Essays on Public Policy in Financial Markets and Government Finance

Dissertation

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Acknowledgement

Writing a dissertation in economics serves two purposes. First, it is the attempt to make a tangible contribution to academic research and a better understanding of the economy. I have greatly enjoyed taking a deep dive into the mechanisms that determine financial markets, monetary policy, and public finance. I hope the research presented in this dissertation will prove meaningful in that respect. Second, studying at PhD level is an inspiring opportunity to strive, grow, and learn. It provides a chance for further steps in one's personal development, for which I am very grateful. I can honestly say that no other educational or professional experience in my life has shaped my way of thinking and working more than the past four and a half years.

This development would not have been possible without the outstanding support by my supervisors Felix Bierbrauer and Andreas Schabert. Not only did their valuable feedback contribute to the progress of my research, but their high responsiveness and open communication has helped me find my path in the somewhat unwieldy world of academia. I will keep our many hours of discussion and guidance in good memory, just like all the lessons they taught me.

Special thanks also goes to my friends and colleagues Marco Wysietzki and Jonas Zdrzalek, with whom I had the honor to collaborate on the first chapter of this dissertation. We have spent innumerable days and weeks developing ideas and models to answer our research questions. We have contributed to our project corresponding to our individual strengths and learned a lot from a each other. More important than anything, however, we became friends – and will hopefully go on as such in the future.

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Contents

List of Figures

List of Tables

Introduction

This dissertation explores the role of public policy in different contexts of financial markets and government finance. Public policy can interact with markets and the macroeconomy in various ways. An obvious role is the correction of market failure. Chapter 1 addresses this function of public policy in the context of macroprudential regulation of financial markets. Conversely, public policy decisions may trigger changes in the functioning of markets, and the formation of market prices in particular. We look into an example in chapter 2, where we examine the relationship between central bank collateral policy as well as fiscal policy and sovereign bond pricing. Furthermore, public policy, markets, and the macroeconomic environment are mutually interdependent, affecting and being affected by one another. This reciprocity raises the normative question of whether or not, and under what conditions, policy frameworks ought to be adjusted to changing circumstances. A policy field frequently confronted by this challenge is income taxation, as we elaborate in chapter 3.

Each chapter hence focuses on a specific area where public policy and the economy interact. Overall, they contribute to the scientific understanding of the role of public policy in the areas considered. They further offer guidance to policy makers on issues of financial stability and public finances, which have proven to be prominent subjects in recent policy debates. We start out by providing a brief outline of the analyses presented in what follows.

Macroprudential regulation. Chapter 1 studies the efficiency implications of macroprudential policy in a model where financial markets are frictional and economic agents disagree on their beliefs about the future state of the world. Belief heterogeneity was a contributing factor in prompting the 2007–2009 global financial crisis, underlying the build-up of leverage in financial balance sheets (Cheng et al., 2014; Gennaioli and Shleifer, 2018; Mian and Sufi, 2022). However, from a theory perspective, a question still to be answered is how the occurrence of a crisis and optimal macroprudential policies are impacted by the belief channel.

There is a vast literature on the link between borrowing, investment, and financial crises. An established result is the efficiency-enhancing effect of macroprudential policy, encompassing both corrective taxes and quantitative restrictions on financial decisions (Geanakoplos and Polemarchakis, 1986; Bianchi, 2011; Dávila and Korinek, 2018; Jeanne and Korinek, 2020). However, in the presence of belief heterogeneity, policy instruments would optimally address the individual behavior of market participants, and the extent to which it contributes to financial distress. That requires a characterization of how differentiated beliefs give rise to such individual contributions. Albeit the literature has provided valuable insights into measuring systemic risk contributions, it lacks an explicit consideration of the role of beliefs (Acharya et al., 2012; Adrian and Brunnermeier, 2016; Acharya et al., 2017).

We fill this gap and analyze the belief channel of financial distress. We build upon an established model that features a pecuniary externality, originating from a price-dependent collateral constraint in the credit market. It is augmented by heterogeneity of beliefs across the population. This setup gives rise to differentiated risk taking in financial decisions. The latter are observable, so we may characterize individual contributions to financial distress explicitly. That allows us to derive optimal macroprudential policies which are calibrated to each individual's type.

