or negative. On the one hand, a higher bonus induces more risk-taking, which increases δ and thus also p^l. On the other hand, a higher bonus leads to more effort, which reduces δ and therefore p^l. In what follows, we assume that $\delta > 0$, implying that the risk effect of the bonus dominates the effort effect and a higher bonus increases the bank's default probability p^l.[17] The effect of the bonus on the medium probability is unambiguously negative, as the bonus shifts probability mass away from the medium state to incentivize risk-taking. Note that an increase in overconfidence amplifies the marginal effects of the bonus on the equilibrium probabilities as overconfidence increases the marginal effect of the bonus on effort- and risk-taking. The equilibrium probabilities are independent of the fixed wage.

Finally, substituting (2.5) and (2.6) in (2.4) gives us the maximized perceived expected utility

$$
\hat{u}^* = \frac{\gamma}{2}(1+\theta)^2 z^2 + F. \tag{2.8}
$$

This shows that both a higher bonus and a higher fixed wage increase the perceived utility. An overconfident manager ($\theta > 0$) overvalues the influence of the bonus on his utility as he overestimates the likelihood of receiving the bonus ($\hat{p}^h > p^h$).

[17]This is in line with Efing et al. (2015), who find that pre-crisis incentive pay was positively correlated with the volatility of bank-trading income and too high to maximize the banks' Sharpe ratio. Cheng et al. (2015) show that there is a positive correlation of higher-powered banker incentives and the probability of losses.

2.4 Stage 2: Bank's Bonus and Fixed Wage Decisions

In Stage 2, we turn to the bank and its behavior. In Section 2.4.1 we look at the bank's financing constraint and how it is influenced by government guarantees and overconfidence. Section 2.4.2 derives and discusses the bank's optimal contract (z and F).

2.4.1 Financing Constraint

The bank is financed by a share $1-s$ of equity and a share s of deposits ($s \in [0;1]$). The share of deposits is determined by an exogenous minimum capital requirement. As the bank prefers deposits over equity due to the deposit insurance, the capital requirement is always binding. The risk-neutral depositors demand an expected return of d per unit of deposits. As the bank's asset volume is normalized to 1, depositors thus demand a total return of sd. We assume that, if the returns Y^h or Y^m are realized, the bank is able to repay the depositors an agreed return $s(d+X)$, where X is the additional unit return the depositors require in order to be compensated for their potential loss in state l. If the bank defaults ($Y^l = 0$), then the bank does not repay the depositors. Instead the government pays an exogenous share $v_i \in [0;1]$ of sd to the depositors of bank i. This share v_i can be interpreted as the level of government guarantees that bank i receives. The financing constraint is then given by

$$(1-p^l)s(d+X) + p^l v_i sd = sd. \tag{2.9}$$

Solving for X, we obtain

$$X = \frac{dp^l(1-v_i)}{1-p^l}. \tag{2.10}$$

Eq. (2.10) shows that the higher is the government guarantee v_i, the smaller is the extent as to which the default probability of the bank, p^l, is priced in by depositors. If depositors are completely insured by the government (i.e., $v_i = 1$), they do not price in the default risk at all ($X = 0$), because the depositors receive their full repayment even in the case of bank default.

Note that the default probability p^l depends positively on the level of overconfidence θ (see eq.(2.7)). An overconfident manager takes on more risk, which increases the likelihood that the bank does not pay back depositors. The lower the government guarantee, the more strongly depositors price in the overconfidence of the manager.

2.4.2 Contract

The expected bank profit is given by

$$\Pi = p^{h*}[Y^h - z(1+t) - s(d+X)] + p^{m*}[Y^m - s(d+X)] - F - (1-s)d. \quad (2.11)$$

Eq. (2.11) shows that the expected bank profit consists of the state-specific profit of the bank in the high and the medium state (weighted by the respective equilibrium probabilities), minus the fixed wage and the opportunity costs of shareholders. If the bank realizes Y^h, it pays $s(d+X)$ to its depositors, the net bonus z to its manager, and bonus taxes tz to the government. In state m, the bank receives a portfolio return of Y^m and pays back $s(d+X)$ to depositors.

If the bank obtains the low return $Y^l = 0$, then it does not pay back depositors. In this case the payments to depositors are partially covered by the deposit insurance, which does not enter the bank's profit expression. As the fixed wage F is paid by the bank in all states, bank's shareholders realize a loss in the case of default.[18] Finally, the term $(1-s)d$ gives the opportunity costs of shareholders. This is the product of the share of equity financing $(1-s)$ and the rate of return, which we assume to equal the expected unit return of depositors, d.

The bank sets the bonus z and the fixed wage F to maximize its expected after-tax profits. We assume that the bank needs the manager to run the bank and that it is thus always in the bank's best interest to hire the manager.

Substituting the financing constraint in (2.10) into (2.11), the bank's maximization

[18]We thus assume that the bank's equity can cover the fixed wage, $F < (1-s)d$.

problem is given by

$$\begin{aligned}
\max_{z,F}\ \Pi &= p^{h*}[Y^h - z(1+t)] + p^{m*}Y^m - F - (1-s)d + p^{l*}v_i sd - sd \\
s.t.\ p^{h*} &= \gamma z(1+\theta) \\
p^{m*} &= p_0^m - \frac{\beta}{\mu} z(1+\theta) \\
p^{l*} &= p_0^l + \delta z(1+\theta) \\
\hat{u}^* &= \frac{\gamma}{2}(1+\theta)^2 z^2 + F \geq \bar{u}. \qquad (2.12)
\end{aligned}$$

The bank's maximization problem in eq. (2.12) effectively has three constraints: the *financing constraint*, the *incentive constraint*, and the *participation constraint*. First, the *financing constraint* implies that the bank has to ensure that depositors invest in the bank. As the depositors are partly insured by the government and do not accurately price in the bank's default risk, the bank derives a subsidy $p^{l*}v_i sd$ from the government guarantee. Second, the *incentive constraint* implies that the bank has to take into account that the equilibrium probabilities are affected by the bonus z. A higher bonus increases effort and risk-taking of the manager, which increases p^{h*} and p^{l*} and decreases p^{m*}. And third, the *participation constraint* implies that the manager's perceived expected utility of the bank's contract must be at least as large as the manager's fixed outside utility ($\bar{u}$). Otherwise the manager will not accept the contract.

We restrict our analysis to the case where both the bonus z and the fixed wage F are used in equilibrium, which is the case generally observed for senior managers.[19] The fixed wage is only used to satisfy the banker's participation constraint (cf. eq. (2.12)). We assume that for all possible levels of bonus taxes (i.e., $t \geq 0$), the condition for the fixed wage to be used holds. This condition is derived in Appendix B.1 and given by

$$(1+\theta) < \frac{2\sqrt{2\bar{u}\gamma}}{\frac{\alpha^2}{\eta}Y^h + \delta v_i sd + \sqrt{2\bar{u}\gamma}}. \qquad (2.13)$$

First, (2.13) rules out the case where the manager is so overconfident that the bonus is too attractive for the bank to pay a positive fixed wage. And second, the condition also ensures that the utility of the manager's outside option, $\bar{u}$, is sufficiently large for the fixed wage to be used.

[19] For bankers earning more than 1 million euros in EU banks, for example, the average ratio between variable and fixed pay was 104% in 2016 (European Banking Authority, 2018).

The first order condition of the bonus z is given by[20]

$$\frac{\partial \Pi}{\partial z} = \frac{\alpha^2}{\eta} Y^h (1+\theta) - 2(1+t)\gamma z(1+\theta) + \delta v_i sd(1+\theta) + \gamma z(1+\theta)^2 = 0. \quad (2.14)$$

An increase in the bonus has four effects on the bank's profit. First, the bonus increases effort-taking of the manager, which increases the mean return of the bank's portfolio. Second, the monetary bonus costs of the bank rise. Third, the bonus increases risk-taking of the manager, which shifts the costs of repaying depositors to the government.

And fourth, the bonus reduces the fixed wage that is necessary for the bank to fulfill the participation constraint of the manager. Importantly, this effect is especially strong for an overconfident manager. Intuitively, as the overconfident manager overestimates the probability of obtaining the bonus ($\hat{p}^h > p^h$), he also overvalues the expected utility he derives from the bonus. This overvaluation creates the possibility for the bank to lower its expected compensation costs at the expense of the biased manager by increasing the bonus and lowering the fixed wage.[21]

The bank's profit-maximizing bonus z_B increases in the marginal profit of a costless bonus, $(1+\theta)\Omega$, and decreases in the marginal net costs of the bonus, $(1+\theta)\Psi$, as shown by

$$z_B = \frac{(1+\theta)\Omega}{(1+\theta)\Psi} = \frac{\Omega}{\Psi},$$
$$\text{where } \Omega \equiv \frac{\alpha^2}{\eta} Y^h + \delta v_i sd > 0 \text{ and } \Psi \equiv \gamma[2(1+t) - (1+\theta)] > 0. \quad (2.15)$$

A costless bonus increases the banker's effort and risk-taking, which raises the probability of realizing the high return, and the probability to draw on the government guarantee. The higher are the bank's risk-shifting incentives ($\delta v_i sd$), the higher is the bank's bonus. The marginal net costs of the bonus, $(1+\theta)\Psi$, are the marginal bonus costs of the bank (which rise in the bonus tax t) minus the bank's marginal savings on

[20]See Appendix B.1 for the detailed solution of the bank's maximization problem in eq. (2.12).

[21]Humphery-Jenner et al. (2016) provide empirical evidence that firms exploit overconfident CEO's overvaluation of incentive pay in order to lower compensation costs. The incentive to exploit managerial overvaluation has also been derived theoretically by De la Rosa (2011) and Gervais et al. (2011).

the fixed wage.[22] These marginal savings stem from the fact that a higher bonus reduces the fixed wage that is necessary to fulfill the manager's participation constraint. Note that the savings are larger for an overconfident manager, as he overvalues the utility that he derives from the bonus and is therefore willing to accept a lower fixed wage. The assumption in (2.13) ensure that $2-(1+\theta)>0$ and thus that the net costs are positive ($\Psi>0$).

The bank's profit-maximizing fixed wage F_B is given by

$$F_B=\bar{u}-\frac{\gamma}{2}(1+\theta)^2 z_B^2=\bar{u}-\frac{\gamma(1+\theta)^2\Omega^2}{2\Psi^2}. \tag{2.16}$$

The fixed wage F_B rises in the utility of the manager's outside option and falls in the manager's level of overconfidence. The latter is due to overconfidence making the bonus relatively more attractive (substitution effect) and lowering the overall compensation needed for satisfying the manager's participation constraint (income effect). A bonus tax increases the fixed wage as it reduces the bonus z_B.

To sum up, the more overconfident the manager, the higher is the bonus that he receives and the lower is his fixed wage. First, this is due to the overconfident manager increasing his effort- and risk-taking more for a given increase in the bonus than a rational manager. And second, an overconfident manager overvalues the bonus. Hence bonuses become more attractive for the bank as they can be used to exploit the manager and lower compensation costs. We also find that the bonus increases in the level of the government guarantee. This is because the government guarantee makes risk-taking more attractive, which can be induced with bonuses.

2.5 Stage 1: Government

In this section we look at the role of the government. In Section 2.5.1 we define and discuss the welfare function. Section 2.5.2 derives the optimal bonus tax and Section 2.5.3 analyzes its properties.

[22] The bonus tax thus always reduces the bonus in our model. Dietl et al. (2013) show that it can be optimal for a principal to increase bonuses as a response to a bonus tax, if an agent is highly risk-averse. The literature on banker's risk preferences, however, shows that banker's are very mildly risk averse or even risk neutral (see Thanassoulis, 2012).

2.5.1 Welfare Function

The government maximizes welfare with respect to the bonus tax t. Bonus taxation can be used to redistribute from the financial sector to taxpayers. Moreover, the bonus tax affects the manager's effort and risk-taking choices in equilibrium. As the government guarantee leads to diverging interests between the bank and the government, the risk-reducing effect of the bonus tax is a valuable Pigouvian tool to decrease the likelihood of bailouts.

Our social welfare function takes into account the bank's profit Π^* in eq. (2.12) and the manager's *actual* expected utility $u = p^{h*} z_B + F_B - \frac{\eta e^{*2}}{2} - \frac{\mu b^{*2}}{2}$.[23] Additionally, the social welfare function entails the government's bailout costs, B, and its bonus tax income T.[24]

The bailout costs are given by

$$B = p^{l*} v_i sd = \left[p_0^l + \delta z_B(1+\theta)\right] v_i sd. \tag{2.17}$$

Note that eq. (2.17) implies that overconfidence increases the likelihood of bailouts, p^{l*}, for two reasons. First, for a given contract, overconfident managers take on more risk as they overestimate the success probability of risky investments. And secondly, the bank creates higher powered compensation contracts for overconfident managers, which amplifies the behavioral effects of overconfidence and increases risk-taking further. As overconfidence raises the likelihood of bailouts, it increases the transfer of taxpayer money to the bank.

The tax revenue T is given by

$$T = t p^{h*} z_B = t(1+\theta)\gamma z_B^2. \tag{2.18}$$

Hence overconfident managers create larger tax revenues, as they generate higher expected bonus payments, $p^{h*} z_B$. First, overconfident managers receive a higher bonus. And secondly, they take on more effort and risk, which lead to a higher probability of

[23]For the *actual* expected utility, the utility derived from the bonus is weighted by the actual probability of the bonus p^h in eq. (2.7) and not by the perceived probability $\hat{p}^h$ as in the perceived utility in eq. (2.4). This is because the *actual outcome* of the manager is determined by p^h and not by his biased beliefs $\hat{p}^h$.

[24]The risk-neutral depositors always receive an expected return of sd independent of the bonus tax. Their payoffs are thus not included explicitly in our welfare function.

the bonus being paid, p^{h*}. Hence with respect to the tax revenue, the government can benefit from overconfident managers as they generate more bonus tax income.

We normalize the welfare weights of the banker and the shareholders to 1 and weigh the bailout costs B and the tax revenue T by λ. We argue that a monetary unit in the pocket of the government is worth more than a monetary unit for the bank or the banker (i.e., $\lambda > 1$). This is due to the marginal costs of public funds, which are the loss of society that the government causes when it raises additional revenues to finance its spending (see e.g. Browning, 1976).[25]

Substituting the bank profit from eq. (2.12), our welfare function is thus given by

$$\begin{aligned} W &= \Pi^* + u + \lambda(T - B) \\ &= p^{h*}(Y^h - tz_B) + p^{m*}Y^m + p^{l*}v_i sd - (1-s)d - sd - \frac{\eta e^{*2}}{2} - \frac{\mu b^{*2}}{2} \\ &\quad + \lambda(tp^{h*}z_B - p^{l*}v_i sd). \end{aligned} \tag{2.19}$$

The welfare function can be subdivided into three parts. First, the first five terms in the second line of eq. (2.19) capture the bank's profit net of the bank's payments to the banker (cf. eq. (2.12)). Note that the expected bonus payments $p^{h*}z$ and the fixed wage F are simply transfers from the bank to the banker and therefore do not directly affect welfare in eq. (2.19). Second, the behavioral costs of the manager (i.e., the effort- and risk-taking costs $\frac{\eta e^{*2}}{2}$ and $\frac{\mu b^{*2}}{2}$) lower welfare, because they reduce the manager's utility.

Finally, the government's net revenue (i.e., tax revenue minus bailout costs) is shown in the third line of eq. (2.19). The government's net revenue is positive, if the tax revenue dominates the bailout costs. It is also possible, however, that the expected bailout costs B dominate the tax revenue T, which implies a negative net revenue for the government. This is the case when the exogenous default probability of the bank p_0^l is large and when the level of government guarantees v_i is high.

[25]The higher weight of tax income and bailout costs in our welfare function can also be explained by a preference for redistribution from banker income and bank profits to taxpayers.

2.5.2 Optimal Bonus Tax

We now proceed to derive the optimal bonus tax t^*. Substituting eqs. (2.5)-(2.7) into (2.19) and differentiating the welfare function with respect to t gives

$$\begin{aligned}\frac{\partial W}{\partial t} = (1+\theta) \times \Big\{ & \frac{\alpha^2}{\eta} Y^h \frac{\partial z_B}{\partial t} - \gamma(1+\theta) z_B \frac{\partial z_B}{\partial t} \\ & + \ (\lambda - 1) \left[\gamma(2 z_B \frac{\partial z_B}{\partial t} t + z_B^2) - \delta v_i s d \frac{\partial z_B}{\partial t} \right] \Big\}. \end{aligned} \tag{2.20}$$

On the one hand, a bonus tax lowers the mean return of the bank's investment due to the lower effort-taking incentives ($\frac{\alpha^2}{\eta} Y^h \frac{\partial z_B}{\partial t} < 0$). On the other hand, the bonus tax has several positive welfare implications. First, it reduces the manager's effort and risk-taking costs ($-\gamma(1+\theta) z_B \frac{\partial z_B}{\partial t} > 0$). Second, the bonus tax redistributes from the financial sector to the government. Note that the tax revenue is especially high for overconfident managers as they receive a higher bonus z and take on more effort and risk for a given bonus. Finally, the bonus tax reduces the net bailout costs, $(\lambda - 1) p^{l*} v_i s d$, as it lowers risk-taking incentives. This is particularly desirable when banks receive large government guarantees and employ overconfident managers.

Whether the bonus tax is used in equilibrium is determined by the first order condition at $t = 0$, which is derived in Appendix B.2 and given by

$$\frac{\partial W}{\partial t}_{|t=0} = \left[\frac{\gamma^2 \Omega (1+\theta)}{\Psi^3} \right] \{ [2 - (1+\theta)][2\lambda \delta v_i s d + (\lambda - 1)\Omega] + 4\theta\Omega \} > 0. \tag{2.21}$$

Eq. (2.21) shows that the first marginal unit of bonus tax always increases welfare. The bonus tax lowers the bank's profit. At $t = 0$ this negative welfare effect is always dominated by the positive effects, namely the reduction of bailout costs, the increase in tax revenue, and the reduction of the manager's effort and risk costs.

We now investigate the condition for the bonus tax to be finite. In Appendix B.2 we show that $\frac{\partial W}{\partial t} > 0 \ \forall t$, if and only if $\delta v_i s d > \frac{(\lambda+1)\frac{\alpha^2}{\eta} Y^h}{(\lambda - 1)}$. Hence if the risk-shifting incentives, $\delta v_i s d$, are very large, then the government optimally sets $t^* \to \infty$ in order to minimize the bailout costs caused by the bonus. If, however,

$$\delta v_i s d < \frac{(\lambda + 1)\frac{\alpha^2}{\eta} Y^h}{\lambda - 1}, \tag{2.22}$$

then there is an interior solution for t^* (see Appendix B.2).

Setting the first order condition in eq. (2.20) equal to zero, we get the optimal interior bonus tax

$$t^* = \frac{[2-(1+\theta)][(\lambda-1)\Omega + 2\lambda\delta v_i sd] + 4\theta\Omega}{2[(\lambda+1)\Omega - 2\lambda\delta v_i sd]}. \tag{2.23}$$

Note that the condition for the interior solution in eq. (2.22) implies that the denominator of the optimal bonus tax in eq. (2.23) is always positve.

2.5.3 Comparative Statics

We can now use comparative statics for eq. (2.23) to analyze the properties of the optimal bonus tax. Differentiating t^* with respect to v_i gives

$$\frac{\partial t^*}{\partial v_i} = \frac{4\delta sd\{\lambda^2[2-(1+\theta)]\frac{\alpha^2}{\eta}Y^h + (\lambda-1)\theta\Omega\}}{2\left[(\lambda+1)\Omega - 2\lambda\delta v_i sd\right]^2} > 0. \tag{2.24}$$

Eq. (2.24) shows that the optimal bonus tax increases in the level of bailout guarantees v_i. The larger the bailout guarantees, the stronger the risk-taking incentives of the bank, since depositors price in the bank's risk-taking to a smaller extent. Hence bailout guarantees make the bonus tax more attractive, as the tax curbs the bank's excessive risk-taking.

The effect of a tightening of capital requirements on the optimal bonus tax is given by

$$\frac{\partial t^*}{\partial(1-s)} = \frac{-4\delta v_i d\{\lambda^2[2-(1+\theta)]\frac{\alpha^2}{\eta}Y^h + (\lambda-1)\theta\Omega\}}{2\left[(\lambda+1)\Omega - 2\lambda\delta v_i sd\right]^2} < 0. \tag{2.25}$$

Tighter capital requirements (i.e., larger $1-s$) reduce the leverage of the bank, which implies that the bank can shift fewer costs onto the government. This decreases the marginal benefit of the tax that arises from reducing the bailout costs. Hence capital requirements and bonus taxes are strategic substitutes.

The effect of the weight of the government's net revenue, λ, on the optimal bonus tax is given by

$$\frac{\partial t^*}{\partial\lambda} = \frac{\Omega\left[(1+\theta)\delta v_i sd + \frac{\alpha^2}{\eta}Y^h(1-3\theta)\right]}{\left[(\lambda+1)\Omega - 2\lambda\delta v_i sd\right]^2}. \tag{2.26}$$

For a rational manager ($\theta = 0$), an increase in the weight of the government's net revenue λ always raises the optimal bonus tax t^*. This is because a higher tax reduces the government's bailout costs and can raise tax revenue, while it hurts the bank's profits.

If the manager is overconfident ($\theta > 0$), the effect of λ on the optimal tax depends on the strength of the bank's risk-shifting incentives. If the bank's risk-shifting incentives are strong (i.e., $\delta v_i sd$ is large and $\frac{\alpha^2}{\eta} Y^h$ is low), then the optimal tax rises in λ, as it becomes increasingly important for the government to reduce its bailout costs.

If the risk-shifting incentives are weak (i.e., $\delta v_i sd$ is small and $\frac{\alpha^2}{\eta} Y^h$ is large), however, a net revenue maximizing government is mainly concerned with the bonus tax revenue the manager generates. In this case, the government maximizes welfare by setting a low bonus tax for an overconfident banker, as the effort of an overconfident manager reacts especially elastically to the bonus tax. This is because overconfident managers overestimate the likelihood of obtaining the bonus, and thus react more elastically to changes in the bonus (cf. the optimal effort in eq. (2.5)). Hence eq. (2.26) shows that if the manager is sufficiently overconfident and risk-shifting incentives are low, an increase in λ can actually lower the optimal bonus tax, because the government does not want to distort the especially elastic effort of an overconfident manager.

Finally, we investigate how the optimal bonus tax depends on overconfidence. Differentiating t^* in eq. (2.23) with respect to θ, we get

$$\frac{\partial t^*}{\partial \theta} = \frac{5\Omega - \lambda\Omega - 2\lambda\delta v_i sd}{2\left[(\lambda+1)\Omega - 2\lambda\delta v_i sd\right]}. \tag{2.27}$$

If the bank's risk-shifting incentives are sufficiently strong ($\delta v_i sd > 3\frac{\alpha^2}{\eta} Y^h$), then overconfidence always increases the optimal bonus tax t^*, as shown in Appendix B.3.[26] An overconfident manager overestimates the returns to risk. Hence managerial overconfidence makes it cheaper for the bank to induce risk-shifting and to draw on the bailout subsidy. These risk-shifting incentives are socially undesirable and can be mitigated with a larger bonus tax.[27]

In other words, overconfidence mitigates the principal-agent problem between the bank and the manager as it becomes cheaper for shareholders to align the manager's behavior with the bank's objective. This is detrimental for welfare, however, if risk-shifting incentives are strong, because it becomes easier for the bank to exploit the

[26]Appendix B.3 also shows that the condition $\delta v_i sd > 3\frac{\alpha^2}{\eta} Y^h$ does not preclude an interior equilibrium for the bonus tax.

[27]It is also easy to see from eq. (2.27) that overconfidence always increases the optimal tax for a sufficiently low weight of the government's net revenue ($\lambda < \frac{5}{3}$).

government subsidy. Hence the principal-agent problem between government and bank becomes more severe in the presence of overconfidence, and the government optimally sets a higher bonus tax in order to align the bank's with the government's interests.

Appendix B.3 shows that a negative effect of overconfidence on the optimal bonus tax arises if simultaneously the risk-shifting incentives are sufficiently weak ($\delta v_i sd < \frac{\alpha^2}{\eta} Y^h$) and the weight of the government's net revenue is large ($\lambda > 5$).[28] In this case the government mainly aims to maximize its bonus tax revenue T. As an overconfident manager's effort reacts more elastically to changes in the bonus, the government then optimally sets a lower bonus tax for an overconfident banker.

We summarize our main results of Section 2.5 in

Proposition 2.1 *Optimal bonus tax*

If eq. (2.22) *holds, then*

(i) *the welfare-maximizing bonus tax* t^* *is given in eq.* (2.23).

(ii) t^* *always increases in the level of overconfidence* θ*, if the risk-shifting incentives are sufficiently strong* ($\delta v_i sd > 3\frac{\alpha^2}{\eta} Y^h$).

Proofs: Appendices B.2 and B.3.

The key finding in Proposition 2.1 is that the optimal bonus tax always increases in overconfidence, if risk-shifting incentives are sufficiently strong. This is particularly the case for systemically important financial institutions as they receive bailout subsidies through both explicit and implicit government guarantees. These guarantees create an externality of the bank's behavior on taxpayers, which is especially attractive to exploit if the manager is overconfident. In systemically important financial institutions, it is thus optimal to curb the social implications of overconfidence with a higher bonus tax.

Recent evidence shows that managerial overconfidence indeed not only affects firm outcomes, but also causes substantial externalities. Banks with overconfident CEOs generally experience higher stock return volatility (Niu, 2010) and have shown higher real estate loan growth prior to the financial crisis (Ma, 2015). During the recent financial crises, banks managed by CEOs suffered from greater increases in loan defaults

[28] This is a sufficient but not a necessary condition for the effect of overconfidence on the optimal bonus tax to be negative (see Appendix B.3).

and a higher likelihood of failure than banks governed by non-overconfident CEOs (Ho et al., 2016). Due to the large externalities on taxpayers caused by banks' risk-taking and failures, it is necessary for the government to counteract the adverse effects arising from overconfidence in the banking industry. In the following section we discuss why the bonus tax is better suited to do so than other instruments (e.g. capital requirements).

2.6 Do we need to Intervene in Banker Pay?

Following the financial crisis of 2007-2009 a lively discussion has emerged about whether or not the government should intervene in banker pay. We shed light on the role of managerial overconfidence in this debate in the following. To do so, Section 2.6.1 derives the socially optimal bonus and compares it to the bonus set by the bank. Section 2.6.2 then uses the example of capital requirements to illustrate why the socially optimal bonus cannot be obtained without interventions in banker pay, if bankers are overconfident.

2.6.1 Socially Optimal Contract

In this section we derive the socially optimal bonus when the government does not directly intervene in the banker's compensation (i.e., $t = 0$). We then compare this bonus to the one chosen by the bank.

In Appendix B.4 we maximize the welfare function in eq. (2.19) with respect to the bonus, which gives us the socially optimal bonus:

$$z_{S_{|t=0}} = \frac{\frac{\alpha^2}{\eta}Y^h - \delta v_i sd(\lambda - 1)}{\gamma(1+\theta)} = \frac{\Omega - \lambda\delta v_i sd}{\gamma(1+\theta)}. \tag{2.28}$$

We can now investigate how the bank's bonus in eq. (2.15) deviates from the socially optimal bonus, if the government does not intervene into banker pay:

$$z_{B_{|t=0}} - z_{S_{|t=0}} = \frac{[2-(1+\theta)]\lambda\delta v_i sd + 2\theta\Omega}{\gamma[(1+\theta)][2-(1+\theta)]} > 0. \tag{2.29}$$

The bonus chosen by the bank is unambiguously larger than the socially optimal bonus.[29] The bank does not internalize the bailout costs of the government. Hence

[29] The fixed wage chosen by the bank, F_B, is smaller than the socially optimal fixed wage, which is given by $F_S = \bar{u} - \frac{\gamma}{2}(1+\theta)^2 z_S^2$.

it prefers more risk, which can be induced with a higher bonus. Moreover, the bank exploits the managerial overvaluation, which leads to the manager providing too much effort and risk relative to the actual probability of getting the bonus.

Note that an upper bound for bonuses, a bonus cap, set at $z_{S_{|t=0}}$ can implement the socially optimal bonus. The cap has the same qualitative behavioral effects as the bonus tax discussed in Sections 2.5.2 and 2.5.3, since it also lowers the bonus and raises the fixed wage. A bonus cap, however, does not raise tax revenue, which is an attractive channel to redistribute from the financial sector to the government. Hence in a setting where the marginal costs of public funds exceed one ($\lambda > 1$), the optimal bonus tax dominates the optimal bonus cap with respect to welfare.

2.6.2 Capital Requirements

This section investigates, if capital requirements can implement the socially optimal bonus. To see if an increase in the capital requirements, $1 - s$, brings the bank bonus closer to the social optimum, we derive eq. (2.29) with respect to $(1 - s)$:

$$\frac{\partial(z_{B_{|t=0}} - z_{S_{|t=0}})}{\partial(1-s)} = -\frac{\lambda\delta v_i d[2-(1+\theta)] + 2\delta v_i d\theta}{\gamma(1+\theta)[2-(1+\theta)]} < 0. \tag{2.30}$$

Eq. (2.30) implies that tighter capital requirements indeed reduce the gap between the bank's bonus and the socially optimal bonus. With tighter capital requirements, the bank internalizes the downside risk of its investment to a larger extent and thus has a smaller incentive to induce risk-taking via bonuses. Whether capital requirements can actually establish the socially optimal bonus is determined by

$$\lim_{(1-s)\to 1} (z_{B_{|t=0}} - z_{S_{|t=0}}) = \frac{2\frac{\alpha^2}{\eta} Y^h \theta}{\gamma(1+\theta)[2-(1+\theta)]} > 0. \tag{2.31}$$

Eq. (2.31) shows that capital requirements alone cannot implement the socially desirable bonus level, if the manager is overconfident ($\theta > 0$). Even in the extreme case with capital requirements approaching 100%, the bank's bonus is higher than socially optimal.[30]

[30]Of course, an increase in capital requirements has other potential downsides (e.g. a decrease in lending to firms) that are not dealt with in our model. See, for example, Van den Heuvel (2008) for an analysis of the welfare costs of capital requirements.

Recall from Section 2.6.1 that there are two reasons why the bank's bonus is higher than the socially optimal bonus. First, the bank uses the bonus to maximize its value of the government subsidy. Capital requirements can tackle this problem, as they force the bank to internalize the externalities of its risk-taking. And second, the bank sets an excessively high bonus in order to exploit the manager, if he is overconfident. An overconfident manager overvalues the utility that he derives from a bonus, because he overestimates the probability to obtain the bonus ($\hat{p}^h > p^h$). Hence, for an overconfident manager, the bank can save compensation costs by offering a higher bonus and a lower fixed wage. This higher bonus has the side effect that risk-taking is greater (see eq. (2.6)) than under the socially optimal bonus. Capital requirements cannot tackle the inefficiencies arising from the exploitation of managerial overvaluation.

For a rational manager ($\theta = 0$), capital requirements can establish the socially optimal bonus (cf. eq. (2.31)), as there is no possibility for the bank to exploit the manager. Unlike an overconfident manager, a rational manager derives the same perceived utility from one dollar of expected bonus payments as from one dollar of fixed wage.

Moving away from capital requirements and generalizing our argument, Appendix B.5 derives the bank's bonus $z_{R_{|t=0}}$ under the assumption that regulation achieves that the bank fully internalizes the bailout costs of the government ($\lambda p^{l*} v_i sd$). Analogously to the capital requirements, the bank's bonus is higher than socially optimal, if the manager is overconfident. In the presence of overconfidence, curbing shareholders' risk-shifting incentives alone is not enough, as the bank has an incentive to use bonuses in order to exploit the manager's overvaluation.

We summarize Section 2.6.2 in

Proposition 2.2 *Shareholders' risk-shifting incentives and the socially optimal bonus*

If the manager is overconfident (i.e., $\theta > 0$),

(i) capital requirements alone cannot implement the socially desirable bonus. The bank's bonus, $z_{B_{|t=0}}$, is then always larger than the socially desirable bonus, $z_{S_{|t=0}}$.

(ii) the bonus , $z_{R_{|t=0}}$, of a bank that fully internalizes the government's bailout costs is always larger than the socially desirable bonus, $z_{S_{|t=0}}$.

Proofs: Equation (2.31) *and Appendix B.5.*

A direct intervention into banker pay (e.g. bonus taxes or bonus caps) can however implement the socially desirable bonus, as it addresses both motives for the excessive use of the bonus at the same time. Direct interventions into banker pay not only tackle the inefficiencies caused by incentives for excessive risk-taking, but also the adverse effects arising from the manager's overvaluation of the bonus. A bonus tax, for example, increases the bank's costs of the bonus relative to its costs of the fixed wage. Hence the higher is the bonus tax, the lower is the incentive of the bank to save fixed wage costs by offering an excessive bonus.[31]

Our results suggest that the EU bonus cap mitigates the socially adverse effects of managerial overconfidence. This regulation became effective across the European Union in 2014 as part of the Capital Requirements Directive IV. The EU bonus cap limits bonuses paid to senior managers and other "material risk takers" in the financial sector to 100% of their fixed salary (200 % with shareholder approval). Our analysis implies that the bonus cap curbs the exploitation of managerial overvaluation, because it limits the banks' ability to lower compensation costs via higher bonuses and lower fixed wages. Hence the EU bonus cap lowers excessive risk-taking in equilibrium.

More generally, Proposition 2.2 suggests that interventions into banker pay are part of the optimal regulatory package for the banking industry. The existing literature has identified competition for mobile bankers as the major reason to intervene directly into banker compensation instead of only curbing shareholders' risk-shifting incentives. For example, Bannier et al. (2013) find that the competition for bankers with heterogeneous and unobservable skill leads to excessive bonuses. This causes a level of risk-taking that is not only excessive for society but also for the banks themselves. Thanassoulis (2012) shows that the competition for bankers increases bankers' pay, which gives rise to a negative externality as rival banks have to increase banker remuneration as well. This increase in banker pay drives up the remuneration costs of banks and thus their default risk. Our finding in Proposition 2.2 adds to these findings by showing that bonuses in the banking industry are excessive from a social point of view, even when competition for managerial talent in the banking sector is *weak*. This is because overconfidence creates an incentive for banks to exploit managerial overvaluation.

[31]Of course Proposition 2.2 does not imply that interventions into banker pay should be the *only* instrument in an optimal regulatory scheme.

2.7 Competition for Overconfident Bankers

In order to shed light on the competition for overconfident managers, this section introduces heterogeneities in bank characteristics and managerial overconfidence. Specifically, we are interested in how government guarantees, bonus taxes, and capital requirements affect the matching between banks and overconfident managers. Section 2.7.1 derives the equilibrium contracts and allocation when banks compete for an overconfident manager. In Section 2.7.2 we analyze how this competitive equilibrium is affected by heterogeneities in government guarantees, capital requirements, and bonus taxes.

2.7.1 Equilibrium Contracts under Competition

In this section, we introduce heterogeneities in bank characteristics and managerial overconfidence. Specifically, there are two banks $i \in (1, 2)$ that potentially differ in the level of government guarantees v_i, the bonus taxes t_i, and the capital requirements $1 - s_i$. There are two types of managers $j \in (OC, N)$ that only differ in managerial overconfidence θ_j. We assume that type OC, who we refer to as overconfident manager, is more overconfident than type N ($\theta_{OC} > \theta_N \geq 0$), who we refer to as rational manager.

The two banks compete for the services of the overconfident manager via their compensation packages. We assume that the overconfident manager is scarce (i.e., there is only one overconfident manager) and that rational managers are abundant.[32] Hence the bank that does not hire the overconfident manager in equilibrium will hire a rational manager instead. The manager j's outside option to working for bank i is determined by the contract that the other bank I ($\forall\ i, I \in \{1, 2\},\ i \neq I$) offers to him.

As rational managers are abundant, the two banks do not compete for their services. Hence the bonus and fixed wage of a rational manager in bank i, $z_{i,N}$ and $F_{i,N}$, are the same as in the previous sections. Substituting the bank bonus from eq. (2.15) and the fixed wage from eq. (2.16), we get bank i's optimal profit when hiring the rational

[32]Our approach is thus similar to Gervais et al. (2011), who model the competition for a scarce overconfident manager in the absence of government guarantees and government policies.

manager N:

$$\Pi^*_{i,N} = p_0^m Y^m + p_0^l v_i s_i d - \bar{u}_N - (1-s_i)d - s_i d + \frac{(1+\theta_N)\Omega_i^2}{2\Psi_{i,N}},$$

$$\text{where } \Omega_i = \frac{\alpha^2}{\eta} Y^h + \delta v_i s_i d \text{ and } \Psi_{i,N} = \gamma[2(1+t_i) - (1+\theta_N)]. \tag{2.32}$$

It is easy to see from eq. (2.32) that bank i's profit rises in the level of overconfidence. This is because overconfidence increases effort- and risk-taking and reduces the compensation costs needed to convince the manager to work for the bank. Hence banks benefit more from hiring an overconfident manager than from hiring a rational manager, and compete for the services of the overconfident manager.

In equilibrium, the overconfident manager OC works for the bank i that is willing to offer him his highest perceived utility. The maximum willingness to pay of bank i for manager OC in terms of his perceived utility, $\hat{u}_{i,max}$, is determined by

$$\Pi^*_{i,OC} = p_0^m Y^m + p_o^l v_i s_i d - \hat{u}_{i,max} - (1-s_i)d - s_i d + \frac{(1+\theta_{OC})\Omega_i^2}{2\Psi_{i,OC}} = \Pi^*_{i,N}. \tag{2.33}$$

Hence $\hat{u}_{i,max}$ is the level of OC's perceived utility for which bank i is indifferent between hiring him and hiring the rational manager N. Substituting $\Pi^*_{i,N}$ from eq. (2.32) and solving for $\hat{u}_{i,max}$, we get

$$\hat{u}_{i,max} = \bar{u}_N + \frac{\gamma\Omega_i^2(1+t_i)(\theta_{OC} - \theta_N)}{\Psi_{i,OC}\Psi_{i,N}}. \tag{2.34}$$

Eq. (2.34) determines in which bank the overconfident manager works. The bank with the higher willingness to pay for the overconfident manager, $\hat{u}_{i,max}$, hires the overconfident manager in equilibrium. This willingness to pay rises in the exogenous outside option of the rational manager $\bar{u}_N$, and in the level of overconfidence of the overconfident manager.

For the bank i that hires the overconfident manager in equilibrium, it is optimal to offer this manager a contract for which he is indifferent between working for bank i and the other bank I.[33]

[33] For simplicity, we assume here that if both banks offer the overconfident manager the same perceived utility, he will decide to work for the bank with a higher maximum willingness to pay.

This is given by

$$\hat{u}_{i,OC} = \hat{u}_{I,max}. \tag{2.35}$$

Recall from eq. (2.8) that the perceived utility $\hat{u}_{i,OC}$ that manager OC derives from bank i, depends on the bonus, $z_{i,OC}$, and the fixed wage $F_{i,OC}$. As in previous sections, bank i chooses the profit-maximizing bonus $z_{i,OC}$ given in eq. (2.15). The fixed wage is used to attract the overconfident manager to work for bank i and thus adjusts to fulfill eq. (2.35). Hence by substituting $\hat{u}_{I,max}$ from eq. (2.34) and the bonus from eq. (2.15), we get the equilibrium wage of the overconfident manager

$$F_{i,OC} = \bar{u}_N + \frac{\gamma\Omega_I^2(1+t_I)(\theta_{OC}-\theta_N)}{\Psi_{I,OC}\Psi_{I,N}} - \frac{\gamma\Omega_i^2(1+\theta_{OC})^2}{2\Psi_{i,OC}^2}, \tag{2.36}$$

The first two terms capture the willingness to pay for the overconfident manager of the bank I that loses the bidding war for the overconfident manager. The first term in eq. (2.36), $\bar{u}_N$, implies that the better the rational manager's outside option, the more expensive he will be for the bank and the more attractive is the overconfident manager in comparison. The second term shows that the higher OC's overconfidence, the more valuable he is for the losing bank, which drives up his fixed wage in the bank that hires him. Hence, due to the competition for his services, the overconfident manager can now capture (some of) the rent that his overconfidence creates.[34] Effectively, the manager's overconfidence commits him to exert more effort and risk, which generates bank profits that he can (partly) capture under competition.[35] The third term is the perceived utility that the overconfident manager derives from the bonus in the bank he works for. The higher this perceived utility from the bonus, the smaller the fixed wage has to be in order to attract the overconfident manager.

To summarize, Section 2.7.1 shows that, in equilibrium, the banks' contracts and the managers' allocation are given by

[34]If the two banks are identical, then the overconfident manager captures the whole rent, $\Pi^*_{i,OC} - \Pi^*_{i,N}$, of his excess overconfidence, $\theta_{OC} - \theta_N$. As under Bertrand Competition, the two banks will in this case overbid each other until the banks' profits for OC are just as low as the banks' profits for the rational manager. If the two banks differ (e.g in the level of the government guarantee v_i), then the overconfident manager will typically not be able to obtain the whole rent, because the losing bank I is not willing to bid up his fixed wage until $\Pi^*_{i,OC} = \Pi^*_{i,N}$ holds.

[35]Gervais et al. (2011) show, in a theoretical model, that a manager can actually benefit from his overconfidence when firms compete for his services.

Lemma 2.1 *Competitive equilibrium*
In equilibrium, the bank i with the higher maximum willingness to pay,

$$\hat{u}_{i,max} = \bar{u}_N + \frac{\gamma\Omega_i^2(1+t_i)(\theta_{OC}-\theta_N)}{\Psi_{i,OC}\Psi_{i,N}},$$

employs the overconfident manager with the bonus $z_{i,OC}$ in eq. (2.15) *and the fixed wage $F_{i,OC}$ in eq.* (2.36). *The other bank I employs the rational manager with the bonus $z_{I,N}$ in eq.* (2.15) *and the fixed wage $F_{I,N}$ in eq.* (2.16).

In Section 2.7.2, we use Lemma 2.1 to see how the matching between overconfident managers and banks depends on government guarantees, bonus taxes, and capital requirements. We can use the maximum willingness to pay, $\hat{u}_{i,max}$, to determine how changes in the exogeneous parameters affect the sorting of managers. If $\hat{u}_{i,max}$, in equilibrium, is an increasing function of an exogenous parameter, then the overconfident manager will ceteris paribus work for the bank with a higher value of this exogenous parameter. If $\hat{u}_{i,max}$ decreases in an exogenous parameter, then the bank with a higher value of this paramter will ceteris paribus employ the rational manager.

2.7.2 Matching

This section analyzes the sorting of managers with respect to government guarantees, capital requirements, and bonus taxes.[36] The effect of the government guarantee on the willingness to pay for the overconfident manager is given by

$$\frac{\partial \hat{u}_{i,max}}{\partial v_i} = \frac{2\gamma(1+t_i)(\theta_{OC}-\theta_N)\Omega_i\delta s_i d}{\Psi_{i,OC}\Psi_{i,N}} > 0. \tag{2.37}$$

Eq. (2.37) shows that the maximum willingness to pay for the overconfident manager, $\hat{u}_{i,max}$, unambiguously increases in the level of government guarantees, v_i. A bank with higher government guarantees benefits more from excessive risk-taking as it can shift more of the repayment costs to depositors, sd, onto the government. An overconfident manager takes on more risk than a rational manager as he overestimates the success probability of risky investments, and is thus especially attractive for banks that receive large government guarantees. Hence the higher is the government guarantee of a bank, the larger is the positive effect of overconfidence on the bank's profit, which drives up the willingness to pay for the overconfident manager, $\hat{u}_{i,max}$.

[36]Throughout this section we assume that the bonus tax is exogenously given.

From eq. (2.37) and Lemma 2.1, it follows that the overconfident manager ceteris paribus works for the bank with a higher level of government guarantees in equilibrium. Lemma 2.1 also implies that the overconfident manager earns a higher bonus than the rational manager. First, overconfidence makes the bonus more attractive for the bank. And second, the overconfident manager works for the bank with a higher government guarantee, which has a higher risk appetite and accordingly sets a higher bonus.

The effect of the capital requirement on the sorting of the overconfident manager is determined by

$$\frac{\partial \hat{u}_{i,max}}{\partial (1-s_i)} = -\frac{2\gamma(1+t_i)(\theta_{OC}-\theta_N)\Omega_i \delta v_i d}{\Psi_{i,OC}\Psi_{i,N}} < 0. \tag{2.38}$$

Eq. (2.38) implies that bank i's willingness to pay for the overconfident manager is the lower, the tighter are the capital requirements (i.e., the higher $(1-s_i)$). From the bank's perspective, overconfident managers have the advantage that they take on more risk and that their risk-taking is cheaper to incentivize. Tighter capital requirements, however, lower the shareholders' risk appetite, as they imply that shareholders internalize a larger share of the bank's risk-taking. The shareholders' lower risk appetite, induced by tighter capital requirements, entails that the bank benefits less from employing an overconfident manager. Hence, ceteris paribus, overconfident managers work for banks with lax capital requirements.

Considering an exogeneous bonus tax, the effect of the bonus tax on the willingness to pay for the overconfident manager is given by

$$\frac{\partial \hat{u}_{i,max}}{\partial t_i} = \frac{\gamma^3\Omega_i^2(\theta_{OC}-\theta_N)[-4(1+t_i)^2+(1+\theta_{OC})(1+\theta_N)]}{\Psi_{i,OC}^2\Psi_{i,N}^2} < 0. \tag{2.39}$$

Eq. (2.39) implies that, ceteris paribus, overconfident managers work for banks where bonus taxes are relatively low. Note that the bonus tax is especially suitable to affect the selection of overconfident managers. Like capital requirements, the bonus tax curbs the bank's incentive to shift risks, which decreases the benefit from employing an overconfident manager. In addition, and unlike capital requirements, the bonus tax makes it more costly for the bank to exploit the fact that an overconfident banker overvalues the bonus. Hence, if the government wants to avoid the selection of overconfident managers into certain institutions, the bonus tax is a particularly effective tool to do so.

We summarize our findings in

Proposition 2.3 *Matching*

The overconfident manager, OC, ceteris paribus works for the bank i with larger government guarantees v_i, lower bonus taxes t_i, and laxer capital requirements $1-s_i$.

The rational manager, N, ceteris paribus works for the other bank I with smaller government guarantees v_I, higher bonus taxes t_I, and stricter capital requirements $1-s_I$.

Proof: Follows directly from equations (2.37), (2.38), (2.39), *and Lemma 2.1.*

The finding that overconfident managers select into banks with large government guarantees has significant implications for taxpayers. It causes equity and efficiency losses. The selection of overconfident managers into institutions with large bailout guarantees increases the likelihood of bailouts, p^{l*}, for two reasons. First, for a given contract, overconfident managers take on more risk as they overestimate the success probability of risky investments. And secondly, the bank creates higher powered compensation contracts for overconfident managers, which amplifies the behavioral effects of overconfidence and increases risk-taking further. The rise in the likelihood of bailouts increases the bailout subsidy, B, and thus the transfer of taxpayer money to the bank and the banker.

Beyond the direct bailout costs, B, the financial crisis of 2007-2009 has shown that there are large externalities both within the financial market as well as from financial institutions to non-financial firms. A selection of overconfident managers, who increase the default risk, into banks that are systemically important enough to receive government guarantees is thus hazardous for the economy.

Proposition 2.3 suggests that a government can influence the selection of managers by changing the bonus tax, t_i, and/or changing the capital requirements, $1-s_i$. Hence the government can counteract the selection of overconfident managers into institutions with large government guarantees. A bonus tax is particularly well suited to do so, because it can tackle the exploitation of managerial overvaluation.

2.8 Discussion

This section briefly investigates some policy implications of our analysis. Section 2.8.1 discusses the international policy competition for mobile bankers. In Section 2.8.2 we summarize why our model supports the implementation of bonus taxes in systemically important financial institutions. Section 2.8.3 considers deferrals and clawbacks of variable renumeration and Section 2.8.4 briefly discusses the role of strong supervisory boards.

2.8.1 International Policy Competition

Proposition 2.3 suggests that governments can affect the matching of managers with banks by changing the bonus tax t and/or changing the capital requirements, $1-s$. This has implications for governments that compete for internationally mobile bankers.[37] In a non-cooperative setting of these two instruments, the governments can set high bonus taxes or strict capital requirements in order to have a selection of rational bankers in the domestic country. Conversely, if governments set low bonus taxes or lax capital requirements, there will be a selection of overconfident bankers in the domestic country. These findings can be of interest to the literature on tax competition for mobile bank managers (see e.g. Gietl and Haufler, 2018) and to the literature on regulatory competition in capital requirements (see e.g. Dell'Ariccia and Marquez, 2006), which do not consider overconfidence.

Recall from Section 2.5.1 that overconfident managers create larger bailout costs, B, but also generate greater tax revenue, T. Hence it is an interesting avenue for future research to investigate under which conditions there is a 'race to the bottom' or a 'race to the top' in bonus taxes when (some) bankers are overconfident. For example, it could be rational for governments to attract overconfident bankers, if there is a joint liability of bailout costs between the countries (i.e., a country partly comes up for the bailout costs of another country and vice versa). In this case, governments can benefit from the greater tax revenue that overconfident managers create, and only partly come up for the larger domestic bailout costs that overconfident managers cause.

[37] There is ample evidence that bankers are mobile across countries (see e.g. Greve et al., 2009, 2015). For example, Staples (2008) shows that almost 70% of the 48 largest commercial banks have one or more non-national board members.

2.8.2 Bonus Taxes and Systemically Important Financial Institutions

Our model supports the implementation of bonus taxes in systemically important financial institutions (SIFIs). In SIFIs, risk-shifting incentives, $\delta v_i sd$, are strong due to explicit (e.g. due to deposit insurance) and implicit (e.g. because the SIFI is too big to fail) government guarantees. The bonus tax can counteract these socially adverse incentives. Hence the optimal bonus tax rises in the bank's risk-shifting incentives (see eq. (2.24)). As managerial overconfidence exacerbates the risk-shifting problem, the optimal bonus tax further increases in overconfidence, if risk-shifting incentives are sufficiently large (see Proposition 2.1). In banks with weak risk-shifting incentives, however, the optimal bonus tax should be lower in order not to deter the manager's effort-taking. This is especially the case if the manager is overconfident, because an overconfident banker's effort reacts more elastically to changes in the bonus tax.

Proposition 2.2 shows that direct interventions into banker pay are best suited to establish the socially optimal bonus if bankers are overconfident. Overconfidence creates an incentive for the bank to exploit the managerial overvaluation of bonus payments. This leads to socially excessive bonuses and excessive risk-taking. Unlike capital requirements, bonus taxes can counteract the bank's incentive to exploit managerial overvaluation and are thus able to deter excessive risk-taking. This is especially important in systemically important financial institutions where the social costs from defaults are large.

Proposition 2.3 shows that overconfident managers select into banks with large government guarantees. This matching implies large bailout costs for taxpayers. Bonus taxes are particularly well suited to counteract this selection. Like capital requirements, they reduce the bank's risk appetite and thus the benefit of employing an overconfident banker. Unlike capital requirements, bonus taxes additionally tackle the exploitation of managerial overvaluation, which further reduces the benefit of hiring an overconfident manager. Hence Proposition 2.3, like Proposition 2.1, suggests that bonus taxes should be larger in systemically important financial institutions than in institutions that carry less systemic risk, albeit for different reasons. Bonus taxes should be higher in SIFIs to mitigate excessive risk-taking (Proposition 2.1) and to deter the matching of overconfident bankers and SIFIs (Proposition 2.3).

2.8.3 Deferred Pay and Clawbacks

Following the financial crisis of 2007-2009, several countries have considered and implemented deferrals and clawbacks of variable renumeration. In the United Kingdom, for example, the variable pay of bankers is partly subject to deferral and clawbacks for up to seven and ten years, respectively, from the date of a variable remuneration award.[38] This regulation aims to reduce excessive risk-taking in the banking industry by forcing bankers to internalize the costs of potential future losses. Thanassoulis and Tanaka (2018) find that, in the presence of government guarantees, clawback rules can establish socially optimal risk choices of a rational bank CEO.[39] In their model, clawbacks can discourage socially excessive risk-taking as they penalize the banker in case of the bank's default.[40]

Our analysis implies, however, that the effectiveness of deferred pay and clawbacks is limited if the banker is overconfident ($\theta > 0$). An overconfident banker underestimates the probability of bank default ($\hat{p^l} < p^l$). He thus underestimates any expected penalty that he might incur in the case of default. Hence overconfidence deters the intended effect of clawbacks and deferred pay to make the banker internalize downside risks.

2.8.4 Strong Boards

In recent years several papers have shown that better board supervision and monitoring can attenuate the adverse effects of overconfidence on firm outcomes. Kolasinski and Li (2013) show that strong boards help overconfident CEOs make better acquisition decisions. Banerjee et al. (2015) use the passage of the Sarbanes-Oxley act as an exogenous shock in governance and find that it has improved operating performance and market value for overconfident-CEO firms.

Our results show that the adverse social effects of managerial overconfidence cannot be attenuated by strengthening boards, if risk-shifting incentives are strong (i.e., $\delta v_i sd$ is

[38] See FCA PS 15/16 for details on the rules regarding bonus deferrals and clawbacks for bankers in the United Kingdom.

[39] Thanassoulis and Tanaka (2018) emphasize that the clawback rules need to be assisted by rules on the convexity of CEO pay. Otherwise the bank can adjust the CEOs renumeration to circumvent the risk-reducing role of clawbacks.

[40] In a similar vein, Chaigneau (2013) suggests that a credible threat of sanctions for CEOs of failed banks can curb risk-shifting incentives.

large). In systemically important financial institutions, a strong board has the incentive to set excessively high bonuses for overconfident managers in order to exploit their overvaluation and to induce them to take on excessive risks. Hence strong supervisory boards can indeed benefit firm value in the presence of managerial overconfidence, but they potentially create substantial welfare losses for taxpayers when risk-shifting incentives are strong. Unlike strong boards, a bonus tax can curb the banks' incentives to exploit managerial overvaluation and it can deter socially excessive risk-taking.

2.9 Conclusion

In this chapter we have incorporated managerial overconfidence and limited bank liability into a principal-agent model of the banking industry. Overconfident managers overestimate the returns to effort and risk-taking, which implies that they exert more effort and risk than rational managers. We find that the optimal bonus tax increases as a response to managerial overconfidence, if risk-shifting incentives are strong. This is because government guarantees create an externality of the bank's behavior on taxpayers, which is especially attractive to exploit, if the manager is overconfident. These socially adverse incentives can be counteracted with a bonus tax.

Our model shows that overconfidence necessitates an intervention into bankers' pay. Curbing the risk-shifting incentives of shareholders (e.g. via capital requirements) alone is not sufficient, as overconfidence leads to excessive bonuses even if shareholders fully internalize the externalities of their risk-taking. This is because shareholders exploit the fact that overconfident managers overestimate the probability of obtaining the bonus. Hence shareholders have an incentive to increase their usage of bonuses to lower their total compensation costs at the expense of the overconfident banker. The bonus tax makes it more expensive for the bank to exploit managerial overvaluation and thus reduces excessive risk-taking in equilibrium.

Finally, our model suggests that overconfident managers work for banks with large government guarantees. These banks have a larger risk appetite and thus benefit more from employing overconfident managers than banks with smaller government guarantees. Hence overconfident managers select into banks where they are particularly detrimental for taxpayers. Bonus taxes are particularly well suited to counteract this selection, as they not only curb the bank's risk-taking incentive, but also make it more costly for the bank to exploit an overconfident manager's overvaluation of the bonus. All in all, our model suggests that the presence of managerial overconfidence makes bonus taxes in systemically important financial institutions necessary.

This chapter raises several questions for future research. For example, our prediction that overconfident managers sort into banks (and, more generally, firms) according to the regulatory environment they face could be empirically tested by using personal portfolios of CEOs to determine overconfidence (as in Malmendier and Tate, 2005). Another promising research avenue is the international policy competition for mobile, overconfident bankers. Our model shows that policy parameters such as bonus taxes and capital requirements affect the selection of overconfident and rational managers in a country. Endogenizing such a policy parameter could shed light on whether it is optimal for all countries to set strict regulation/taxation and drive out overconfident managers, or if it's actually optimal for some countries to have a high-risk banking sector run by overconfident agents. We plan to cover this issue in future research.

Chapter 3

Risk-Taking under Limited Liability: The Role of Motivated Beliefs[1]

3.1 Introduction

Limited liability has been identified as one of the main reasons for the financial crisis of 2007-2009. The implicit and explicit guarantees inherent in the financial sector create a situation in which banks and bankers do not fully internalize the losses of failed investments (Hakenes and Schnabel, 2014). As a result, bankers have a monetary incentive to engage in socially excessive risk-taking. At the same time, financial markets are characterized by their opaqueness. Virtually all decisions in the financial sector are taken under uncertainty (i.e., in environments where the probabilities of different outcomes are unknown and individuals have to make subjective probability evaluations).

Indeed, the incentives provided by limited liability and the uncertainty in the financial sector may crucially interact. Uncertainty might exacerbate risk-taking under limited liability, as it provides flexibility to justify acting egoistically. A recent literature claims that, in the face of uncertainty, bankers manipulated their beliefs about excessively risky investments prior to the financial crisis in order to keep a positive self-image. Besides bad incentives and faulty risk models, motivated beliefs are thus

[1] This chapter is based on joint work with Ciril Bosch-Rosa and Frank Heinemann (Bosch-Rosa et al., 2019) and still work in progress.

a potential explanation for why bankers built up a large exposure to subprime loans and subprime-linked securities in the pre-crisis period (Barberis, 2013). This argument relates to a broader literature, which reasons that individuals have an incentive to distort their own beliefs and judgements when a trade-off between personal benefits and moral self-esteem arises (e.g. Bénabou, 2015; Gneezy et al., 2016). Whether these self-serving judgements and motivated belief distortions actually matter in a given situation depends critically on whether "the context provides sufficient flexibility to allow plausible justification that one can both act egoistically while remaining moral" (Gino et al., 2016).[2]

We argue that uncertainty may offer such moral wiggle room in the presence of limited liability. More precisely, limited liability can create a situation where an investor monetarily benefits from a risky investment, but feels bad about its negative implications for others. For decisions that involve only deterministic outcomes, it is difficult for the investor to resolve this trade-off. Under uncertainty, however, the investor can justify his risky investment by convincing himself that the investment is unlikely to fail. This way he can increase his monetary payoffs while maintaining a positive self-image, since he perceives it as improbable that the investment will actually hurt others. Hence motivated beliefs might be a driver of risk-taking under limited liability. Up to this point, however, there is no empirical evidence about whether limited liability affects risk-taking through motivated beliefs. It is thus not clear if risk-taking under limited liability is solely driven by the incentives themselves or whether motivated beliefs also play a role.

This chapter investigates whether limited liability affects risk-taking through motivated beliefs. To do so, we run a laboratory experiment using a within-subject design. Experimental subjects, henceforth "investors", are given a fixed endowment and decide on how much of their endowment to invest in a binary risky asset, which can either be successful or fail (Gneezy and Potters, 1997).[3] Before this decision, the investors receive a noisy signal (our source of uncertainty) that indicates whether the investment will be successful or fail. Based on the signal, investors evaluate their subjective success probability of the risky asset and take their investment decision.

[2] A large body of empirical evidence supports this quote. See, for example, Dana et al. (2007), Haisley and Weber (2010), Exley (2016), Exley and Kessler (2018) as well as Gino et al. (2016) and the references therein.

[3] Our subject pool mainly consists of students.

If the risky asset is successful, the investor always receives all the gains. Our three treatments differ only with respect to the distribution of losses among subjects in case the risky asset fails. In the *Baseline* treatment, the investor internalizes all loses arising from his risky investments. The other two treatments (see details below) incorporate limited liability – here the investor only covers 25% of all losses – and thus allow for motivated beliefs.

We find that both limited liability treatments significantly increase risk-taking (i.e., investment in the risky asset) in comparison to the *Baseline* treatment. However, this result does not necessarily imply that investors invest more under limited liability because of motivated beliefs. To further examine if, at least a part of the effect, runs through a shift in beliefs, we exploit a mediator analysis (Imai et al., 2011, 2013). We use variations in the noisy signals about the success probabilities of investments to disentangle the causal effect of limited liability that works through the shift of beliefs (i.e., the motivated beliefs) from all other effects of the limited liability treatments on risk-taking (e.g. the direct effect of changed incentives). We find a statistically positive causal effect of limited liability through beliefs on the investment level of bankers. For a given signal, investors have a higher expected success probability for investments under limited liability, and these motivated beliefs cause higher investments in the limited liability treatments.

Another part of our analysis focuses on whether the two limited liability treatments, *Matched* and *Diffusion*, differ with respect to their effects on risk-taking. Both treatments have in common that the investor only comes up for 25% of all losses. In *Matched* the remaining 75 % of losses are borne by a single passive individual, whereas in the *Diffusion* treatment this loss is split up equally among *many* passive subjects.[4] We hypothesize that investors may invest more in the *Diffusion* treatment, as the concerns for the agents covering the losses get diluted, so that an individual passive subject is not heavily affected by the banker's decision. Yet, our analysis shows that we cannot reject the null hypothesis of no differences in investment levels between the *Matched* and *Diffusion* treatments.

Our study is mainly related to two strands in the literature. First, we relate to the

[4]The *Diffusion* treatment is thus a stylized representation of the monetary incentives that are present when *many* taxpayers bail out a bank and its bankers (e.g. due to deposit insurance). The *Matched* treatment more closely captures the monetary incentives of a banker who can invest in assets that potentially hurt an individual customer.

literature on motivated reasoning (Hastorf and Cantril, 1954; Messick and Sentis, 1979; Kunda, 1990). Many individual decisions involve a trade-off between acquiring a personal benefit and feeling moral. A large body of empirical evidence finds that individuals use self-serving beliefs and justifications in such a situation if it contains enough flexibility for the individual to plausibly maintain a positive self-image (see Gino et al., 2016, for an overview). For example, Exley (2016) demonstrates experimentally that individuals use risk as an *excuse* to give less to charity.[5] Garcia et al. (2018) replicate the finding of Exley (2016) and, additionally, show that ambiguity leads to similar excuse-driven behavior in charitable giving. Haisley and Weber (2010) study binary dictator games. They find that dictators more often choose the selfish and unfair option when the payoffs of the recipient are determined by a lottery under ambiguity instead of a lottery under risk.[6] In addition, individuals make errors due to self-serving motives (Exley and Kessler, 2018) and motivated beliefs facilitate corrupt behavior (Gneezy et al., 2018). We contribute to this strand of literature by showing that motivated beliefs are a driver of risk-taking under limited liability.

The second strand of literature concerns risk-taking on behalf of others. In general, this literature provides mixed evidence regarding the question whether subjects take more risk on behalf of themselves or on behalf of others (see Eriksen et al., 2017, for an overview). We relate most closely to the papers in this area that involve substantial monetary conflicts between the investor and other subjects. Ahrens and Bosch-Rosa (2018) find that experimental subjects invest significantly more when they invest the money of a client and keep half of the investment gains to themselves than when they are fully liable and only invest their own money. Most closely related, Füllbrunn and Neugebauer (2013) compare risk-taking under individual liability and under a social safety net. They find that risk-taking increases when the losses from risk-taking behavior are shared within the group (and risk-taking thus occurs partly at the expense of others). We add to this body of research by investigating how motivated beliefs as well as diffused liability affect the risk-taking on behalf of others.

[5] This excuse-driven effect is cleanly disentangled from other effects of risk, for example the effect that individuals give less when there is a larger risk that their donation will be less impactful.

[6] In Haisley and Weber (2010), the objective probability distributions of the lotteries under ambiguity and risk are known by subjects. However, as dictators' evaluations of the expected values of the receivers are raised under ambiguity, the authors argue that dictators form self-serving beliefs about ambiguity.

This chapter is structured as follows. Section 3.2 explains the experimental design of the study. Section 3.3 shows the results of the experiment. Section 3.4 debates several limitations of our study, before Section 3.5 concludes.

3.2 Experimental Design

We use a within-subject design, in which each subject participates in three treatments: *Baseline*, *Matched*, and *Diffusion*. In order to control for potential order effects (e.g. learning effects and treatment spillovers), we run three orders of treatments.[7] In each of the three treatments, subjects receive an endowment of €8 and decide on the percentage share of their endowment they want to invest in a risky asset. The risky asset yields a gain of $0.75X$ if the investment is successful and leads to a loss of X if the investment fails, where $X \in [€0; €8]$ is the amount invested in the risky asset. The three *treatments* differ in how the loss is distributed among the subjects (see Section 3.2.1).

Several additional aspects are worth noting. First, each treatment contains ten rounds. Second, before each round, subjects receive a new noisy signal, which gives a hint whether the investment in this round will be successful or fail (see Section 3.2.2). Third, to avoid learning and income effects, subjects receive no feedback regarding their decisions in the three treatments until the end of the experiment. Fourth, to avoid any hedging, we randomly determine at the end of the experiment which of the decisions become payoff relevant (see Section 3.2.5).

3.2.1 Treatments

In all three treatments, the gains of a successful investment (75 cents per euro invested) go to the subject that makes the investment. In the *Baseline* treatment, all subjects internalize all losses of their own investments. In the *Matched* treatment, half of our subjects are randomly assigned the role of "bankers" and the other half are "loss-takers".[8] Each loss-taker is matched with one banker and bears 75% of the losses that his matched banker creates, and the banker only covers 25% of the losses he causes. In

[7] These orders are 1. *BL*, *MA*, *DF*; 2. *MA*, *DF*, *BL*; 3. *DF*, *MA*, *BL*.

[8] In the experiment we use a neutral framing and refer to bankers as Type A and loss-takers as Type B (see the instructions in Section C.3).

the *Diffusion* treatment, 75% of the losses a banker creates are split up equally among *all* loss-takers in his experimental session, and the banker, again, only bears 25% of the losses he triggers. Importantly, we thus hold the efficiency (i.e., the total sum of expected payoffs for a given investment) constant across all treatments. Consequently, the treatments only differ in how the losses of failed investments are split up among the subjects. In the following, we outline the details of our treatments.

Baseline (BL)

In the *Baseline (BL)* treatment, subject i wins $0.75X_i$ if his investment is successful and loses X_i if it fails. The payoffs of a subject are not affected by the decisions of other participants. Hence, in *Baseline*, the payoff P_i^{BL} of subject i is given by

$$P_i^{BL} = \begin{cases} €8 + 0.75 \times X_i^{BL} & \text{if the investment of } i \text{ is successful.} \\ €8 - 1.00 \times X_i^{BL} & \text{if the investment of } i \text{ fails.} \end{cases} \tag{3.1}$$

Matched (MA)

In the treatment *Matched (MA)*, half of our subjects are randomly assigned the role of "bankers" and the other half are "loss-takers". Each subject is made aware of his own type before MA starts, and subjects know that they keep their role for the whole *Matched* treatment.[9]

In each experimental session, every banker b $\in \{1, 2, ..., B\}$ is matched with exactly one loss-taker t $\in \{1, 2, ..., T\}$ and vice versa.[10] The investment of the banker, X_b, affects the payoff of his matched loss-taker if and only if the investment fails. If the investment is successful, the banker gains $0.75X_b$ in addition to his initial endowment. If the investment fails, the banker loses $0.25X_b$ and the loss-taker loses $0.75X_b$.

[9] An alternative to this design would have been to make all subjects invest under all treatments and only randomly decide at the end of the experiment, which subject is a banker and who is a loss-taker. This would have provided us with more observations. However, we decided against this design, as it possibly would have distorted our treatment effects. For example, in this alternative design subjects might have been more considerate of loss-takers when making their investment decisions, because they are potentially a loss-taker themselves.

[10] We ran nine sessions in total. Eight sessions had 20 subjects and thus 10 loss-takers and 10 bankers. The ninth session only had 18 subjects (9 bankers and 9 loss-takers) as too many invited subjects did not show up.

Hence in *Matched* the payoff of banker b for the investment X_b is

$$P_b^{MA} = \begin{cases} €8 + 0.75 \times X_b^{MA} & \text{if the investment of } b \text{ is successful.} \\ €8 - 0.25 \times X_b^{MA} & \text{if the investment of } b \text{ fails.} \end{cases} \tag{3.2}$$

In case of default, the payoffs of a loss-taker t depend on the investment of her matched banker b:

$$P_t^{MA} = \begin{cases} €8 & \text{if the investment of } b \text{ is successful.} \\ €8 - 0.75 \times X_b^{MA} & \text{if the investment of } b \text{ fails.} \end{cases} \tag{3.3}$$

Both payoffs, P_b^{MA} and P_t^{MA}, are explained in detail to all subjects before the start of the *Matched* treatment. Hence bankers are aware how their investment decisions can affect loss-takers.

Diffusion (DF)

In the treatment *Diffusion (DF)*, subjects keep the roles (banker or loss-taker) they had in *Matched* for the entire *DF* treatment.[11] In the *Diffusion* treatment, the decision of a banker influences the payoffs of *all* loss-takers in his experimental session if and only if the investment fails. If the banker's investment is successful, he gains $0.75X_b$ in addition to his initial endowment of €8. If the investment fails, the banker loses $0.25X_b$ and all loss-takers in the experimental session lose $0.75X_b$ *on aggregate*. The loss-takers' losses are distributed equally among all loss-takers in the experimental session. Hence the payoffs of a banker b in *DF* are equivalent to the banker payoffs in *MA* in equation (3.2). The payoffs of a loss-taker in the *Diffusion* treatment are given by

$$P_t^{DF} = €8 - \frac{0.75}{T} \times \sum_{b=1}^{B} (\mathbb{1}_{\mathbb{b}}^{\mathbb{DF}} X_b^{DF}), \tag{3.4}$$

where T is the number of loss-takers in the experimental session, B is the number of bankers in the experimental session, and $\mathbb{1}_{\mathbb{b}}^{\mathbb{DF}}$ is an indicator variable that takes on the value 1 if banker b's investment fails and 0 otherwise.

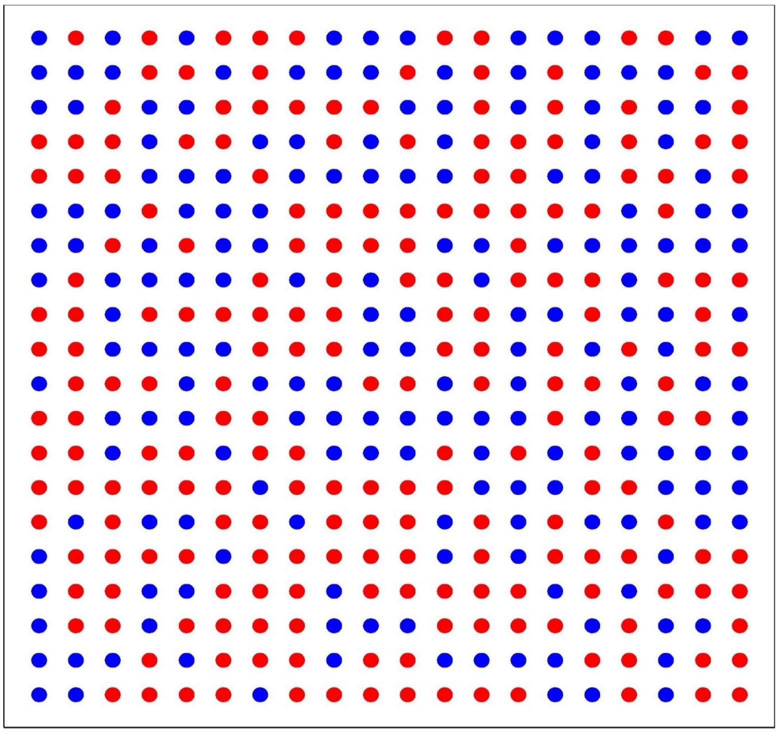
[11] Analogously, in the treatment order *DF*, *MA*, *BL* subjects are first randomly assigned to the role of banker or loss-taker in the *Diffusion* treatment, and then keep their roles for the *Matched* treatment.

The payoffs of bankers and loss-takers are explained in detail to all subjects before the start of the *Diffusion* treatment. Hence bankers are, again, aware how their investment decisions affect loss-takers.

3.2.2 Signal

Before each of the ten rounds of every treatment, subjects receive a new noisy signal which indicates whether the investment in the corresponding round will be successful or fail. This signal is a graph containing a total of 400 red and blue dots, which we refer to as "Dot Spot" (see Figure 3.1 for an example).

Figure 3.1: Dot Spot



A Dot Spot with 215 red dots and 185 blue dots.

Before each round, a new Dot Spot is shown for 8 seconds and disappears afterwards. With a probability of 50%, this Dot Spot contains *more red* than blue dots. In this case, the investment in this round will always be successful. With a probability of 50%, the Dot Spot shows *more blue* than red dots, and the investment in this round will always fail. Subjects do not have sufficient time to count the number of red dots and thus have to form subjective beliefs about the state of the investment. After seeing the Dot Spot for 8 seconds, subjects state their estimated success probability of the investment and the percentage share of €8 they want to invest riskily in this round.[12] Then the next round starts with a new Dot Spot and a new endowment of €8. Hence, in every round subjects receive a new signal (i.e., Dot Spot) based upon which they form a new belief and make a new investment decision. The Dot Spots thus provide a fast way to implement decisions under uncertainty.

All information mentioned thus far in Section 3.2.2 are explained in detail to all participants, but subjects are not aware of the exact distribution of the dots in the Dot Spots, which we explain in the following. For each of the 10 Dot Spots in a treatment, it is determined randomly (with p = 1/2) whether the number of red dots would come from Row 1 or from Row 2 in Table 3.1. For Dot Spot 1, for example, the computer would either choose a Dot Spot with 120 red and 280 blue dots or a Dot Spot with 280 red and 120 blue dots. Accordingly, the investment in the round where Dot Spot 1 is shown will only be successful in the latter case with 280 red dots.

Table 3.1: Dot Distribution of Dot Spots

Dot Spot	1	2	3	4	5	6	7	8	9	10
Row 1: # Red	120	185	190	195	199	201	205	210	215	280
Row 2: # Red	280	215	210	205	201	199	195	190	185	120

Dot distribution of Dot Spots in all three treatments.

Within each column, the Dot Spots are mirror images of each other. Thus, the difficulty of reading the signal is held constant within a column, whereas we vary the difficulty of reading the signal across columns (e.g. column 1 and 10 are easiest and column 5 and 6 are most difficult to read).[13] For each treatment seperately, we randomized the sequence of the 10 columns in Table 3.1.[14]

Note from Table 3.1 that the *same number* of red dots can be shown twice in the *same*

[12] The estimated success probability is not incentivized, because this might counteract the occurence of motivated beliefs. See Section 3.4 for more details.

[13] As every subject sees exactly one Dot Spot from each of the ten columns in Table 3.1 per treatment, the difficulty of reading the signals is thus the same across all subjects.

[14] We created three random sequences for the numbers 1 to 10 on www.random.org and used each of the three sequences for one treatment.

treatment (e.g. 120 red dots can potentially be shown in Dot Spot 1 and Dot Spot 10). Additionally, Dot Spots with the *same number* of red dots can be shown in *different treatments*, as the dot distribution in Table 3.1 is the same across all three treatments. Importantly, however, the Dot Spots – both within and across treatments – always differ in the *pattern* of dots (i.e., how a given number of red dots is graphically located in a Dot Spot). For each number of red dots in Table 3.1, we randomized the location of the red dots within the Dot Spot. Hence each single Dot Spot in the experiment is unique. Having Dot Spots with the *same number* of red dots that differ in their *randomized patterns* enables us to compare the investments across treatments more directly, while preventing subjects from learning from (or anchoring to) previously shown Dot Spots. In addition, the variation in the number of red dots in the Dot Spots induces variations in the beliefs about the success probabilities of investments, which we use to identify whether limited liability affects risk-taking through motivated beliefs (see Section 3.3.2 for details).

3.2.3 Practice Rounds

In order to facilitate the understanding of the experiment, subjects participate in *practice rounds* before the first treatment starts. These *practice rounds* are identical to the first treatment of an experiment,[15] except that (i) subjects are informed that the practice rounds have no monetary consequences and (ii) that participants receive some feedback regarding their choices.[16] After each of the five practice rounds, every subject is informed about whether the investment would have been successful (i.e., if there were actually more red dots than blue dots in the previously shown Dot Spot) and the hypothetical payoff for their investment.

3.2.4 Risk

Due to, for example, ambiguity aversion, investments under *uncertainty* (i.e., situations where subjects have to form subjective beliefs about success probabilities based

[15]Recall that we run three orders of treatments (1. *BL*, *MA*, *DF*; 2. *MA*, *DF*, *BL*; 3. *DF*, *MA*, *BL*). Accordingly, order 1 had practice rounds for *BL*, order 2 had practice rounds for *MA*, and order 3 had practice rounds for *DF*.

[16]We do not use the data from the practice rounds for our analysis.

on a noisy signal) might differ from investments under *risk* where subjects know the objective probabilities of investments. In order to also see how our treatments affect investments under risk, we – in addition to the 10 rounds of Dot Spots per treatment – implement one *part* per treatment, in which subjects know the success probabilities of their investments.

In this Risk part, subjects do not receive a noisy signal. Instead, we use the strategy method to elicit subjects' investments for different given success probabilities of investments. More precisely, subjects are shown a table where they decide, using slide bars, how much to invest in the risky asset for each of 11 given success probabilities (0%, 10%, 20%, ..., 100 %). The 11 decisions for these different success probabilities can be chosen completely independent of each other. For each single success probability, the subject has a new endowment of €8 and chooses an amount X $\in$ [€0; €8] he wants to invest in the risky asset. For example, a subject might decide to invest €4 if the success probability is 60% and €8 if the success probability is 100%.[17]

3.2.5 Details on Payoffs

Each of the three treatments thus consists of one Risk part and ten rounds of Dot Spots. In each treatment, the computer randomly and with equal probability (p = 1/11) chooses exactly one of these eleven *elements* (one Risk part, ten rounds of Dot Spots) to become payoff relevant. Hence, in the *Baseline* treatment, for each subject exactly one element is randomly determined to become payoff relevant. Recall that in the *Matched* and *Diffusion* treatments, the payoffs of loss-takers depend on the bankers' investment decisions. Hence the computer chooses for each banker exactly one element of *Matched* and exactly one element of *Diffusion* which become payoff relevant for both loss-takers and bankers. For all three treatments it holds that if the Risk part is chosen for payoff, the computer randomly determines which of the eleven decisions in the Risk part is paid off.[18]

While making their decisions, subjects do not know which decision will become payoff

[17]For easy comprehension of this Risk part, we also implemented three practice rounds of the Risk part before the first treatment starts.

[18]Hence our decisions of main interest, the Dot Spots, are each chosen to become payoff relevant with a probability of $p = 1/11$. Each decision of the Risk part only becomes payoff relevant with a probability of $p = 1/11 \times 1/11 = 1/121$.

relevant. The first and only time subjects get feedback on their payoff-relevant choices is after the experiment. This way we avoid learning and income effects, and incentivize subjects to think carefully about each single investment decision as every investment could become payoff relevant in the end.

3.2.6 Additional Variables

After the three treatments, we elicit additional variables. These are cognitive ability, overestimation, overplacement, overprecision, risk aversion, loss aversion, field of study, age, and gender. See Appendix C.1 for the details on how exactly we elicit the additional variables. In future versions of this chapter's project, we plan to use the additional variables in order to investigate which personal traits and characteristics predict motivated beliefs (e.g. whether it is rather men or women that form motivated beliefs). After we elicit all additional variables, each participant is shown his own payoffs for all treatments and all other segments of the experiment.

3.3 Results

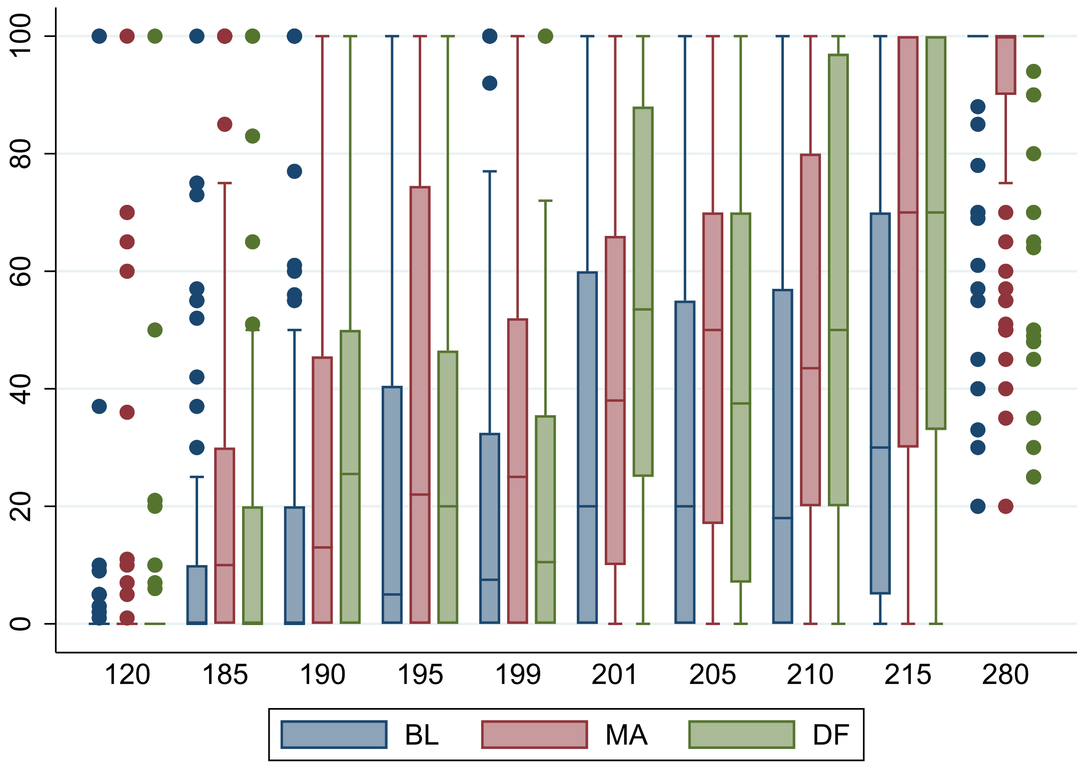
A total of 178 subjects were recruited through ORSEE (Greiner, 2004). Of these 58 participated in Order 1 (*BL*, *MA*, *DF*), 60 in Order 2 (*MA*, *DF*, *BL*), and 60 in Order 3 (*DF*, *MA*, *BL*). All of the nine sessions lasted roughly 130 minutes and were conducted at the Experimental Economics Laboratory of the Technische Universität Berlin. Subjects earned on average €32, and the experiment was programmed and conducted using oTree (Chen et al., 2016). For the entire results section, we only analyze the decisions made by bankers. In addition, as we are mainly interested in investments under uncertainty, Section 3.3 only investigates the decisions for the Dot Spot rounds.[19]

3.3.1 Treatment Effects

In this subsection, we investigate the effects of the treatments (*BL*, *MA*, *DF*) on the investment levels. Because we expect subjects to care more about their own monetary

[19]The treatment effects for the Risk part are shown in Appendix C.2 and are qualitatively similar to the results in Section 3.3.1.

Figure 3.2: Investments for Given Numbers of Red Dots



Investments made by bankers. The vertical axis represents the investment made as a percentage of the endowment. The horizontal axis shows the number of red dots in a Dot Spot. For each number of red dots, we show a box plot for every treatment (*BL*, *MA*, *DF*).

payoffs than about the payoffs of others, we hypothesize that the limited liability treatments, *MA* and *DF*, both lead to higher investment levels than the *Baseline*. For the comparison of the two limited liability treatments, we hypothesize that subjects invest more in the *Diffusion* treatment, where the losses of an investment are distributed among many loss-takers. For a selfish banker (i.e., one that only cares about his own monetary payoffs), the two limited liability treatments provide exactly the same incentives. We argue, however, that bankers might invest more if the concerns for the agents covering the losses get diluted, so that an individual loss-taker is not heavily affected by the banker's decision.

In Figure 3.2 we present the bankers' investments. The vertical axis illustrates the investment made by bankers as a percentage share of their endowment. The horizontal axis represents the number of red dots in a Dot Spot. For every given number of red

Table 3.2: Mean Investments for Dot Spots

	Total	120	185	190	195	199	201	205	210	215	280
BL	27.88	2.64	9.03	15.94	21.75	20.72	33.82	33.52	29.55	39.85	89.59
	(36.30)	(14.05)	(19.40)	(26.22)	(30.31)	(28.82)	(37.33)	(36.59)	(33.05)	(37.13)	(21.95)
MA	41.44	4.73	21.02	27.28	36.16	32.95	41.93	47.43	49.29	61.37	88.47
	(38.80)	(17.28)	(29.86)	(33.29)	(39.13)	(33.79)	(36.01)	(34.91)	(35.26)	(35.12)	(21.23)
DF	39.27	2.82	13.36	28.88	27.54	21.66	53.07	41.55	51.75	61.85	91.40
	(38.41)	(12.06)	(22.13)	(28.34)	(29.80)	(27.17)	(35.11)	(35.64)	(37.32)	(36.81)	(19.84)

Mean investments as a percentage share of the endowment. The column *Total* shows the aggregated average of all investments in a treatment. The other columns show the average investment for a given number of red dots in the Dot Spot. Standard Deviations are shown in parentheses.

dots in a Dot Spot, we plot one box plot for each of the three treatments (*BL*, *MA*, *DF*). In general, the box plots indicate that bankers invest more for a higher number of red dots, suggesting that variations in the number of red dots carry informational content and influence the decisions of bankers.

Furthermore, Figure 3.2 indicates that limited liability increases the bankers' risk-taking, as investments in the limited liability treatments (*MA* and *DF*) are, in most cases, higher than in the *Baseline*. Table 3.2, where we show the mean investments across treatments, confirms these differences. While bankers invested on average only 27.9% of their endowment in the *Baseline* treatment, they invested 41.4% and 39.3% in *MA* and *DF*. In line with this finding, the investments in the limited liability treatments are also higher for most Dot Spots. These investment differences vanish for the extreme signals (Dot Spots with 120 and 280 red dots) where – independent of the treatment – bankers tend to invest either nothing or their entire endowment.

In Table 3.3 we use within-subject Wilcoxon signed-rank tests to compare the investments across treatments. For these tests we only use the observations for which a banker saw a Dot Spot with the same number of dots for the two treatments that are being compared.[20] The p-values of the within-subject Wilcoxon signed-rank tests

[20] Recall from Section 3.2.2 that for each treatment (*BL*, *MA*, *DF*) a banker might see up to two times an image with the same number of dots. For example, a banker might see a Dot Spot with 195 red dots twice in *BL*, never in *MA*, and once in *DF*. In this case, for the Dot Spot with 195 red dots, this banker's data would neither be used for the comparisons between *MA* and *BL* nor for the comparisons between *MA* and *DF*. In the case a subject sees twice an image in the same treatment for a given number of red dots, we take the average between both investments for the

Table 3.3: Wilcoxon Signed-Rank Tests for Dot Spots

	Total	120	180	190	195	199	201	205	210	215	280
p-value BL = MA	<0.001	0.406	0.001	0.032	0.052	0.009	0.027	0.002	<0.001	<0.001	0.305
p-value BL = DF	<0.001	0.019	0.019	0.015	0.166	0.043	<0.001	0.004	<0.001	<0.001	0.075
p-value DF = MA	0.286	0.993	0.543	0.713	0.455	0.632	0.343	0.520	0.392	0.288	0.220

The p-values comparing (paired) investments across treatments. We compare the aggregate investment for the same banker for the subset of similar Dot Spots (i.e., Dot Spots with the same number of red dots) that the banker sees in both treatments that are being compared. Note that, unlike in Table 3.2 and Figure 3.2, we thus only use a subset of banker data in Table 3.3.

comparing the *total* amount invested in the treatments clearly indicate that there are significant investment differences between MA and BL as well as between DF and BL (p-value < 0.001 in both cases).[21]

While we observe substantial effects of limited liability compared to the *Baseline*, there are no significant differences between the two limited liability treatments, MA and DF. This is also indicated by the within-subject Wilcoxon signed-rank tests comparing the total amounts invested in MA and DF (p-value 0.286).

Overall, our data thus shows two clear results. First, the limited liability treatments have a significant positive effect on the level of risk-taking of bankers. Second, we cannot reject the null hypothesis that the investment levels in MA and DF are the same. We can thus summarize the results of Section 3.3.1 in

Result 3.1 *Treatment Effects*
i) The investments in the limited liability treatments, MA and DF, are both statistically significantly higher than in the Baseline treatment.

ii) The investment levels in both limited liability treatments are similar, and we cannot reject the null hypothesis that there are no differences in investment levels between MA and DF.

3.3.2 Investment Effects of Motivated Beliefs

In this subsection, we investigate whether limited liability affects risk-taking through motivated beliefs. A broad literature suggests that "people often act as 'motivated

comparison with the other treatment(s).

[21]We correct the variance of the statistic for those cases in which the differences between both cases are zero.

Bayesians' — while they gather and process information before and during the decision-making process, they tend to do so in a way that is predictably biased toward helping them to feel that their behavior is moral, honest, or fair, while still pursuing their self-interest" (Gino et al., 2016). Following this literature, we argue that, under limited liability, subjects may upward bias their beliefs regarding the success probabilities of investments. This type of belief bias then allows subjects to invest more under limited liability (i.e., pursue their self-interest) without feeling bad about risking other people's money, and might thus cause higher risk-taking under limited liability. Overall, we are thus interested in the effect of limited liability that affects investments *through* beliefs.

Note that, while the analysis in Section 3.3.1 shows that bankers invest significantly more under limited liability, this does not necessarily imply that limited liability affects investments through beliefs. To test the causal effect of motivated beliefs on the investment level, we employ a mediator analysis along the lines of Imai et al. (2011, 2013). In particular, they demonstrate that an IV-approach can be used to disentangle the treatment effect (e.g. the effect of limited liability) through the mediator (e.g. the belief about the success probability of an investment) from all other effects of the treatment. To see that this disentanglement is not possible by simply randomizing the treatment, consider first a not yet fully complete benchmark IV regression:

$$Prob_{b,r} = \gamma_0 + \gamma_1 \times Treatment_{b,r} + \rho_{b,r}, \tag{3.5}$$

$$Investment_{b,r} = \delta_0 + \delta_1 \times \widehat{Prob_{b,r}} + \mu_{b,r}. \tag{3.6}$$

$Prob_{b,r}$ captures banker b's belief about the success probability of an investment in round r. $Treatment_{b,r}$ is a dummy variable that takes on the value 1 in the limited liability treatments *Matched* and *Diffusion*, and 0 if the treatment is *Baseline*.[22] Finally, $Investment_{b,r}$ captures how much banker b invests into the risky asset in round r in percentage points of their endowment. The first stage in eq. (3.5) thus regresses the beliefs on the treatment. The second stage, eq. (3.6), regresses the investment on the estimated beliefs.

As can be seen from these two equations, this specification assumes that the treatment impacts investments only through beliefs. If the treatment also has a direct impact on investments, the exclusion restriction is violated and the model is misspecified. In our experiment, this is likely to be the case. For example, bankers might simply invest more

[22]Hence we pool the two limited liability treatments as they are statistically not distinguishable (recall Section 3.3.1).

under limited liability, because they care more about their own than other subjects' payoffs.

To isolate the causal investment effect of motivated beliefs, we thus need to disentangle the investment effect of limited liability that works only through beliefs, henceforth "indirect effect", from all other investment effects of limited liability, henceforth "direct effects". To achieve separate identification, we design our experiment such that it introduces a second source of exogeneous variation in beliefs. This source of variation are the number of red dots in the Dot Spots, as a higher number of red dots in a Dot Spot should increase the perceived success probability of an investment. We thus introduce the variable $Dots_{b,r}$, which comprises dummies for the 10 different numbers of red dots that we used for the Dot Spots (recall Table 3.1 in Section 3.2.2), into the first stage and run the following IV regression:

$$Prob_{b,r} = \alpha_0 + \alpha_1 \times Treatment_{b,r} + \alpha_2 \times Dots_{b,r} + \epsilon_{b,r}, \tag{3.7}$$

$$Investment_{b,r} = \beta_0 + \beta_1 \times \widehat{Prob_{b,r}} + \beta_2 \times Treatment_{b,r} + u_{b,r}. \tag{3.8}$$

Identification works as follows. First, we identify the effect of beliefs on investments by exploiting variation in beliefs due to $Dots_{b,r}$ (instead of solely exploiting variation in beliefs due to $Treatment_{b,r}$). Second, this feature allows us to include $Treatment_{b,r}$ as an explanatory variable in the second stage, which enables us to isolate the limited liability effect through beliefs from all other investment effects of limited liability. The main identifying assumption of our regression model in eqs. (3.7) and (3.8) is that the number of red dots in a Dot Spots, $Dots_{b,r}$, only affects the investment decision through a shift in beliefs about the success probability of the investment.

We can now simply compute the complier average mediation effect, CACME, as the product of α_1 from eq. (3.7) and β_1 from eq. (3.8). This is the average effect of limited liability on investment that is mediated by beliefs among those bankers whose beliefs are affected by the number of red dots (cf. e.g. Imai et al., 2011).[23] The complier average direct treatment effect (CADE), in contrast, captures all causal mechanisms of limited liability on investment that do not work through the beliefs and is simply given by β_2 in eq. (3.8).

We run four specifications for our IV regression in eqs. (3.7) and (3.8) for our balanced panel of 89 bankers and 30 rounds. Specification (1) uses clustered standard errors at

[23]The concept of the CACME is thus similar to the local average treatment effect obtained from standard IV estimations.

Table 3.4: First Stage Regressions for Prob

Dep. Variable: *Prob*	(1)	(2)	(3)	(4)
Constant	7.145***	8.665***		
	(1.986)	(2.211)		
Treatment	3.368***	3.363***	3.346***	3.346***
	(0.942)	(0.942)	(0.942)	(0.883)
Dots 185	19.025***	19.080***	19.862***	19.862***
	(1.920)	(1.923)	(1.889)	(1.846)
Dots 190	29.178***	29.170***	29.056***	29.056***
	(2.157)	(2.166)	(2.104)	(1.854)
Dots 195	32.141***	32.211***	31.677***	31.677***
	(2.452)	(2.434)	(2.460)	(1.857)
Dots 199	32.707***	32.724***	33.164***	33.164***
	(2.460)	(2.463)	(2.553)	(1.866)
Dots 201	44.187***	44.299***	44.946***	44.946***
	(2.653)	(2.641)	(2.652)	(1.808)
Dots 205	40.962***	41.026***	42.574***	42.574***
	(2.383)	(2.369)	(2.377)	(1.811)
Dots 210	44.266***	44.402***	45.558***	45.558***
	(2.636)	(2.608)	(2.711)	(1.816)
Dots 215	53.306***	53.385***	53.709***	53.709***
	(2.950)	(2.933)	(3.029)	(1.827)
Dots 280	80.790***	80.939***	82.157***	82.157***
	(2.721)	(2.709)	(2.812)	(1.904)
Observations	2670	2670	2670	2670
Number of Bankers	89	89	89	89
R^2	0.438	0.439	0.480	0.480
Test of excl. instr.: F-statistic	110.88	111.69	109.37	259.76
Control for Treatment Order	No	Yes	No	No
Banker Fixed Effects	No	No	Yes	Yes
Standard Errors Clustered at Banker Level	Yes	Yes	Yes	No

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In all four columns the dummy for $Dots120$ is not included because of multicollinearity. In specifications (3) and (4) the constant is additionally dropped, since we are using banker fixed effects. Robust standard errors in parentheses.

banker level to correct for the fact that observations within banker and across rounds might be correlated. In specification (2), we additionally add dummies for the three session orders to control for order effects. The banker fixed effects in specification (3) exploit the within banker variation and thus control for all banker specific effects (e.g. individual traits). Specification (4) also uses banker fixed effects but, unlike specification (3), does not cluster standard errors at banker level.

Table 3.4 shows the results from the first stage in eq. (3.7) for these four different specifications. In general, Table 3.4 indicates that variations in the number of red dots have a large impact on the beliefs. For example, the perceived success probabilities in specification (3) are, on average, 31.7 percentage points larger for a Dot Spot with 195 red dots (*Dots 195*) than for Dot Spots with 120 red dots. Importantly, all four specifications in Table 3.4 show a statistically significant effect of limited liability on the reported beliefs of roughly 3.3 percentage points. This indicates that bankers indeed upward bias their beliefs in the presence of limited liability.

Table 3.5: Second Stage with Instruments for Prob

Dep. Variable: *Investment*	(1)	(2)	(3)	(4)
Constant	-19.176***	-18.589***		
	(2.510)	(2.816)		
Prob (instrumented)	1.091***	1.092***	1.088***	1.088***
	(0.038)	(0.038)	(0.036)	(0.019)
Treatment	6.971***	6.969***	6.986***	6.986***
	(1.414)	(1.412)	(1.409)	(0.825)
Observations	2670	2670	2670	2670
Number of Bankers	89	89	89	89
R^2	0.591	0.591	0.682	0.682
Control for Treatment Order	No	Yes	No	No
Banker Fixed Effects	No	No	Yes	Yes
Standard Errors Clustered at Banker Level	Yes	Yes	Yes	No

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In all four columns the dummy for *Dots*120 is not included because of multicollinearity. In specifications (3) and (4) the constant is additionally dropped, since we are using banker fixed effects. Robust standard errors in parentheses.

Table 3.5 presents the second stage results for our four specifications. On average, an increase in the perceived success probabilities by one percentage point increases the investment by approximately 1.1 percentage points in all four specifications. This effect is statistically significant at the one percent level. In specification (3), the CADE (i.e., β_2 in eq. (3.8)) is approximately 6.99 percentage points. Using the first and second stage results from Tables 3.4 and 3.5, we can also obtain the CACME, which is $3.346 \times 1.088 \approx 3.64$ in specification (3).

In Table 3.6 we use bootstrapped standard errors to test whether the effect of limited liability through the beliefs, $\alpha_1 \times \beta_1$, is statistically significant. We find that this effect of motivated beliefs is statistically significant at the one percent level in all four specifications.

Table 3.6: Indirect (CACME) and Direct Treatment Effects (CADE)

Dep. Variable: *Investment*	(1)	(2)	(3)	(4)
Indirect Treatment Effect (CACME)	3.675***	3.671***	3.642***	3.642***
	(1.015)	(1.014)	(1.007)	(0.982)
Direct Treatment Effects (CADE)	6.971***	6.969***	6.986***	6.986***
	(1.356)	(1.353)	(1.349)	(0.896)
Observations	2670	2670	2670	2670
Number of Bankers	89	89	89	89
Control for Treatment Order	No	Yes	No	No
Banker Fixed Effects	No	No	Yes	Yes
Standard Errors Clustered at Banker Level	Yes	Yes	Yes	No

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Standard errors obtained from bootstrapping by resampling observations (with replacements) for 1,000 times. Bootstrap standard errors in parentheses.

Overall, our analysis in Tables 3.4 - 3.6 indicates that – beyond the direct effects – limited liability has a further effect on investments which works through beliefs. In our setting, motivated beliefs are, thus, a driver of risk-taking under limited liability. We summarize our findings of Section 3.3.2 in

Result 3.2 *Investment Effects of Motivated Beliefs*

Limited liability increases the perceived success probability of investments, which causes bankers to invest more under limited liability.

3.4 Limitations

Experimental and quasi-experimental studies are often criticised for only focusing on the causal effect of a treatment on an outcome without explaining *how* and *why* it actually affects the outcome (e.g. Deaton, 2010; Heckman and Smith, 1995). Yet, the empirical identification of causal mediator effects is often challenging.[24] Randomization of the treatment alone is not sufficient to uncover the causal mediator effect, as it is unable to disentangle the direct treatment effects from the treatment effects through the mediator. Using an additional source of variation (i.e., the Dot Spots) in our mediator (i.e., the beliefs), our design aims to avoid confounding the causal mediator effect.

Yet, our empirical identification and design also entails certain limitations. First, our regression specification, eqs. (3.7) and (3.8), assumes a linear functional form. We will aim to address this concern in future versions of this project by nonparametrically estimating the average causal mediation effect as in Imai et al. (2010). Second, while we incentivize the outcomes, we do not incentivize the beliefs of banker subjects.[25] This might lead to experimenter demand effects. Incentivizing the beliefs, however, would potentially counteract banker subjects' incentives to form motivated beliefs. In fact, it might be a potential debiasing treatment for motivated beliefs and therefore counterproductive for investigating whether limited liability causes motivated beliefs.

Third, a potential limitation of our project is external validity. Our subject pool mainly consists of students who may or may not behave differently than financial employees. In a meta study, Fréchette (2011) finds that there are some instances in which student subjects and professionals show behavioral differences, but these differences are small provided that the two populations are playing the same game. Hence, while the external validity of an experiment with financial employees would be higher, we still expect our analysis to be informative. Another concern related to external validity is that we would ideally investigate decision-making in real financial markets. Yet, unlike observational data, the laboratory setting enables us to vary the limited liability incentives within-subject, to control the information that subjects receive regarding the success probabilities of investments, and to elicit individual beliefs.

[24] See Imai et al. (2011, 2013) for the difficulties associated with uncovering causal mechanisms.

[25] See Schlag et al. (2015) for a discussion of the trade-offs related to the usage of incentives for belief elicitation in experiments.

3.5 Conclusion

This experiment showed that limited liability increases risk-taking. In a next step, we used a mediator analysis to disentangle the effect of limited liability that works through motivated beliefs from all other investment effects of limited liability. Our key result is that motivated beliefs are a driver of risk-taking under limited liability. For a given signal, subjects hold higher beliefs under limited liability than in the full liability treatment, and this effect significantly increases risk-taking in the limited liability treatments. Our results are thus in line with the theoretical literature arguing that motivated beliefs may have contributed to bankers taking on too much risk in the years preceding the financial crisis (Barberis, 2013; Bénabou, 2015).

The finding that motivated beliefs contribute to risk-taking under limited liability raises the question how policy could affect them. In general, research has shown that debiasing motivated beliefs is difficult. Even experienced professionals (e.g. teachers, lawyers, and judges) are prone to self-serving biases (Babcock and Loewenstein, 1997a; Eisenberg, 1994) and simply informing individuals about the existence of self-serving biases is an ineffectual debiasing tool (Babcock and Loewenstein, 1997a). However, there have been some successful attempts at debiasing motivated beliefs. It has been shown that self-serving assessments are mitigated when subjects make judgements *before* they receive information regarding their incentives (Gneezy et al., 2016, 2018). Motivated beliefs and its consequences are also reduced by a more objective decision environment (Gneezy et al., 2018). Finally, Babcock et al. (1997b) show that instructing subjects to question their own assessment by thinking about the weaknesses and counterarguments to their judgement mitigates self-serving biases substantially.

For policymakers that aim to reduce risk-taking under limited liability, it might thus be beneficial to force material risk-takers in the financial sector more strongly to rationalize their investment behaviour based on objective and hard facts of the investment target, or to make them justify in much detail why a potential investment could go wrong and who would suffer from it. Yet, all these treatments might lead to other distortions and their effectiveness in a financial context has not yet been tested. How to tackle motivated beliefs in the financial sector is thus an interesting and important question for future research.

Conclusion

This thesis has considered risk-taking under limited liability. The first two chapters investigate how to intervene in banker pay when limited liability provides banks with an incentive to induce excessive risk-taking. Both chapters thereby incorporate distinct features of the financial sector, which are based upon recent empirical evidence. These are the international mobility of bankers (Chapter 1) and managerial overconfidence (Chapter 2). Incorporating these features into a theoretical analysis, this thesis provides answers to policy questions that have thus far not been sufficiently addressed.

Chapter 1 shows how the policy competition for mobile bankers affects governments' incentives to intervene into banker pay. An important policy implication is that the international competition for bankers tends to incentivize governments to adjust their bonus taxes and caps downwards when bailout costs are partly shared between countries. Chapter 1 thus implies that the bonus caps introduced by the European Union complement the creation of the European banking union.

Chapter 2 addresses the policy question on how regulation and taxation have to adapt when bankers are not fully rational but overconfident. Importantly, overconfidence provides a rationale to intervene into banker pay even in the presence of capital requirements, as the latter are unable to address the distortions in banker pay that arise from overconfidence. More generally, Chapter 2 suggests that the presence of managerial overconfidence calls for bonus taxes in systemically important financial institutions. Bonus taxation can curb the bank's risk-shifting incentives, deter the exploitation of managerial overvaluation, and avoid the selection of overconfident managers into systemically important financial institutions.

A common feature of the first two chapters is that limited liability causes bankers to take on socially excessive risks. This is however not a result of bankers being particularly immoral or selfish. As Chapter 3 shows, even students' risk-taking decisions and beliefs respond strongly to the monetary incentives provided by limited liability. Instead, it is the specific incentives in the banking industry that drive overly risky investments. Researchers and policymakers are at the helm of investigating and implementing institutions that create incentives which align the interests of bankers and the public. I hope this dissertation provides a small step in the right direction.

For academics and policymakers alike, there are many important questions and challenges on the horizon. One major challenge to the regulation of banker pay might arise in the wake of Brexit. The United Kingdom has long been a fierce opponent of the EU bonus cap, and is contemplating to scrap it after a potential Brexit (Financial Times, 2017). The implications of such a move (e.g. for the international labor market for bankers, their contracts, and risk-taking) are currently unclear and should be of major interest to both researchers and policymakers. Another challenge for the regulation of banker pay is provided by shadow banking. The global post-crisis regulation has increased the costs of compensation and risk-taking for banks within the regulatory perimeter. This might have the unintended effect that talented bankers instead move to the less regulated, but economically very important, shadow banking sector. How relevant this channel is and how regulators should respond to it deserves attention, as it may crucially affect financial stability. Overall, banker pay thus remains an important topic in the foreseeable future.

Appendices

A Appendix to Chapter 1

A.1 Derivation of Equation 1.17

The bank in country i chooses the bonus z_i and the fixed wage w_i, which depends on z_j and w_j. Hence the system of first-order conditions in (1.15) is interdependent, and given by

$$\frac{\partial \Pi_i}{\partial w_i} = \frac{1}{a}\left\{p_i^{h*}[Y^h - sd - z_i(1+t_i)] + p_i^{m*}(Y^m - sd) - w_i - (1-s)d\right\}$$
$$- \bar{N} - \frac{1}{a}\left[\frac{\gamma}{2}(z_i^2 - z_j^2) + w_i - w_j\right] = 0, \tag{A.1}$$
$$\frac{\partial \Pi_j}{\partial w_j} = \frac{1}{a}\left\{p_j^{h*}[Y^h - sd - z_j(1+t_j)] + p_j^{m*}(Y^m - sd) - w_j - (1-s)d\right\}$$
$$- \bar{N} - \frac{1}{a}\left[\frac{\gamma}{2}(z_j^2 - z_i^2) + w_j - w_i\right] = 0. \tag{A.2}$$

Solving both (A.1) and (A.2) for w_j, setting the two expressions equal to each other, and solving for w_i gives

$$w_i = \frac{1}{3}p_j^{h*}[Y^h - sd - z_j(1+t_j)] + \frac{1}{3}p_j^{m*}(Y^m - sd) + \frac{2}{3}p_i^{h*}[Y^h - sd - z_i(1+t_i)]$$
$$+ \frac{2}{3}p_i^{m*}(Y^m - sd) - (1-s)d - a\bar{N} + \frac{1}{6}\gamma(z_j^2 - z_i^2).$$

Substituting in the equilibrium bonuses z_i and z_j from (1.16) and the equilibrium probabilities from (1.4)–(1.6) yields

$$\begin{aligned} w_i = {} & \frac{1}{3}\frac{\gamma\Omega}{(1+2t_j)}\left[Y^h - sd - \frac{\Omega(1+t_j)}{1+2t_j}\right] + \frac{1}{3}\left(p_0^m - \frac{\beta}{\mu}\frac{\Omega}{1+2t_j}\right)(Y^m - sd) \\ & + \frac{2}{3}\frac{\Omega\gamma}{(1+2t_i)}\left[Y^h - sd - \frac{\Omega(1+t_i)}{1+2t_i}\right] + \frac{2}{3}\left(p_0^m - \frac{\beta}{\mu}\frac{\Omega}{1+2t_i}\right)(Y^m - sd) \\ & - (1-s)d - a\bar{N} + \frac{1}{6}\gamma\left[\left(\frac{\Omega}{1+2t_j}\right)^2 - \left(\frac{\Omega}{1+2t_i}\right)^2\right]. \end{aligned} \tag{A.3}$$

Using $\Omega = Y^h - sd - \frac{\beta}{\mu\gamma}(Y^m - sd)$ from (1.16) and symmetry, this simplifies to

$$w_i = p_0^m(Y^m - sd) - (1-s)d + \frac{\gamma\Omega^2}{6}\left[\frac{1}{(1+2t_j)} + \frac{4t_i - 1}{(1+2t_i)^2}\right] - \bar{N}a, \tag{A.4}$$

which corresponds to eq. (1.17) in the main text.

A.2 Second-Order Condition for Optimal Bonus Taxes

Differentiating the first-order condition for bonus taxes (1.22) with respect to t_i gives

$$\frac{\partial^2 W_i}{\partial t_i^2} = N_i\,\frac{\partial^2 F_i}{\partial t_i^2} + F_i\,\frac{\partial^2 N_i}{\partial t_i^2} + 2\,\frac{\partial F_i}{\partial t_i}\,\frac{\partial N_i}{\partial t_i}. \tag{A.5}$$

Substituting in from (1.20), (1.22) and (1.24) gives, in a first step

$$\begin{aligned} \frac{\partial^2 W_i}{\partial t_i^2} = {} & N_i\left[4\gamma z_i\tfrac{\partial z_i}{\partial t_i} + 2\gamma t_i\left(\tfrac{\partial z_i}{\partial t_i}\right)^2 + 2\gamma t_i z_i\tfrac{\partial^2 z_i}{\partial t_i^2} - \delta sd\tfrac{\partial^2 z_i}{\partial t_i^2}\right] \\ & + [\gamma z_i^2 t_i - (p_0^l + \delta z_i)sd]\ \tfrac{4\gamma\Omega^2}{3a(1+2t_i)^3} - \tfrac{2\gamma\Omega^2}{3a(1+2t_i)^2}\left[\gamma z_i^2 + 2\gamma t_i z_i\tfrac{\partial z_i}{\partial t_i} - \delta sd\tfrac{\partial z_i}{\partial t_i}\right]. \end{aligned}$$

Further substituting in from (1.16) and (1.18) gives

$$\frac{\partial^2 W_i}{\partial t_i^2} = \frac{-2\gamma\Omega^2}{3a(1+2t_i)^3}\left[2p_0^l sd + \frac{4\delta\Omega sd}{(1+2t_i)} + \frac{\gamma\Omega^2(1-4t_i)}{(1+2t_i)^2}\right] - \frac{8N_i\Omega}{(1+2t_i)^3}\left[\delta sd + \frac{\gamma\Omega(1-t_i)}{(1+2t_i)}\right].$$

This expression can be further simplified by adding the first-order condition for the optimal bonus tax rate in the symmetric equilibrium [eq. (1.23)]. This gives

$$\frac{\partial^2 W_i}{\partial t_i^2} = \frac{-2\gamma\Omega^2}{(1+2t_i)^4}\left[\frac{\gamma\Omega^2(1-2t_i)}{3a(1+2t_i)} + \frac{2\delta\Omega sd}{3a} + 2\bar{N}\right]. \tag{A.6}$$

The last two terms in (A.6) are unambiguously negative if $\delta \geq 0$, but the first term cannot be signed, in general. However, for a wide range of parameters, the second-order condition will be fulfilled. As a concrete example, let $\alpha = 0.4$, $\beta = 0.5$, $\eta = 0.5$,

$\mu = 0.5$. This implies $\gamma = 0.82$, $\delta = 0.18$ and $\Omega = 1.237$. Moreover, assume $s = 0.8$, $\bar{N} = 10$, $a = 0.025$, $d = 1$, $Y^h = 3.5$ and $Y^m = 2$. Then the following numerical results are obtained for varying levels of the baseline probability of default, p_0^l:

(1)	p_0^l	0.10	0.20	0.25	0.30	0.35
(2)	F_i	0.74	0.39	0.08	-0.40	-1.15
(3)	t_i	0.58	0.75	0.87	1.02	1.21
(4)	SOC	-7.68	-7.20	-6.76	-6.08	-4.97

When p_0^l is gradually increased, the fiscal value of a manager, F_i falls continuously and turns negative for $p_0^l \geq 0.3$ [row (2)]. At the same time the tax rate rises continuously, and exceeds unity for $p_0^l \geq 0.3$ [row (3)]. Nevertheless, the second-order condition holds for all computed equilibria with $p_0^l \leq 0.35$ [row (4)]. Analogous results are obtained if the remaining, exogenous parameters are modified.

A.3 Proof of Proposition 1.2

We establish the conditions under which W_i is rising in t at $t = 0$, but falling in t when $t \to \infty$. Evaluating the first-order condition for the optimal bonus tax rate, given in eq. (1.23), in the main text, at $t = 0$ gives

$$\left.\frac{\partial W_i}{\partial t_i}\right|_{t=0} = \bar{N}(\gamma\Omega + 2\delta sd) + \frac{\gamma\Omega sd}{3a}(p_0^l + \delta\Omega) > 0, \tag{A.7}$$

which is always positive for $\delta \geq 0$.

Evaluating (1.23) at $t \to \infty$, using L'Hôpital's rule and inserting the migration elasticity (1.11) gives

$$\left.\frac{\partial W_i}{\partial t_i}\right|_{t\to\infty} = \bar{N}\left[-\gamma\Omega\left(1 - \frac{\varepsilon p_0^l sd}{3}\right) + 2\delta sd\right]. \tag{A.8}$$

This is negative if the term in squared brackets is negative. The condition for this to hold is summarized in Proposition 1.2. □

A.4 Proof of Proposition 1.3

We evaluate

$$\frac{dF_i}{d\chi} = \frac{\partial F_i}{\partial \chi} + \frac{\partial F_i}{\partial t_i}\frac{dt_i^*}{d\chi}, \quad \chi \in \{p_0^l, s\}.$$

(i) The direct effect of a change in p_0^l on F_i is

$$\frac{\partial F_i}{\partial p_0^l} = -sd < 0. \tag{A.9}$$

The indirect effect of p_0^l on F_i via the induced change in t_i is

$$\frac{\partial F_i}{\partial t_i}\frac{dt_i}{dp_0^l} = \frac{[\gamma\Omega^2(1-2t)+2\delta\Omega sd(1+2t)]}{(1+2t)^3}\,\frac{\gamma\Omega^2 sd}{3a(1+2t)^2}\,\frac{(-1)}{\partial^2 W/\partial t_i^2} \equiv \Psi sd, \tag{A.10}$$

where $\partial^2 W/\partial t_i^2$ is given in (A.6). From (A.9) and (A.10), the total effect is thus

$$\frac{dF_i}{dp_0^l} = -sd\,(1-\Psi)\,. \tag{A.11}$$

The direct effect of p_0^l on F_i will dominate when $\Psi < 1$. Using (A.6), the condition for this to hold is

$$\frac{1}{3a(1+2t)}[\gamma\Omega^2(1-2t)+2\delta\Omega sd(1+2t)] + 4\bar{N} > 0 \tag{A.12}$$

The squared bracket in the first term equals the numerator of $\partial F_i/\partial t_i$ in (A.10). If this squared bracket is positive, condition (A.12) is definitely met. If the squared bracket is instead negative, then $\partial F_i/\partial t_i < 0$. Since $dt/dp_0^l > 0$ holds unambiguously, the indirect effect must then also be negative, reinforcing the direct effect. Therefore, $dF_i/dp_0^l > 0$ holds unambiguously.

(ii) The direct effect of a change in s on F_i for $\delta = 0$ is

$$\frac{\partial F_i}{\partial s} = -p_0^l d < 0. \tag{A.13}$$

The indirect effect of s on F_i via the induced change in t_i is

$$\frac{\partial F_i}{\partial t_i}\frac{dt_i}{ds} = \frac{\gamma\Omega^2(1-2t)}{(1+2t)^3}\,\frac{\gamma\Omega^2 p_0^l d}{3a(1+2t)^2}\,\frac{(-1)}{\partial^2 W/\partial t_i^2} \equiv \tilde{\Psi} p_0^l d, \tag{A.14}$$

where $\tilde{\Psi}$ corresponds to Ψ in (A.10) when $\delta = 0$. From (A.13) and (A.14), the total effect is

$$\frac{dF_i}{ds} = -p_0^l d\,(1-\Psi)\,, \tag{A.15}$$

The above argument applies that either $\tilde{\Psi} < 1$, or the indirect effect is negative. Hence $dF_i/ds < 0$ holds unambiguously when $\delta = 0$. □

B Appendix to Chapter 2

B.1 Bank's Maximization Problem

From eq. (2.12), the bank's maximization problem is given by

$$\begin{aligned} \max_{z,F} \Pi &= p^{h*}\left[Y^h - z(1+t)\right] + p^{m*}Y^m + p^{l*}v_i sd - F - d \\ s.t.\ \hat{u}^* &= \frac{\gamma}{2}(1+\theta)^2 z^2 + F \geq \bar{u}. \end{aligned} \tag{B.1}$$

Using the equilibrium probabilities from eq. (2.7), we get the following Lagrangian:

$$\begin{aligned} \max_{z,F} \mathcal{L} =& [\gamma z(1+\theta)][Y^h - z(1+t)] + [p_0^m - \frac{\beta}{\mu} z(1+\theta)]Y^m + [p_0^l + \delta z(1+\theta)]v_i sd \\ & - F - d + \kappa\left[\frac{\gamma}{2}(1+\theta)^2 z^2 + F - \bar{u}\right]. \end{aligned} \tag{B.2}$$

As risk-taking is a mean-preserving spread, $\beta Y^h = Y^m$ holds. The three first order conditions are then given by

$$\frac{\partial \mathcal{L}}{\partial z} = \frac{\alpha^2}{\eta} Y^h(1+\theta) - 2(1+t)\gamma z(1+\theta) + \delta v_i sd(1+\theta) + \kappa\gamma z(1+\theta)^2 = 0, \tag{B.3}$$

$$\frac{\partial \mathcal{L}}{\partial F} = -1 + \kappa \leq 0, \tag{B.4}$$

$$\frac{\partial \mathcal{L}}{\partial \kappa} = \frac{\gamma}{2}(1+\theta)^2 z^2 + F - \bar{u} \geq 0. \tag{B.5}$$

The bonus will always be used in equilibrium ($z > 0$) as the marginal costs of the bonus at z=0 are zero, while the marginal benefits are positive due to the positive effect of the bonus on effort- and risk-taking.

We focus on the case where the bonus and the fixed wage are used in equilibrium (**Case 1**: $z > 0$ and $F > 0$). From the complementary slackness condition it follows that a positive fixed wage ($F > 0$) implies $\kappa = 1$ in eq. (B.4). Note also that for the fixed wage to be used ($F > 0$), the participation constraint must be binding (i.e., eq. (B.5) holds with equality). Otherwise profits could be increased by lowering the fixed wage.

Solving eq. (B.3) for z and using $\kappa = 1$, we get the bank bonus z_B in eq. (2.15). Using the participation constraint in (B.5) gives the bank's fixed wage F_B in eq. (2.16). The second order condition with respect to z_B is given by

$$\frac{\partial^2 \mathcal{L}}{\partial z^2} = -\gamma(1+\theta)[2(1+t) - (1+\theta)]. \tag{B.6}$$

In the two other possible cases, the fixed wage is not used. In **Case 2** ($z > 0$, $F = 0$ and $0 < \kappa < 1$) only the bonus is used and the participation constraint is binding. In **Case 3** ($z > 0$, $F = 0$ and $\kappa = 0$) only the bonus is used and the participation constraint is not binding.

Analyzing the conditions under which $\kappa = 0$ and $\kappa = 1$, we can derive the conditions for the three cases. Case 1 holds if overconfidence is sufficiently low:

$$(1+\theta) < \frac{2\sqrt{2\bar{u}\gamma}(1+t)}{\Omega + \sqrt{2\bar{u}\gamma}}, \text{where } \Omega \equiv \frac{\alpha^2}{\eta} Y^h + \delta v_i sd. \tag{B.7}$$

Note that (B.7) implies that $(1+\theta) < 2(1+t)$, which ensures that there is an interior solution for the bonus (cf. eq. (B.6)). We assume that the fixed wage is used for any possible bonus tax (i.e., $t \geq 0$). This assumption can be derived by setting $t = 0$ in eq. (B.7), and is given in eq. (2.13).

Case 2 holds for $\frac{2\sqrt{2\bar{u}\gamma}(1+t)}{\Omega+\sqrt{2\bar{u}\gamma}} < (1+\theta) < \frac{2\sqrt{2\bar{u}\gamma}(1+t)}{\Omega}$. If overconfidence is very high, $(1+\theta) > \frac{2\sqrt{2\bar{u}\gamma}(1+t)}{\Omega}$, the participation constraint does not bind and Case 3 holds.

B.2 Optimal Bonus Tax

Substituting the bank's bonus z_B from eq. (2.15) and $\frac{\partial z_B}{\partial t}$ into eq. (2.20), we get

$$\begin{aligned} \frac{\partial W}{\partial t} = &- \frac{2\gamma(1+\theta)\Omega\frac{\alpha^2}{\eta}Y^h}{\Psi^2} + \frac{2\gamma^2(1+\theta)^2\Omega^2}{\Psi^3} \\ &+ (\lambda - 1)\left\{\frac{(1+\theta)\gamma^2\Omega^2[2-(1+\theta)-2t]}{\Psi^3} + \frac{2\gamma(1+\theta)\Omega\delta v_i sd}{\Psi^2}\right\}. \end{aligned} \tag{B.8}$$

Collecting terms in eq. (B.8) gives

$$\begin{aligned} \frac{\partial W}{\partial t} = &\left[\frac{(1+\theta)\gamma^2\Omega}{\Psi^3}\right] \times \\ &\{-2[\Omega - \lambda\delta v_i sd][2(1+t)-(1+\theta)] + 2\Omega(1+\theta) + (\lambda-1)\Omega[2-(1+\theta)-2t]\}. \end{aligned} \tag{B.9}$$

Setting $t = 0$ and summarizing terms in eq. (B.9), we get the first order condition at $t = 0$, as given in eq. (2.21).

Using the fact that $\left[\frac{(1+\theta)\gamma^2\Omega}{\Psi^3}\right] > 0$ always holds, and collecting terms in (B.9), we find that

$$sgn\left\{\frac{\partial W}{\partial t}\right\} = sgn\{[2-(1+\theta)]\,[2\lambda\delta v_i sd + (\lambda-1)\Omega] + 4\Omega\theta + t[-2(1+\lambda)\Omega + 4\lambda\delta v_i sd]\}. \tag{B.10}$$

Eq. (B.10) shows that there is a corner solution (i.e., $\frac{\partial W}{\partial t} > 0\ \forall t \geq 0$), if

$$\delta v_i sd > \frac{(\lambda+1)\frac{\alpha^2}{\eta}Y^h}{(\lambda-1)}. \tag{B.11}$$

This condition implies that the last term in squared brackets in eq. (B.10) is positive. As all other terms in eq. (B.10) are positive as well, eq. (B.11) is thus a sufficient condition for a corner solution. Intuitively, this condition shows that if the risk-shifting incentives, $\delta v_i sd$, are very large, the government optimally chooses $t^* \to \infty$ in order to minimize its bailout costs.

If eq. (2.22) holds, however, then there is an interior solution for the optimal bonus tax. Setting $\frac{\partial W}{\partial t}$ in eq. (B.9) equal to zero, dividing both sides by $\frac{(1+\theta)\gamma^2\Omega}{\Psi^3}$, and solving for t, we get the optimal bonus tax in eq. (2.23). It's easy to show that eq. (2.22) implies that $\frac{\partial W}{\partial t} > 0$ for $0 \leqslant t < t^*$, and that $\frac{\partial W}{\partial t} < 0$ for $t > t^*$. Hence t^* in eq. (2.23) is a global maximum, if eq. (2.22) holds. □

B.3 Effect of Overconfidence on Optimal Bonus Tax

The effect of overconfidence on the optimal tax is negative, if and only if simultaneously (i) the condition for an interior tax (cf. eq. (2.22)) holds, and (ii) the effect of θ on t^* in (2.27) is negative. Solving (2.22) for λ, we get two cases:

$$\lambda < \frac{\frac{\alpha^2}{\eta}Y^h + \delta v_i sd}{\delta v_i sd - \frac{\alpha^2}{\eta}Y^h} \quad if \quad \delta v_i sd > \frac{\alpha^2}{\eta}Y^h, \tag{B.12}$$

$$\lambda > \frac{\frac{\alpha^2}{\eta}Y^h + \delta v_i sd}{\delta v_i sd - \frac{\alpha^2}{\eta}Y^h} \quad if \quad \delta v_i sd < \frac{\alpha^2}{\eta}Y^h. \tag{B.13}$$

Case 1

For the effect of θ on t^* to be negative in **Case 1** (i.e., $\delta v_i sd > \frac{\alpha^2}{\eta}Y^h$), (2.27) has to be negative and simultaneously (B.12) has to hold. These two conditions hold simultaneously if and only if

$$\frac{5(\frac{\alpha^2}{\eta}Y^h + \delta v_i sd)}{\frac{\alpha^2}{\eta}Y^h + 3\delta v_i sd} \; < \; \lambda \; < \; \frac{\frac{\alpha^2}{\eta}Y^h + \delta v_i sd}{\delta v_i sd - \frac{\alpha^2}{\eta}Y^h}. \tag{B.14}$$

A necessary condition for (B.14) to hold is thus

$$\frac{5(\frac{\alpha^2}{\eta}Y^h + \delta v_i sd)}{\frac{\alpha^2}{\eta}Y^h + 3\delta v_i sd} \; < \; \frac{\frac{\alpha^2}{\eta}Y^h + \delta v_i sd}{\delta v_i sd - \frac{\alpha^2}{\eta}Y^h}.$$

This condition is satisfied for $\delta v_i sd > \frac{\alpha^2}{\eta}Y^h$, if and only if $\delta v_i sd < 3\frac{\alpha^2}{\eta}Y^h$. We have thus proven that the effect of overconfidence on the optimal bonus tax can never be negative, if the risk-shifting incentives are sufficiently strong as given by

$$\delta v_i sd > 3\frac{\alpha^2}{\eta}Y^h. \tag{B.15}$$

Hence the effect of overconfidence on the optimal bonus tax is positive for any interior solution of t^*, if (B.15) holds. Eq. (B.15) does hold for an interior solution of the optimal bonus tax, if (B.15) and (B.12) hold simultaneously. This is the case, if

$$3\frac{\alpha^2}{\eta}Y^h < \delta v_i sd < \frac{\lambda + 1}{\lambda - 1}\frac{\alpha^2}{\eta}Y^h, \tag{B.16}$$

which holds for a wide range of combinations of exogenous parameter values (e.g. it is always fulfilled for (B.15), if λ is sufficiently close to 1).

To summarize, **Case 1** proves that the effect of overconfidence on the optimal bonus tax is positive for any interior optimal bonus tax, if risk-shifting incentives are sufficiently strong (i.e., if eq. (B.15) holds). The strong risk-shifting incentives in (B.15) do not rule out an interior optimal bonus tax as shown by (B.16).

Case 2

For the effect of θ on t^* to be negative in **Case 2** (i.e., $\delta v_i sd < \frac{\alpha^2}{\eta}Y^h$), (2.27) has to be negative and simultaneously (B.13) has to hold. For $\delta v_i sd < \frac{\alpha^2}{\eta}Y^h$, the bonus tax is always finite (i.e., (B.13) always holds). Hence, the condition for a negative effect of θ on t^* in **Case 2** is the same as the condition for (2.27) to be negative, and given by

$$\lambda > \frac{5(\frac{\alpha^2}{\eta}Y^h + \delta v_i sd)}{\frac{\alpha^2}{\eta}Y^h + 3\delta v_i sd}. \tag{B.17}$$

For $\delta v_i sd < \frac{\alpha^2}{\eta}Y^h$, (B.17) never holds if $\lambda \leq 2.5$ and always holds if $\lambda > 5$. Hence a sufficient condition for the effect of θ on t^* to be negative is given by

$$\delta v_i sd < \frac{\alpha^2}{\eta}Y^h \quad \wedge \quad \lambda > 5. \tag{B.18}$$

B.4 Socially Optimal Bonus

In the absence of bonus taxes, social welfare is the (weighted) sum of bank profit $\Pi^* = p^{h*}(Y^h - z) + p^{m*}Y^m + p^{l*}v_i sd - F - sd - (1-s)d$, actual manager utility $u = p^{h*}z + F - \frac{\eta e^{*2}}{2} - \frac{\mu b^{*2}}{2}$, and the weighted bailout costs $\lambda B = \lambda p^{l*} v_i sd$.

The social planer's maximization problem is then given by

$$\begin{aligned}\max_z W &= \Pi^* - \lambda B + u \\ &= p^{h*}Y^h + p^{m*}Y^m - p^{l*}v_i sd(\lambda - 1) - \frac{\eta e^{*2}}{2} - \frac{\mu b^{*2}}{2} - (1-s)d - sd. \end{aligned} \tag{B.19}$$

Substituting eqs. (2.5), (2.6), and (2.7) into eq. (B.19), we get

$$\begin{aligned} W &= \gamma z(1+\theta)Y^h + \left[p_0^m - \frac{\beta}{\mu}z(1+\theta)\right]Y^m - \left[p_0^l + \delta z(1+\theta)\right]v_i sd(\lambda - 1) \\ &\quad - \frac{1}{2}\gamma z^2(1+\theta)^2 - (1-s)d - sd. \end{aligned} \tag{B.20}$$

Deriving eq. (B.20) with respect to z gives

$$\frac{\partial W}{\partial z} = \gamma(1+\theta)Y^h - \frac{\beta}{\mu}(1+\theta)Y^m - \delta(1+\theta)v_i sd(\lambda - 1) - \gamma z(1+\theta)^2. \tag{B.21}$$

As risk-taking is a mean-preserving spread, we can use $\beta Y^h = Y^m$. Setting (B.21) equal to zero, and solving for z, we get the socially optimal bonus in eq. (2.28).

The second order condition is given by

$$\frac{\partial^2 W}{\partial z^2} = -\gamma(1+\theta)^2 < 0. \tag{B.22}$$

B.5 Internalized Risk-Shifting Incentives

We can derive the bonus of a bank that fully internalizes the government's bailout costs by adding the term $-\lambda p^{l*} v_i sd$ to the bank profit in eq. (2.12). Setting $t = 0$, the bank's maximization problem is then given by

$$\begin{aligned}
&\max_{z,F} \Pi^R = p^{h*}(Y^h - z) + p^{m*}Y^m - F - (1-s)d + p^{l*}v_i sd - sd - \lambda p^{l*} v_i sd \\
&s.t.\ p^{h*} = \gamma z(1+\theta) \\
&\qquad p^{m*} = p_0^m - \frac{\beta}{\mu} z(1+\theta) \\
&\qquad p^{l*} = p_0^l + \delta z(1+\theta) \\
&\qquad \hat{u}^* = \frac{\gamma}{2}(1+\theta)^2 z^2 + F \geq \bar{u}. \qquad \text{(B.23)}
\end{aligned}$$

Solving the maximization problem in (B.23), we get the bonus of a bank that fully internalizes the government's bailout costs

$$z_{R|_{t=0}} = \frac{\Omega - \lambda\delta v_i sd}{\gamma[2-(1+\theta)]}. \qquad \text{(B.24)}$$

Eq. (B.24) shows that the internalisation of bailout costs indeed reduces the bank's bonus, $z_{R|_{t=0}}$. Comparing this bonus to the socially optimal bonus, we get

$$z_{R_{|t=0}} - z_{S_{|t=0}} = \frac{\Omega - \lambda\delta v_i sd}{\gamma[2-(1+\theta)]} - \frac{\Omega - \lambda\delta v_i sd}{\gamma(1+\theta)} = \frac{2\theta(\Omega - \lambda\delta v_i sd)}{\gamma[2-(1+\theta)](1+\theta)}. \qquad \text{(B.25)}$$

It follows from eq. (B.25) that the bank's bonus, $z_{R_{|t=0}}$, equals the socially optimal bonus, $z_{S_{|t=0}}$, only if the manager is rational ($\theta = 0$). If the manager is overconfident $\theta > 0$, the bank's bonus will be higher than the socially optimal bonus. The reason is analogous to the argument why capital requirements alone cannot achieve the socially optimal bonus. If a bank internalizes the externalities of its risk-taking, then the bank chooses a lower bonus in order to reduce bailout costs. If the manager is overconfident, however, the participation constraint of a manager (cf. eq. (B.23)) provides an additional incentive for the bank to choose an excessive bonus in order to save compensation costs. □

C Appendix to Chapter 3

C.1 Additional Variables

After the three treatments, subjects participate in a final block of 5 *parts*, which we use to elicit additional variables. In the first part, all subjects take a Raven test, which measures the participants' reasoning abilities. In this test, a subject is given eight graphical elements and must choose the missing ninth elements, which completes the pattern (see Figure C.3 in Appendix C.3 for an example). The test consists of three sets of twelve items each, and subjects are given 5 minutes per set. For each correctly answered item participants receive €0.10.

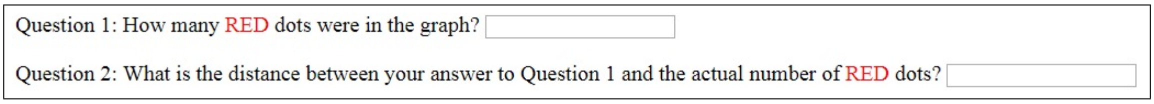
In part 2, subjects are asked two questions about their performance in the Raven test, which determine overestimation and overplacement, respectively. In the first question, we ask subjects how many of the 36 items in the Raven test they have answered correctly. The difference between this estimated number of correct answers, EOE_i, and the actual number of correct answers in the Raven test, AOE_i, gives us the level of *overestimation of subject i*, OE_i.

In the second question of part 2, each subject is asked how many participants in their own experimental session have answered less Raven questions correctly than they did, $EOPL_i$. The difference between $EOPL_i$ and the actual number of subjects that performed worse than subject i, $AOPL_i$, determines the *overplacement of subject i*, OPL_i.

The computer randomly chooses one of the two questions of part 2 to become payoff relevant. If the first question is chosen, the subject receives $P_i^{OE} = max\{€2 - €0.15 \times |EOE_i - AOE_i|; €0\}$. In case the second question is selected, the payoff for subject i is given by $P_i^{OPL} = max\{€2 - €0.15 \times |EOPL_i - AOPL_i|; €0\}$. Hence the more accurately the subject estimates his performance and relative performance in the Raven test, the higher is his expected payoff.

Part 3 elicits overprecision and consists of 10 rounds. Before each round, subjects are shown a new Dot Spot containing a total of 400 red and blue dots. After seeing the graph, subjects answer the two questions shown in Figure C.1. In the first question, subjects give an estimate $N_{i,r}$ of the number of red dots shown in round r. In the second question, subjects state their expected error, $EE_{i,r}$. This expected error is subject i's

Figure C.1: Overprecision Questions


Question 1: How many RED dots were in the graph?

Question 2: What is the distance between your answer to Question 1 and the actual number of RED dots?

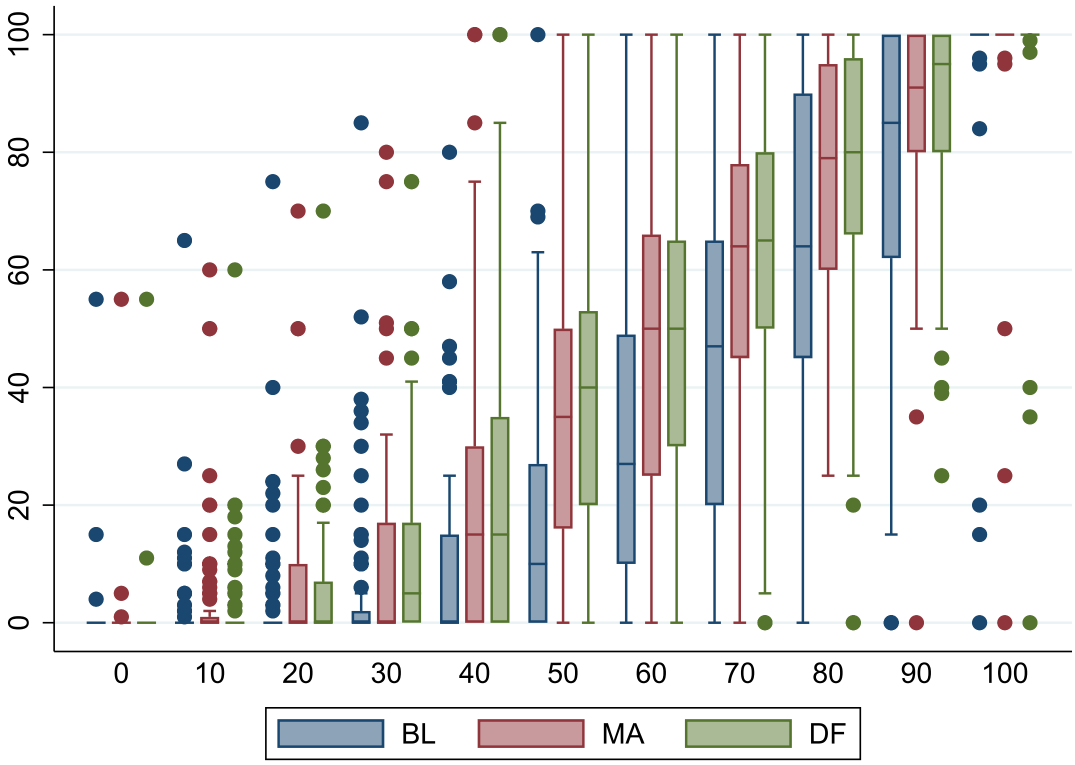
expected absolute distance between his estimate of the number of red dots $N_{i,r}$ and the actual number of red dots in the graphic, $A_{i,r}$.

For round r, we define overprecision as the difference between a subject's stated expected error $EE_{i,r}$ and his actual error, $AE_{i,r}$. Hence the overprecision of subject i in round r is given by $OP_{i,r} = AE_{i,r} – EE_{i,r}$ where $AE_{i,r} = |A_{i,r} - N_{i,r}|$. We define the *overprecision* of a subject i, OP_i, as the median value of the ten $OP_{i,r}$ values that we collect for each individual i. A subject is overprecise if $OP_i > 0$ (i.e., when her actual error is larger than her expected error) and underprecise if $OP_i < 0$.

The computer randomly chooses only one of the ten rounds and only one of the two questions for a subject's payoff in part 3. If the first question of round r is paid off, then the subject receives $P^{OP1}_{i,r} = max\{€5 - €0.05 \times AE_{i,r}; €0\}$. If the second question becomes payoff relevant, then the subject obtains $P^{OP2}_{i,r} = max\{€5 - €0.05 \times |AE_{i,r} – EE_{i,r}|; €0\}$. Hence the subject's payoff for both questions in part 3 is higher, the closer are the answers of the subject to the correct answers. Part 4 of the final block elicits risk and loss aversion using multiple price lists (see Tables C.6 and C.7 in Appendix C.3). In part 5, subjects state their field of study, age, and gender.

C.2 Risk

Figure C.2: Investments for Given Probabilities in Risk Part



Investments made by bankers in the Risk part. The vertical axis represents the investment made as a percentage of the endowment. The horizontal axis shows the given success probabilities. For each success probability, we show a box plot for every treatment (*BL*, *MA*, *DF*).

In the Risk part, the success probabilities of all investments are objectively given. Figure C.2 shows the investments as a percentage share of the endowment (vertical axis) for a given exogenous success probability (horizontal axis). Overall, the box plots in Figure C.2 indicate that bankers understood the incentives, as they tend to invest more for higher success probabilities.

Figure C.2, as well as the means reported in Table C.1, show that subjects invest significantly more in the limited liability treatments than in the *Baseline*. On average, subjects invest 31.7 (*BL*), 40.6 (*MA*), and 41.5 (*DF*) percent of their endowment. In line with this, the investment in the limited liability treatments are also higher for most success probabilities. Exceptions only arise for the extreme probabilities (0% and

Table C.1: Mean Investments in Risk Part

	Total	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
BL	31.69	0.83	1.94	3.29	5.08	8.56	17.30	30.13	45.46	62.83	76.43	96.74
	(37.98)	(6.03)	(7.83)	(10.18)	(12.99)	(14.86)	(20.48)	(25.61)	(29.27)	(29.40)	(27.64)	(16.16)
MA	40.56	0.69	3.94	5.69	9.94	19.43	36.21	49.26	61.73	75.49	86.42	97.37
	(38.95)	(5.85)	(10.54)	(11.92)	(16.00)	(24.30)	(26.88)	(26.33)	(25.13)	(19.54)	(18.24)	(14.12)
DF	41.50	0.74	2.92	5.39	12.08	21.13	39.70	51.21	63.36	75.74	86.82	97.43
	(39.15)	(5.93)	(7.79)	(10.80)	(16.96)	(23.98)	(27.79)	(26.46)	(25.25)	(23.06)	(17.64)	(14.00)

Mean investments as a percentage share of the endowment for the Risk part. The column *Total* shows the aggregated average of all investments in a treatment. The other columns show the average investment for a given success probability of the investment. Standard deviations are shown in parentheses.

100%) where – independent of the treatment – bankers tend to invest either nothing or their whole endowment. Finally, we present a within-subject Wilcoxon signed-rank test comparing the total investments made in the three treatments (Table C.2) which confirms that the investments in both *MA* and *DF* are significantly higher than in *BL* (p-value < 0.001 in both cases).

Table C.2: Wilcoxon Signed-Rank Tests for Risk Part

	Total	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
p-value BL = MA	<0.001	0.554	0.034	0.020	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.320
p-value BL = DF	<0.001	0.1573	0.071	0.012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.105
p-value DF = MA	0.431	0.993	0.543	0.7133	0.455	0.632	0.343	0.520	0.392	0.288	0.220	0.186

The p-values of the within-subject Wilcoxon signed-rank test comparing (paired) investments in the Risk part across treatments. The *Total* column compares the *total* amount invested in the treatments. The other columns compare the investments for given exogenous probabilities in the treatments.

While we observe substantial effects of the limited liability treatments compared to the *Baseline*, there are no significant differences between the two limited liability treatments, *MA* and *DF*. Not only are the total investment levels in these treatments similar, but also the investments for a given success probability (Table C.1). A within-subject Wilcoxon signed-rank test comparing the *total* amount invested in both treatments confirms this picture, as the null hypothesis of no difference cannot be rejected (p-value $= 0.431$).

C.3 Instructions

These are the instructions for the treatment order *Baseline*, *Matched*, *Diffusion*. The instructions are translated from German.

Welcome to our Experiment!

During the experiment it is neither allowed to use any electronic devices nor to communicate with other participants. Please do only use the programs and functions designed for the experiment. Please do not talk to other participants. Please do not write on the instructions. You will find pen and paper in front of your computer for additional notes. If you have any questions, please raise your hand. We will then come to you and answer your question. In any case, please do not ask the question out loud. If the question is relevant for all participants, we will repeat and answer it aloud. If you do not comply with these rules, we have to exclude you from the experiment and the payoff.

This experiment consists of **four blocks**. Each **block** consists of several **parts**. We will read the instructions before working on the respective blocks and parts together. At the end of the experiment, the payoff for the four blocks is disclosed to you.

General Instructions for Block 1

Block 1 consists of **two parts. Part 1 has one round, part 2 has ten rounds.** The computer will randomly choose **exactly one** of these eleven rounds for your payoff whereby each round is chosen with the same probability. The payoff for block 1 is disclosed at the end of the experiment.

In each round of block 1 you have an **initial endowment of 8 euro** and decide on the percentage share of your 8 euro you want to invest. Thereby, you can choose an arbitrary **percentage** between 0% and 100%. In order to do so, we provide a **scroll bar** with which you can state the share of your endowment you want to invest.

Payoff:

Your **amount to be invested** is your chosen **percentage times 8 euro**. The investment can either succeed or fail.

- If the investment is **successful**, the amount to be invested is multiplied by 1.75. **Hence, you will additionally gain three quarters (75%) of your amount to be invested.**
- If the investment **fails**, the amount to be invested is multiplied by 0. **Hence, you will lose the entire amount to be invested (100%).**

You will receive the share of the initial endowment which you do not invest, 8 euro minus the amount to be invested I, irrespective of whether the investment succeeds or fails.

Example:

Suppose you decide to invest 60% of your 8 euro. The amount to be invested equals I $= 0.6 \times 8$ euro = 4.80 euro. The remainder of the initial endowment (3.20 euro) is not invested.

- If the investment succeeds, I = 4.80 is multiplied with 1.75. Hence, you will gain three quarters (75%) of the amount to be invested. The amount not invested, 3.20 euro, remains in your possession. Altogether you receive 3.20 euro + $1.75 \times$ 4.80 euro = 11.60 euro.
- If the investment fails, you will lose the amount to be invested I = 4.80. The amount not invested, 3.20 euro, remains in your possession. Altogether you receive 3.20 euro.

These payoffs for successful or failed investments respectively **apply for the entire block** (part 1 and part 2). **The conditions under which the investment is successful, however, differ among part 1 and part 2.**

Specific Instructions for Block 1 Part 1

Part 1 consists of **one round with 11 decision situations**, summarized in a table (see Table C.3). If **part 1 is paid off**, the computer randomly chooses **one** of the 11 situations to be executed. Thereby, each of the 11 situations is chosen with the same probability.

Situation	Success probability of the investment	Amount to be invested (Percentage of 8 euro)
1	0%	Scroll bar
2	10%	Scroll bar
3	20%	Scroll bar
4	30%	Scroll bar
5	40%	Scroll bar
6	50%	Scroll bar
7	60%	Scroll bar
8	70%	Scroll bar
9	80%	Scroll bar
10	90%	Scroll bar
11	100%	Scroll bar

Table C.3

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table C.3, this **success probability** increases from 0% (in decision situation 1) to 100% (in decision situation 11) in increments of 10 percentage points.

Please indicate for each of these 11 situations how much of your initial endowment of 8 euro you want to invest if the respective situation is drawn.

Example:

Suppose you would have stated, among other things, in Table C.3 (using the scroll bar) that you want to invest 40% of your endowment in *decision situation 6* and 70% of your endowment in *decision situation 9*.

- If the computer randomly chooses *decision situation 6* for the payoff, the investment will be successful with a probability of 50% (see Table C.3) and your amount to be invested equals 40% $\times$ 8 euro = 3.20 euro.

- If the computer randomly chooses *decision situation 9* for the payoff, the investment will be successful with a probability of 80% (see Table C.3) and your amount to be invested equals 70% $\times$ 8 euro = 5.60 euro.

In each situation you use a scroll bar to state the percentage of the endowment of 8 euro you want to invest, if this situation is paid off. As soon as you have made your eleven decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the eleven scroll bars. In order to complete part 1 and to start the next round, you have to click on "confirm entry".

Specific Instructions for Block 1 Part 2

Part 2 consists of **ten rounds**. In each round you decide which percentage share of your 8 euro you want to invest. Thereby, you can choose any arbitrary percentage between 0% and 100%. Your amount to be invested I equals percentage $\times$ 8 euro. Remember: In the end exactly one of the eleven rounds from both parts of block 1 is randomly chosen for your payoff.

Before each round of part 2, the computer randomly chooses whether or not the investment will be successful . Before your investment decision you will receive a **hint** in each round whether the investment will be successful or fail in this round. This hint consists of a graph containing a total of **of 400 RED and BLUE dots** that will be shown to you for 8 seconds. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more RED than BLUE dots. In this case the investment will be successful. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more BLUE than RED dots. In this case the investment fails.

If the graph contains more RED than BLUE dots, the investment succeeds with certainty.

If the graph contains more blue than RED dots, the investment fails with certainty.

By using the scroll bar you state which percentage share of your 8 euro you want to invest. Moreover, in each round of part 2 you will be asked for your estimation of the probability that there were more RED than BLUE dots in the preceding graph (hence, you state your estimation of the success probability of the investment). This statement does not affect your payoff.

As soon as you made both decisions, please click on “confirm entry”. As long as you did not confirm your entries, you can change the position of the scroll bar and change your opinion on the success probability. In order to complete a round in part 2 and to continue, you have to click on “confirm entry”.

Summary of Block 1

In block 1 you make investment decisions. The **payoffs** of a successful or failed investment respectively are **identical** for part 1 and part 2:

If the investment is **successful**, you will gain three quarters (75%) of the amount to be invested. If the investment **fails**, you will lose the entire (100%) amount to be invested.

Part 1 and part 2 differ with respect to the conditions under which the investment is successful. In part 1 the success probability is given in each situation. In part 2 you receive a hint in each round whether the investment will be successful in this round.

To begin with, you will do three practice rounds for part 1 and five practice rounds for part 2. **In these practice rounds you cannot earn money**, they are only there in order to clarify both parts. After the practice rounds you will do block 1 consisting of one round of part 1 with eleven decision situations and ten rounds of part 2. Out of these eleven rounds the computer randomly chooses exactly one round for **your actual payoff**.

This is the end of the instructions for block 1. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the “Continue” button in order to start with block 1.

General Instructions for Block 2

Block 2 consists of **two parts. Part 1 has one round, part 2 has ten rounds.** The computer will randomly choose **exactly one** of these eleven rounds for your payoff whereby each round is chosen with the same probability. The payoff for block 2 is disclosed at the end of the experiment.

In block 2 the computer will randomly choose whether you are **type A or type B.** This role will persist throughout all eleven rounds of block 2. On your screens you can see whether you are type A or type B. **Each type A will be assigned to exactly one type B (and each type B will assigned to exactly one type A).** You will neither learn throughout nor after the experiment which type B is assigned to which type A.

Each type A will make an investment decision in **block 2** which can influence his own payoff and also the payoff of his assigned type B. If you receive the role of type B, your decision will not have any effects on the payoff.

<u>For all type A the following holds:</u>

In each round of block 2 you have an **initial endowment of 8 euro** and you decide which percentage share you want to **invest**. Thereby, you can choose an arbitrary **percentage** between 0% and 100%. In order to do so, we will provide a **scroll bar** with which you can indicate the percentage share of your endowment you want to invest.

The **amount to be invested** is the chosen **percentage times 8 euro**. The investment can either be successful or fail.

- If the investment is **successful**, the amount to be invested is multiplied by 1.75. **Hence, you will gain three quarters (75%) of your amount to be invested.**
- If the investment **fails**, the amount to be invested is multiplied by 0.75. **Hence, you will lose one quarter (25%) of the amount to be invested. An amount of three quarters (75%) of your amount to be invested is subtracted from the endowment of 8 euro of the type B assigned to you.**

You will keep the share of the endowment you do not invest, 8 euro minus the amount to be invested I, irrespective of whether the investment succeeds or fails.

Example:

Suppose you decide to invest 60% of your 8 euro. Then the amount to be invested equals I = 0.6 × 8 euro = 4.80 euro. The rest of the endowment (3.20 euro) is not invested.

- If the investment is successful, I = 4.80 euro is multiplied by 1.75. Hence, you will gain three quarters (75%) of the amount to be invested. The amount not invested, 3.20 euro, will remain in your possession. In total you will receive 3.20 euro + 1.75 × 4.80 euro = 11.60 euro. Type B is not influenced by your decision and receives 8 euro.
- If the investment fails, you will lose one quarter of the amount to be invested I = 4.80 (i.e., 1.20 euro). The amount not invested will entirely remain in your possession. In total you will receive 8 euro – 1.20 euro = 6.80 euro. The type B assigned to you loses three quarters of your amount to be invested, hence, 3.60 euro. Type B, hence, receives 8 euro – 3.60 euro = 4.40 euro.

For all type B the following holds:

In block 2 you have an initial endowment of 8 euro. Your payoff depends on the investment of the type A assigned to you.

You will make the same decisions as participant of type A. **However, all your decisions in block 2 will not affect your payoff.** Your payoff of block 2 only depends on the decisions of the type A assigned to you.

For all type A and B the following holds:

These payoffs for successful or failed investments respectively **hold for the entire block 2** (part 1 and part 2). **The conditions under which the investment is successful differ between part 1 and part 2.**

Specific instructions for Block 2 Part 1

As in block 1, part 1 consists of **one round with 11 decision situations**, summarized in a table (see Table C.4). If **part 1 is paid off**, the computer randomly chooses **one** of the 11 situations to be executed. Thereby, each of the 11 situations is chosen with the same probability.

Situation	Success probability of the investment	Amount to be invested (Percentage of 8 euro)
1	0%	Scroll bar
2	10%	Scroll bar
3	20%	Scroll bar
4	30%	Scroll bar
5	40%	Scroll bar
6	50%	Scroll bar
7	60%	Scroll bar
8	70%	Scroll bar
9	80%	Scroll bar
10	90%	Scroll bar
11	100%	Scroll bar

Table C.4

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table C.4, this **success probability** increases from 0% (in decision situation 1) to 100% (in decision situation 11) in increments of 10 percentage points.

Please indicate for each of these 11 situations how much of your initial endowment of 8 euro you want to invest if the respective situation is drawn.

In each situation you use a scroll bar to state the percentage of the endowment of 8 euro you want to invest, if this situation is paid off. As soon as you have made your eleven decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the eleven scroll bars. In order to complete part 1 and to start the next round, you have to click on "confirm entry".

Specific instructions for Block 2 Part 2

As in the previous block, part 2 consists of **ten rounds**. In each round you decide which percentage share of your 8 euro you want to invest. Thereby, you can choose any arbitrary percentage between 0% and 100%. Your amount to be invested

I equals percentage $\times$ 8 euro. Remember: In the end exactly one of the eleven rounds from both parts of block 2 is randomly chosen for your payoff.

As in part 2 of block 1, **before each round** the computer randomly chooses whether or not the investment will be successful. Before your investment decision you will receive a **hint** in each round which indicates whether the investment will be successful or fail in this round. This hint consists of a graph containing a total **of 400 RED and BLUE dots** that will be shown to you for 8 seconds. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more RED than BLUE dots. In this case the investment will be successful. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more BLUE than RED dots. In this case the investment fails.

If there are more RED than BLUE dots in the graph, the investment succeeds with certainty.

If there are more BLUE than RED dots in the graph, the investment fails with certainty.

By using the scroll bar you state which percentage share of your 8 euro you want to invest. Moreover, in each round of part 2 you will be asked for your estimation of the probability that there were more RED than BLUE dots in the preceding graph (hence, you state your estimation of the success probability of the investment). This statement does not affect your payoff.

As soon as you made both decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the scroll bar and change your opinion on the success probability. In order to complete a round in part 2 and to continue, you have to click on "confirm entry".

Summary of Block 2

In block 2 you make investment decisions. The **payoffs** of a successful or failed investment respectively are **identical** for part 1 and part 2:

For type A it holds for both parts: If the investment is **successful**, you will gain three quarters (75%) of the amount to be invested. If the investment **fails**, you will lose one quarter (25%) of your amount to be invested. The type B assigned to you will lose three quarters (75%) of your amount to be invested.

For type B it holds for both parts: You make the same decisions as participants of type A. However, your decisions in block 2 do not have any effects on the payoff.

Part 1 and part 2 differ with respect to the conditions under which the investment is successful. In part 1 the success probability is given in each situation. In part 2 you receive a hint in each round which indicates whether the investment will be successful in this round.

This is the end of the instructions for block 2. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the "Continue" button in order to start with block 2.

General Instructions for Block 3

Block 3 consists of **two parts. Part 1 has one round, part 2 has ten rounds.** The computer will randomly choose **exactly one** of these eleven rounds for your payoff whereby each round is chosen with the same probability. The payoff for block 3 is disclosed at the end of the experiment.

In block 3 you will be the same type (type A or type B) as in block 2. Each type A will make an investment decision in **block 3** which can influence his own payoff and also the payoff of all type B individuals. If you received the role of type B, your decision will not have any effects on the payoff.

For all type A the following holds:

In each round of block 3 you have an **initial endowment of 8 euro** and you decide which percentage share of your 8 euro you want to **invest**. Thereby, you can choose an arbitrary **percentage** between 0% and 100%. In order to do so, we will provide a **scroll bar** with which you can indicate the percentage share of your endowment you want to invest.

The **amount to be invested** is the chosen **percentage times 8 euro**. Thereby, the investment can either be successful or fail.

- If the investment is **successful**, the amount to be invested is multiplied by 1.75. **Hence, you will gain three quarters (75%) of your amount to be invested.**
- If the investment **fails**, the amount to be invested is multiplied by 0.75. **Hence, you will lose one quarter (25%) of your amount to be invested. The type B individuals on aggregate will lose three quarters (75%) of your amount to be invested. Thereby, each type B will bear the same share of the loss in this experiment.**

You will keep the share of the endowment you do not invest, 8 euro minus the amount to be invested I, irrespective of whether the investment succeeds or fails.

Example:

Suppose you decide to invest 60% of your 8 euro. Then the amount to be invested equals I = 0.6 × 8 euro = 4.80 euro. The rest of the endowment (to the amount of 3.20 euro) is not invested.

- If the investment is successful, I = 4.80 euro is multiplied by 1.75. Hence, you will gain three quarters (75%) of the amount to be invested. The amount not invested, 3.20 euro, will remain in your possession. In total you will receive 3.20 euro + 1.75 × 4.80 euro = 11.60 euro. No type B individual is influenced by your decision.
- If the investment fails, you will lose one quarter of the amount to be invested I = 4.80 (i.e., 1.20 euro). The amount not invested will entirely remain in your possession. In total you will receive 8 euro – 1.20 euro = 6.80 euro. The type B individuals on aggregate lose three quarters (75%) of your amount to be invested (i.e., 3.60 euro). This loss is shared equally among all type B individuals. If, for example, 10 type B individuals participate in your experiment, each type B individual loses 0.36 euro.

For all type B the following holds:

In block 3 you have an initial endowment of 8 euro. Your payoff depends on the investment of the type A individuals. You will make the same decisions as participants of type A. However, all your decisions in block 3 will not affect your payoff. Your payoff of block 3 only depends on the decisions of the type A individuals.

For all type A and B the following holds:

These payoffs for successful or failed investments respectively **hold for the entire block 2** (part 1 and part 2). **The conditions under which the investment is successful differ between part 1 and part 2.**

Specific instructions for Block 3 Part 1

As in both previous blocks, part 1 again consists of **one round with 11 decision situations**, summarized in a table (see Table C.5). If **part 1 is paid off**, the computer randomly chooses **one** of the 11 situations to be executed. Thereby, each of the 11 situations is chosen with the same probability.

Situation	Success probability of the investment	Amount to be invested (Percentage of 8 euro)
1	0%	Scroll bar
2	10%	Scroll bar
3	20%	Scroll bar
4	30%	Scroll bar
5	40%	Scroll bar
6	50%	Scroll bar
7	60%	Scroll bar
8	70%	Scroll bar
9	80%	Scroll bar
10	90%	Scroll bar
11	100%	Scroll bar

Table C.5

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table C.5, this **success probability** increases from 0% (in decision situation 1) to 100% (in decision situation 11) in increments of 10 percentage points.

Please indicate for each of these 11 situations how much of your initial endowment of 8 euro you want to invest if the respective situation is drawn.

In each situation you use a scroll bar to state the percentage of the endowment of 8 euro you want to invest, if this situation is paid off. As soon as you have made your eleven decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the eleven scroll bars. In order to complete part 1 and to start the next round, you have to click on "confirm entry".

Specific instructions for Block 3 Part 2

As in the previous blocks, part 2 again consists of **ten rounds**. In each round you decide which percentage share of your 8 euro you want to invest. Thereby, you can choose any arbitrary percentage between 0% and 100%. Remember: In the end exactly one of the eleven rounds from both parts of block 3 is randomly chosen for your payoff.

Before each round in part 2, the computer randomly chooses whether or not the investment will be successful. Before your investment decision you will receive a **hint** in each round which indicates whether the investment will be successful or fail in this round. This hint consists of a graph containing a total **of 400 RED and BLUE dots** that will be shown to you for 8 seconds. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more RED than BLUE dots. In this case the investment will be successful. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more BLUE than RED dots. In this case the investment fails.

If there are more RED than BLUE dots in the graph, the investment succeeds with certainty.

If there are more BLUE than RED dots in the graph, the investment fails with certainty.

By using the scroll bar you state which percentage share of your 8 euro you want to invest. Moreover, in each round of part 2 you will be asked for your estimation of the probability that there were more RED than BLUE dots in the preceding graph (hence, you state your estimation of the success probability of the investment). This statement does not affect your payoff.

As soon as you made both decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the scroll bar and change your opinion on the success probability. In order to complete a round in part 2 and to continue, you have to click on "confirm entry".

Summary of Block 3

In block 3 you make investment decisions. The **payoffs** of a successful or failed investment respectively are **identical** for part 1 and part 2:

For type A it holds for both parts:

If the investment is **successful**, you will gain three quarters (75%) of the amount to be invested. If the investment **fails**, you will lose one quarter (25%) of your amount to be invested. The type B individuals on aggregate will lose three quarters (75%) of your amount to be invested. Thereby, each type B will bear the same share of the loss in this experiment.

For type B it holds for both parts:

You make the same decisions as participants of type A. However, your decisions in block 3 do not have any effects on the payoff.

Part 1 and part 2 differ with respect to the conditions under which the investment is successful. In part 1 the success probability is given in each situation. In part 2 you receive a hint in each round which indicates whether the investment will be successful in this round.

This is the end of the instructions for block 3. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the “Continue” button in order to start with block 3.

General Instructions for Block 4

Block 4 consists of **four parts**. We will read the specific instructions for each part together directly before the respective part.

Specific Instructions for Block 4 Part 1

In this part you will solve 36 **exercises**. These **36 exercises** will be split on **three pages** such that there will be twelve exercises on each page.

All exercises follow the same structure as shown in Figure C.3. There are three rows and three columns with geometric patterns and the **element** on the bottom right is missing. Your task is to choose the **element** among eight given elements which fits best to the other patterns. Only one of the eight elements given is correct.

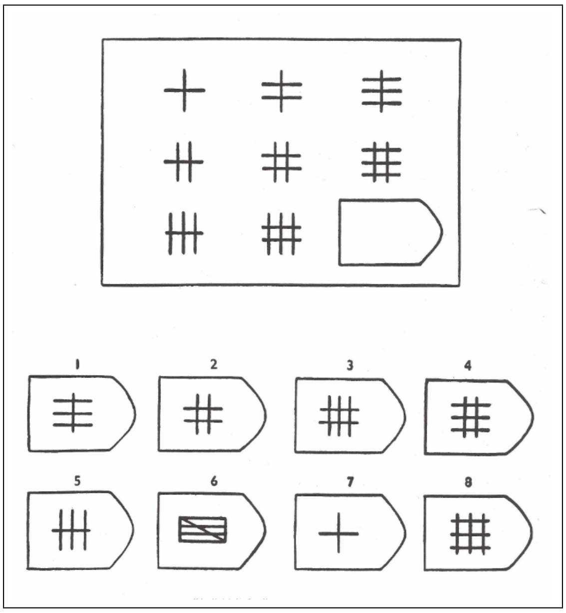


Figure C.3

You **choose the element** using a **drop-down list** (see Figure C.4). You will find this drop-down list on the left below each task. In order to complete the 12 tasks of each page, you can arbitrarily scroll up or down. You do not have to answer the tasks in the specified order. **For all three pages you have 5 minutes <u>each</u>.** If the time is up for one page, the computer registers all your answers and you will receive 0.10 euro for each correct answer. At the end of the experiment you will learn how many tasks you solved correctly. You can of course click on “continue” before the expiration of the 5 minutes. However, in this case you cannot return to this page anymore.

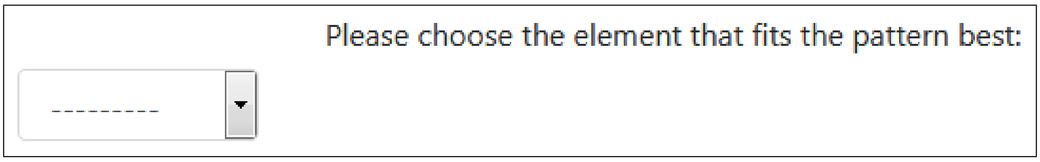


Figure C.4

This is the end of the instructions for part 1. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the “Continue” button in order to answer the questions.

Specific Instructions for Block 4 Part 2

In **part 2** you will be asked two questions regarding **part 1.**

Question 1: What do you think, how many exercises did you solve correctly in the previous part?

Here you indicate, in how many of the exercises of the previous part (block 4, part 1) you have chosen the correct element in your opinion. Remember: in part 1 there were three pages with 12 exercises each, hence, in total 36 exercises. You can type in every number from 0 to 36.

Question 2: What do you think, how many participants have solved less exercises correctly than you in the previous part?

Here you indicate, how many of the present 20 participants in your opinion have chosen less often the correct element than you in part 1. You can type in every number from 0 to 19.

Payoff:

For both questions your payoff depends on the precision of your answer. The lower the distance between your answer and the correct answer to a question, the larger your payoff. The payoff for one question equals **€2 - €0.15 $\times$ distance**. If the payoff should be smaller than zero euro, you will receive zero euro instead. Hence, you cannot incur any losses in part 2.

Example Question 1:

Suppose the answer to Question 1 regarding your number of correctly solved exercises is 10 and in fact you have solved 12 exercises correctly. Then the distance equals 2. Your payoff for Question 1 is thus **€2 - €0.15 $\times$ 2 = €1.70**.

Example Question 2:

Suppose the answer to Question 2 is 11 and in fact 12 participants have solved less exercises correctly than you. Then the distance equals 1. Your payoff for question 2 is thus **€2 - €0.15 $\times$ 1 = €1.85**.

The computer will randomly choose **exactly one** of both questions of **part 2** for your payoff. You will learn about your payoff for part 2 at the end of the experiment.

Question 1 will appear first. As soon as you have answered Question 1, please click on "confirm entry". Afterwards, question 2 appears. As soon as you have answered Question 2, please again click on "confirm entry" in order to complete part 2 and to start with the next part.

This is the end of the instructions for part 2. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the "Continue" button in order to answer the questions.

Specific instructions for Block 4 Part 3

Part 3 consists of **10 rounds.** In **each round** a new graphic consisting of a total of 400 dots will be shown to you. In each graphic there are between 0 an 400 RED dots and all the other dots are BLUE. Each graphic is shown to you for 8 seconds and completely disappears from your screen afterwards. Afterwards, you will make **two estimations.**

Estimation 1: How many RED dots were in the graphic?

Estimation 2: How large is the difference between your Estimation 1 and the actual number of RED dots?

In **Estimation 1** you indicate your estimate about how many RED dots were in the graphic shown to you. In **Estimation 2** you indicate your estimate about how far your **Estimation 1** is off the **actual number** of RED dots in the graphic.

Example:

Suppose you estimate that there were 211 RED dots in the graphic. Hence, your estimate 1 is 211. Suppose you think that your Estimation 1 deviates by 24 in expected values from the actual number of RED dots. Hence, your Estimation 2 is 24.

Payoff:

For both questions your payoff depends on the precision of your answer. The smaller the **absolute distance** of your answer to the correct answer of an estimation, the higher your payoff. The payoff for an estimation equals **€5 - €0.05 $\times$ absolute distance.** If this payoff should be smaller than zero, you will receive zero euro instead. Hence, you cannot make any losses in part 3.

Example for Estimation 1:

Suppose your estimation about the number of RED dots is 211 and the actual number of RED dots is 180. Then, the absolute distance equals 211 - 180 = 31. Hence, the payoff for Estimation 1 is €5 - €0.05 $\times$ 31 = €3.45.

Example for Estimation 2:

Suppose you estimated that the distance of your Estimation 1 to the actual number of RED dots equals 24 in expected values and therefore indicated 24 as Estimation 2. In fact, your estimation error in Estimation 1 was 31. Therefore, the distance between your Estimation 2 and the correct answer equals: 31 - 24 = 7. Hence, the payoff for Estimation 2 is €5 - €0.05 $\times$ 7 = €4.65.

Your payoff for part 3 is determined by the computer randomly choosing **exactly one of both estimations** from **one of the ten rounds** of part 3. You will learn about your payoff at the end of the experiment.

Please click on "confirm entry" in each round as soon as you have entered Estimation 1 as well as Estimation 2.

This is the end of the instructions for part 3. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the "Continue" button in order to start with the 10 rounds of part 3.

Specific instructions for Block 4 Part 4

In this part we will subsequently present you **two tables** with **15 rows each**. In both tables, **Table C.6** and **Table C.7**, you have to choose between **lotteries** and a **safe amount**. At the end of the experiment the computer randomly chooses **one row** from **one of both tables** for your payoff with an equal probability. Both tables are chosen with a probability of 50 percent and each row within a table has the same probability to be chosen.

Table C.6:

In the **lotteries** of Table C.6 you will win a positive amount in addition to your previously achieved credit with a probability of 50% and with a probability of 50% your credit will remain unchanged.

As you can infer from Table C.6, **the lottery becomes more unattractive the lower the row**. In row 1 there is a 50 percent chance that you gain **€8.00**. In row 2, in contrast, there is a 50 percent chance, that you gain **€7.50**. **Your task is to decide until which row you prefer the lottery over a safe payment of €2.50.**

Example (see Table C.6): Suppose that you prefer the lottery over the safe amount of €2.50 as soon as the lottery increases your credit by at least €4.50 in the case of success. In this case you choose row 8 in Table C.6. This means that you receive the safe payment of €2.50 if the computer randomly chooses one of the rows 9 to 15. If the computer randomly chooses one of the rows 1 to 8, your payoff is decided upon by the lottery given in the chosen row. Hence, if the computer chooses, for example, row 5, you will gain €6 in addition to your previous credit with a probability of 50% and with a probability of 50% your credit remains unchanged.

Table C.7:

In the **lotteries** of Table C.7 you will win 5 euro in addition to your previously achieved credit with a probability of 50% and with a probability of 50% a given amount will be deducted from your previous credit.

As you can infer from Table C.7, **the lottery becomes more unattractive the lower the row**. In row 1 there is a 50 percent chance that you lose **€0.50** of your previous credit. In row 2, in contrast, there is a 50 percent chance, that you lose **€1.00**

Please choose up to which row you prefer the lottery over a safe amount of €2.50.

		Choose the safe amount for ALL rows
1	**€8.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for row 1 and the safe amount for rows 2 to 15
2	**€7.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 2 and the safe amount for rows 3 to 15
3	**€7.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 3 and the safe amount for rows 4 to 15
4	**€6.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 4 and the safe amount for rows 5 to 15
5	**€6.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 5 and the safe amount for rows 6 to 15
6	**€5.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 6 and the safe amount for rows 7 to 15
7	**€5.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 7 and the safe amount for rows 8 to 15
8	**€4.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 8 and the safe amount for rows 9 to 15
9	**€4.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 9 and the safe amount for rows 10 to 15
10	**€3.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 10 and the safe amount for rows 11 to 15
11	**€3.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 11 and the safe amount for rows 12 to 15
12	**€2.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 12 and the safe amount for rows 13 to 15
13	**€2.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 13 and the safe amount for rows 14 to 15
14	**€1.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 14 and the safe amount for row 15
15	**€1.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for ALL rows

Table C.6

of your previous credit. **Your task is to decide until which row you prefer the lottery over a safe payment to the amount of €0.**

Example (see Table C.7): Suppose that you prefer the lottery over the safe amount of 0€ as long as the lottery decreases your credit by at most €3.50 in the case of a loss. In this case you choose row 7 in Table C.7. This means that you receive the safe payment to the amount of €0 if the computer randomly chooses one of the rows 8 to 15. If the computer randomly chooses one of the rows 1 to 7, your payoff is de-

Please choose up to which row you prefer the lottery over a safe amount of €0.00.

		Choose the safe amount for ALL rows
1	€5.00 with 50% prob. & -€0.50 with 50% prob.	Choose the lottery for row 1 and the safe amount for rows 2 to 15
2	€5.00 with 50% prob. & -€1.00 with 50% prob.	Choose the lottery for rows 1 to 2 and the safe amount for rows 3 to 15
3	€5.00 with 50% prob. & -€1.50 with 50% prob.	Choose the lottery for rows 1 to 3 and the safe amount for rows 4 to 15
4	€5.00 with 50% prob. & -€2.00 with 50% prob.	Choose the lottery for rows 1 to 4 and the safe amount for rows 5 to 15
5	€5.00 with 50% prob. & -€2.50 with 50% prob.	Choose the lottery for rows 1 to 5 and the safe amount for rows 6 to 15
6	€5.00 with 50% prob. & -€3.00 with 50% prob.	Choose the lottery for rows 1 to 6 and the safe amount for rows 7 to 15
7	€5.00 with 50% prob. & -€3.50 with 50% prob.	Choose the lottery for rows 1 to 7 and the safe amount for rows 8 to 15
8	€5.00 with 50% prob. & -€4.00 with 50% prob.	Choose the lottery for rows 1 to 8 and the safe amount for rows 9 to 15
9	€5.00 with 50% prob. & -€4.50 with 50% prob.	Choose the lottery for rows 1 to 9 and the safe amount for rows 10 to 15
10	€5.00 with 50% prob. & -€5.00 with 50% prob.	Choose the lottery for rows 1 to 10 and the safe amount for rows 11 to 15
11	€5.00 with 50% prob. & -€5.50 with 50% prob.	Choose the lottery for rows 1 to 11 and the safe amount for rows 12 to 15
12	€5.00 with 50% prob. & -€6.00 with 50% prob.	Choose the lottery for rows 1 to 12 and the safe amount for rows 13 to 15
13	€5.00 with 50% prob. & -€6.50 with 50% prob.	Choose the lottery for rows 1 to 13 and the safe amount for rows 14 to 15
14	€5.00 with 50% prob. & -€7.00 with 50% prob.	Choose the lottery for rows 1 to 14 and the safe amount for row 15
15	€5.00 with 50% prob. & -€7.50 with 50% prob.	Choose the lottery for ALL rows

Table C.7

cided upon by the lottery given in the chosen row. Hence, if the computer chooses, for example, row 3, you will gain €5 in addition to your previous credit with a probability of 50% and with a probability of 50% you will lose €1.50 of your previous credit.

Note that the computer randomly chooses exactly **one row** from **one of both tables** with an equal probability for your payoff. At the end of the experiment you will learn which table and row has been chosen randomly by the computer. If you have chosen the lottery in the row chosen by the computer, you will additionally learn the outcome of the lottery.

If you have any questions, please raise your hand. We will then come to you and answer quietly. If prompted, please click on the "continue" button in order to continue.

This is the last part of the experiment. After the experiments ends, there will be a short questionnaire. Thank you for your participation!

Bibliography

Acharya, V. V., 2003. Is the international convergence of capital adequacy regulation desirable? Journal of Finance 58, 2745–2782.

Acharya, V. V., Pagano, M., Volpin, P., 2016. Seeking alpha: Excess risk taking and competition for managerial talent. Review of Financial Studies 29, 2565–2599.

Adams, R. B., 2012. Governance and the financial crisis. International Review of Finance 12, 7–38.

Ahrens, S., Bosch-Rosa, C., 2018. Heads we both win, tails only you lose: The effect of limited liability on risk-taking in financial decision making. Mimeo, Berlin.

Andersson, O., Holm, H. J., Tyran, J.-R., Wengström, E., 2013. Risking other people's money: Experimental evidence on bonus schemes, competition, and altruism. IFN Working Paper No. 989.

Atkinson, T., Luttrell, D., Rosenblum, H., 2013. How bad was it? The costs and consequences of the 2007–09 financial crisis. Federal Reserve Bank of Dallas Staff Papers July.

Babcock, L., Loewenstein, G., 1997a. Explaining bargaining impasse: The role of self-serving biases. Journal of Economic Perspectives 11, 109–126.

Babcock, L., Loewenstein, G., Issacharoff, S., 1997b. Creating convergence: Debiasing biased litigants. Law & Social Inquiry 22, 913–925.

Banerjee, S., Humphery-Jenner, M., Nanda, V., 2015. Restraining overconfident CEOs through improved governance: Evidence from the Sarbanes-Oxley Act. Review of Financial Studies 28, 2812–2858.

Bannier, C. E., Feess, E., Packham, N., 2013. Competition, bonuses, and risk-taking in the banking industry. Review of Finance 17, 653–690.

Barberis, N., 2013. Psychology and the financial crisis of 2007-2008. In Financial innovation: Too much or too little?, Cambridge, MIT Press, 15–28.

Barth, J. R., Lee, C., Phumiwasana, T., 2006. Deposit insurance schemes. In Encyclopedia of Finance, Springer, 299–306.

BBC, 2010. Osborne and Cable to step up pressure over bank bonuses. British Broadcasting Corporation, 17 December 2010.

Bell, B., Van Reenen, J., 2014. Bankers and their bonuses. Economic Journal 124, 1–21.

Bénabou, R., 2015. The economics of motivated beliefs. Revue d'économie politique 125, 665–685.

Bernanke, B., 2008a. Reducing systemic risk. The Federal Reseve, Speech at the Federal Reserve Bank of Kansas City's Annual Economic Symposium, 22 August 2008.

Bernanke, B., 2008b. Developments in the financial markets. The Federal Reserve, Testimony Before the Committee on Banking, Housing, and Urban Affairs, U.S. Senate, 03 April 2008.

Besley, T., Ghatak, M., 2013. Bailouts and the optimal taxation of bonus pay. American Economic Review Papers & Proceedings 103, 163–167.

Bhagat, S., Bolton, B., 2014. Financial crisis and bank executive incentive compensation. Journal of Corporate Finance 25, 313–341.

Bierbrauer, F., Brett, C., Weymark, J. A., 2013. Strategic nonlinear income tax competition with perfect labor mobility. Games and Economic Behavior 82, 292–311.

Bosch-Rosa, C., Gietl, D., Heinemann, F., 2019. Risk-Taking under Limited Liability: The Role of Motivated Beliefs. Mimeo, Munich.

Boustanifar, H., Grant, E., Reshef, A., 2017. Wages and human capital in finance: International evidence, 1970–2011. Review of Finance 22, 699–745.

Browning, E. K., 1976. The marginal cost of public funds. Journal of Political Economy 84, 283–298.

Buch, C. M., Koch, C. T., Koetter, M., 2011. Size, productivity, and international banking. Journal of International Economics 85, 329–334.

Burbidge, J., Cuff, K., Leach, J., 2006. Tax competition with heterogeneous firms. Journal of Public Economics 90, 533–549.

Campello, M., Giambona, E., Graham, J. R., Harvey, C. R., 2011. Access to liquidity and corporate investment in Europe during the financial crisis. Review of Finance 16, 323–346.

Caprio, G., Levine, R., 2002. Corporate governance in finance: Concepts and international observations. In Financial Sector Governance: The Roles of the Public and Private Sectors, Brookings Institution Press Washington, DC, 17–50.

Chaigneau, P., 2013. Risk-shifting and the regulation of bank CEOs' compensation. Journal of Financial Stability 9, 778–789.

Chen, D. L., Schonger, M., Wickens, C., 2016. oTree - An open-source platform for laboratory, online, and field experiments. Journal of Behavioral and Experimental Finance 9, 88–97.

Cheng, I.-H., Hong, H., Scheinkman, J. A., 2015. Yesterday's heroes: Compensation and risk at financial firms. Journal of Finance 70, 839–879.

Dana, J., Weber, R. A., Kuang, J. X., 2007. Exploiting moral wiggle room: Experiments demonstrating an illusory preference for fairness. Economic Theory 33, 67–80.

Daniel, K., Hirshleifer, D., Subrahmanyam, A., 1998. Investor psychology and security market under- and overreactions. Journal of Finance 53, 1839–1885.

Deaton, A., 2010. Instruments, randomization, and learning about development. Journal of Economic Literature 48, 424–55.

Dell'Ariccia, G., Marquez, R., 2006. Competition among regulators and credit market integration. Journal of Financial Economics 79, 401–430.

Deshmukh, S., Goel, A. M., Howe, K. M., 2013. CEO overconfidence and dividend policy. Journal of Financial Intermediation 22, 440–463.

DeYoung, R., Peng, E. Y., Yan, M., 2013. Executive compensation and business policy choices at US commercial banks. Journal of Financial and Quantitative Analysis 48, 165–196.

Diamond, D. W., Dybvig, P. H., 1983. Bank runs, deposit insurance, and liquidity. Journal of Political Economy 91, 401–419.

Diamond, D. W., Rajan, R. G., 2009. The credit crisis: Conjectures about causes and remedies. American Economic Review Papers & Proceedings 99, 606–610.

Dietl, H. M., Grossmann, M., Lang, M., Wey, S., 2013. Incentive effects of bonus taxes in a principal-agent model. Journal of Economic Behavior & Organization 89, 93–104.

Duchin, R., Sosyura, D., 2014. Safer ratios, riskier portfolios: Banks' response to government aid. Journal of Financial Economics 113, 1–28.

Efing, M., Hau, H., Kampkötter, P., Steinbrecher, J., 2015. Incentive pay and bank risk-taking: Evidence from Austrian, German, and Swiss banks. Journal of International Economics 96, 123–140.

von Ehrlich, M., Radulescu, D., 2017. The taxation of bonuses and its effect on executive compensation and risk-taking: Evidence from the UK experience. Journal of Economics and Management Strategy 26, 712–731.

von Ehrlich, M., Seidel, T., 2015. Regional implications of financial market development: Industry location and income inequality. European Economic Review 73, 85–102.

Eisenberg, T., 1994. Differing perceptions of attorney fees in bankruptcy cases. Washington University Law Quarterly 72, 979–996.

Englmaier, F., 2010. Managerial optimism and investment choice. Managerial and Decision Economics 31, 303–310.

Eriksen, K. W., Kvaloy, O., Luzuriaga, M., 2017. Risk-taking on behalf of others. CESifo Working Paper No. 6378.

European Banking Authority, 2016. Benchmarking of remuneration practices at the European Union level and data on high earners. 30 March.

European Banking Authority, 2018. Benchmarking of remuneration practices at the European Union level and data on high earners. 10 April.

Exley, C., Kessler, J. B., 2018. Motivated errors. Harvard Business School NOM Unit Working Paper No. 18–017.

Exley, C. L., 2016. Excusing selfishness in charitable giving: The role of risk. Review of Economic Studies 83, 587–628.

Financial Times, 2017. Bankers' bonus cap could be scrapped after Brexit, says Carney. The Financial Times, article by Caroline Binham, 29 November 2017.

Fréchette, G. R., 2011. Laboratory experiments: Professionals versus students. SSRN Working Paper 13 October.

Füllbrunn, S., Neugebauer, T., 2013. Limited liability, moral hazard, and risk taking: A safety net game experiment. Economic Inquiry 51, 1389–1403.

Garcia, T., Massoni, S., Villeval, M. C., 2018. Ambiguity and excuse-driven behavior in charitable giving. SSRN Working Paper 13 November.

Gervais, S., Heaton, J. B., Odean, T., 2011. Overconfidence, compensation contracts, and capital budgeting. Journal of Finance 66, 1735–1777.

Gervais, S., Odean, T., 2001. Learning to be overconfident. Review of Financial Studies 14, 1–27.

Gietl, D., 2018. Overconfidence and bailouts. SFB TRR Discussion Paper No. 132.

Gietl, D., Haufler, A., 2017. Bonus taxes and international competition for bank managers. CESifo Working Paper No. 6495.

Gietl, D., Haufler, A., 2018. Bonus taxes and international competition for bank managers. European Economic Review 110, 41–60.

Gino, F., Norton, M. I., Weber, R. A., 2016. Motivated Bayesians: Feeling moral while acting egoistically. Journal of Economic Perspectives 30, 189–212.

Glaser, M., Langer, T., Weber, M., 2005. Overconfidence of professionals and lay men: Individual differences within and between tasks? Mimeo, Mannheim.

Gneezy, U., Potters, J., 1997. An experiment on risk taking and evaluation periods. Quarterly Journal of Economics 112, 631–645.

Gneezy, U., Saccardo, S., Serra-Garcia, M., van Veldhuizen, R., 2016. Motivated self-deception, identity and unethical behavior. Mimeo.

Gneezy, U., Saccardo, S., van Veldhuizen, R., 2018. Bribery: Behavioral drivers of distorted decisions. Journal of the European Economic Association.

Goel, A. M., Thakor, A. V., 2008. Overconfidence, CEO selection, and corporate governance. Journal of Finance 63, 2737–2784.

Gorton, G., Metrick, A., 2012. Getting up to speed on the financial crisis: A one-weekend-reader's guide. Journal of Economic Literature 50, 128–150.

Graham, J. R., Harvey, C. R., Puri, M., 2013. Managerial attitudes and corporate actions. Journal of Financial Economics 109, 103–121.

Greenbaum, S. I., Thakor, A. V., Boot, A., 2015. Contemporary financial intermediation. Third Edition, Academic Press, Cambridge.

Greiner, B., 2004. The online recruitment system ORSEE 2.0 - A guide for the organization of experiments in economics. University of Cologne Department of Economics Working Paper Series in Economics 10, 63–104.

Greve, P., Biemann, T., Ruigrok, W., 2015. Foreign executive appointments: A multilevel examination. Journal of World Business 50, 674–686.

Greve, P., Nielsen, S., Ruigrok, W., 2009. Transcending borders with international top management teams: A study of European financial multinational corporations. European Management Journal 27, 213–224.

Gropp, R., Gruendl, C., Guettler, A., 2014. The impact of public guarantees on bank risk-taking: Evidence from a natural experiment. Review of Finance 18, 457–488.

Grossman, Z., Owens, D., 2012. An unlucky feeling: Overconfidence and noisy feedback. Journal of Economic Behavior & Organization 84, 510–524.

Guardian, 2016. Over-confidence is a still a risk in the City, says new FCA chief. The Guardian, article by Jill Treanor, 9 May 2016.

Haisley, E. C., Weber, R. A., 2010. Self-serving interpretations of ambiguity in other-regarding behavior. Games and Economic Behavior 68, 614–625.

Hakenes, H., Schnabel, I., 2014. Bank bonuses and bailouts. Journal of Money, Credit and Banking 46, 259–288.

Hastorf, A. H., Cantril, H., 1954. They saw a game: A case study. Journal of Abnormal and Social Psychology 49, 129–134.

Haufler, A., Maier, U., 2016. Regulatory competition in capital standards with selection effects among banks. CESifo Working Paper No. 5839.

Heckman, J. J., Smith, J. A., 1995. Assessing the case for social experiments. Journal of Economic Perspectives 9, 85–110.

Van den Heuvel, S. J., 2008. The welfare cost of bank capital requirements. Journal of Monetary Economics 55, 298–320.

Hirshleifer, D., Low, A., Teoh, S. H., 2012. Are overconfident CEOs better innovators? Journal of Finance 67, 1457–1498.

Hirshleifer, D., Luo, G. Y., 2001. On the survival of overconfident traders in a competitive securities market. Journal of Financial Markets 4, 73–84.

Ho, P.-H., Huang, C.-W., Lin, C.-Y., Yen, J.-F., 2016. CEO overconfidence and financial crisis: Evidence from bank lending and leverage. Journal of Financial Economics 120, 194–209.

Humphery-Jenner, M., Lisic, L. L., Nanda, V., Silveri, S. D., 2016. Executive overconfidence and compensation structure. Journal of Financial Economics 119, 533–558.

Imai, K., Keele, L., Tingley, D., Yamamoto, T., 2011. Unpacking the black box of causality: Learning about causal mechanisms from experimental and observational studies. American Political Science Review 105, 765–789.

Imai, K., Keele, L., Yamamoto, T., 2010. Identification, inference and sensitivity analysis for causal mediation effects. Statistical Science 25, 51–71.

Imai, K., Tingley, D., Yamamoto, T., 2013. Experimental designs for identifying causal mechanisms. Journal of the Royal Statistical Society: Series A (Statistics in Society) 176, 5–51.

International Monetary Fund, 2010. A fair and substantial contribution by the financial sector: Final report for the G-20. Washington, DC.

Keen, M., 2011. Rethinking the taxation of the financial sector. CESifo Economic Studies 57, 1–24.

Keen, M., Konrad, K. A., 2013. The theory of international tax competition and coordination. Handbook of Public Economics 5, 257–328.

Kleven, H. J., Landais, C., Saez, E., Schultz, E., 2014. Migration and wage effects of taxing top earners: Evidence from the foreigners' tax scheme in Denmark. Quarterly Journal of Economics 129, 333–378.

Kolasinski, A. C., Li, X., 2013. Can strong boards and trading their own firm's stock help CEOs make better decisions? Evidence from acquisitions by overconfident CEOs. Journal of Financial and Quantitative Analysis 48, 1173–1206.

Kunda, Z., 1990. The case for motivated reasoning. Psychological Bulletin 108, 480–498.

Laeven, L., Levine, R., 2009. Bank governance, regulation and risk taking. Journal of Financial Economics 93, 259–275.

Laeven, L., Valencia, F., 2012. Systemic banking crises database: An update. IMF Working Paper 12/163.

Langer, E. J., 1975. The illusion of control. Journal of Personality and Social Psychology 32, 311–328.

Lehmann, E., Simula, L., Trannoy, A., 2014. Tax me if you can! Optimal nonlinear income tax between competing governments. Quarterly Journal of Economics 129, 1995–2030.

Lipatov, V., Weichenrieder, A., 2015. Welfare and labor supply implications of tax competition for mobile labor. Social Choice and Welfare 45, 457–477.

Ma, Y., 2015. Bank CEO optimism and the financial crisis. SSRN Working Paper 7 December.

Malmendier, U., Tate, G., 2005. CEO overconfidence and corporate investment. Journal of Finance 60, 2661–2700.

Malmendier, U., Tate, G., 2008. Who makes acquisitions? CEO overconfidence and the market's reaction. Journal of Financial Economics 89, 20–43.

Malmendier, U., Tate, G., 2015. Behavioral CEOs: The role of managerial overconfidence. Journal of Economic Perspectives 29, 37–60.

Markusen, J. R., Morey, E. R., Olewiler, N., 1995. Competition in regional environmental policies when plant locations are endogenous. Journal of Public Economics 56, 55–77.

Messick, D. M., Sentis, K. P., 1979. Fairness and preference. Journal of Experimental Social Psychology 15, 418–434.

Moore, D. A., Healy, P. J., 2008. The trouble with overconfidence. Psychological Review 115, 502–517.

Niepmann, F., 2015. Banking across borders. Journal of International Economics 96, 244–265.

Niu, J., 2010. The effect of CEO overconfidence on bank risk taking. Economics Bulletin 30, 3288–3299.

Philippon, T., Reshef, A., 2012. Wages and human capital in the U.S. finance industry: 1909–2006. Quarterly Journal of Economics 127, 1551–1609.

Radulescu, D., 2012. The effects of a bonus tax on manager compensation and welfare. FinanzArchiv/Public Finance Analysis 68, 1–16.

De la Rosa, L. E., 2011. Overconfidence and moral hazard. Games and Economic Behavior 73, 429–451.

Santos, J. A., 2011. Bank corporate loan pricing following the subprime crisis. Review of Financial Studies 24, 1916–1943.

Schlag, K. H., Tremewan, J., Van der Weele, J. J., 2015. A penny for your thoughts: A survey of methods for eliciting beliefs. Experimental Economics 18, 457–490.

Siegert, C., 2014. Bonuses and managerial misbehaviour. European Economic Review 68, 93–105.

Simula, L., Trannoy, A., 2010. Optimal income tax under the threat of migration by top-income earners. Journal of Public Economics 94, 163–173.

Sinn, H.-W., 1997. The selection principle and market failure in systems competition. Journal of Public Economics 66, 247–274.

Sinn, H.-W., 2003. Risk taking, limited liability, and the competition of bank regulators. FinanzArchiv/Public Finance Analysis 59, 305–329.

Spiegel, 2009. Shameless Greed - Global Rage at Bankers' Bonus Excesses. Spiegel Online, article by Spiegel staff, 20 February 2009.

Staples, C. L., 2008. Cross-border acquisitions and board globalization in the world's largest TNCs, 1995–2005. Sociological Quarterly 49, 31–51.

Taylor, S. E., Brown, J. D., 1988. Illusion and well-being: A social psychological perspective on mental health. Psychological Bulletin 103, 193–210.

Thakor, A. V., 2015. The financial crisis of 2007–2009: Why did it happen and what did we learn? Review of Corporate Finance Studies 4, 155–205.

Thanassoulis, J., 2012. The case for intervening in bankers' pay. Journal of Finance 67, 849–895.

Thanassoulis, J., Tanaka, M., 2018. Optimal pay regulation for too-big-to-fail banks. Journal of Financial Intermediation 33, 83–97.

Van Veen, K., Sahib, P. R., Aangeenbrug, E., 2014. Where do international board members come from? Country-level antecedents of international board member selection in European boards. International Business Review 23, 407–417.

Wall Street Journal, 2009a. Bank bonus tab: 33 billion. The Wall Street Journal, article by Susanne Craig and Deborah Solomon, 31 July 2009.

Wall Street Journal, 2009b. Obama slams 'fat cat' bankers. The Wall Street Journal, article by Elizabeth Williamson, 14 December 2009.

Wall Street Journal, 2009c. Crazy compensation and the crisis. The Wall Street Journal, article by Alan S. Blinder, 28 May 2009.

Wall Street Journal, 2017. Regulators drop pursuit of banker, CEO pay restrictions. The Wall Street Journal, article by Dave Michaels, 20 July 2017.

Weinstein, N. D., 1980. Unrealistic optimism about future life events. Journal of Personality and Social Psychology 39, 806–820.