The main result is that belief disagreements increase the likelihood and the extent of financial distress. Specifically, crises occur under less severe macroeconomic shocks, and the associated loss of efficiency is larger than in an economy populated by homogeneous individuals. This finding rests upon the fact that economic agents contribute to financial distress asymmetrically, with optimistic agents making larger contributions than pessimistic agents. That has notable implications for macroprudential policy. We show that, while corrective policy interventions are generally efficiency-enhancing, type-specific policies generate additional efficiency gains. Against this background, we propose a system of non-linear, i. e. type-specific, macroprudential taxes. This policy outperforms linear taxes, which are typically proposed in the literature, in reducing indebtedness and stabilizing collateral prices.

Central bank collateral frameworks and fiscal policy. Chapter 2 as well approaches the interplay of public policy and financial markets, however, with a focus on sovereign debt markets. We examine how a change of the ECB collateral framework impacted the pricing of Eurozone sovereign bonds in the 2000s. In general, Eurozone governments have experienced diverging sovereign bond yield spreads in the past 20 years, inspiring a debate on whether government debt should be considered safe or risky (Cœuré, 2016). While it is established that sovereign risk during and after the 2007–2009 financial crisis has been driven by variations in macroeconomic fundamentals, including fiscal policy stances, the determinants of sovereign spreads prior to the crisis are still largely unexplored.

In this chapter, we trace the pre-crisis emergence of Eurozone government bond yield spreads back to the revision of the ECB's collateral framework in 2005. The reform involved a shift from an unconditional to a conditional treatment of sovereign bonds as eligible central bank collateral, requiring them henceforth to hold a minimum credit rating. We show that the event of making eligibility conditional induced a significant widening of spreads.

We further investigate the underlying channels of this effect. Theoretically, sovereign spreads ought to rise in countries featuring unfavorable current macroeconomic and fiscal positions or inferior credit ratings. However, we show that spreads were unresponsive to either one. Instead, we propose a new channel that links yield differentials to asymmetries in business cycles. Our results indicate that sovereign spreads surged in countries whose business cycles were least aligned with the Eurozone average. Since these countries are commonly grouped under the term *periphery*, as opposed to the more homogeneous *core*, we frame this channel the *periphery premium*. We provide descriptive evidence that the periphery status at the time was correlated with markets expecting a deterioration of future macro-financial trends. Notably, these negative expectations were not reflected in credit ratings.

Tax policy. The third chapter of this dissertation is also related to fiscal policy, but puts emphasis on the revenue side of the government budget, and how it is affected by the macroeconomy. Specifically, it provides a normative analysis of the interplay of inflation and income taxation, giving rise to the phenomenon of *bracket creep*. It describes the effect of inflation pushing tax payers into higher tax brackets and has long been a controversially debated subject in many countries. It is commonly associated with economic costs, by lowering productive activity, and questionable legitimacy, constituting a de-facto tax increase "through the back door". With that said, this chapter analyzes the political economy and efficiency properties of bracket creep.

There is a scarce literature providing empirical country studies of the economic effects of bracket creep. However, although being a recurrent topic in the political sphere, a stringent analysis of the political economy of bracket creep is missing. Is it always rejected or can there be a majority of tax payers in favor? If yes, under what conditions? Is political support for bracket creep in line with its efficiency implications? We develop a theoretical framework where bracket creep is analyzed as a tax reform. Accounting for the effects of inflation on both tax rates and the real value of taxes and transfers, we derive formal conditions to test these questions.

Our main finding is a median voter result for bracket creep. Under plausible assumptions on the tax system, if the median tax payer is a beneficiary, bracket creep has majority support from the poorer half of the population. We then check whether political support is always aligned with welfare improvements. We find that this may or may not be the case, depending on the social welfare function used for evaluation. While political support comes along with positive welfare effects under a Rawlsian measure, this is not true if evaluated based on the total surplus. Ultimately, we examine how bracket creep interferes with the efficiency of existing tax systems. We show that, for a tax system that maximizes either social welfare or government revenue ex ante, bracket creep is efficiency-reducing in a welfare and a Pareto sense, respectively.

Personal contribution. Two of the three chapters of this dissertation are joint work with co-authors. Individual contributions have been made as follows.

Chapter 1 is joint work with Marco Wysietzki and Jonas Zdrzalek. The research idea was developed together, as was the basic setup of the theoretical framework and the formal analysis. My individual contributions are twofold. On the one hand, I developed most parts of the mathematical derivations underlying section 1.3.3. On the other hand, I was responsible for most of the drafting, which was then complemented by the co-authors. Marco Wysietzki provided the numerical application of the model. Jonas Zdrzalek individually prepared the section *Related literature*.

Chapter 3 is joint work with Felix Bierbrauer. While he initially came up with the research idea, and we developed the basic framework together, I finalized the model and formally derived the results. Moreover, the version of the chapter presented in this dissertation was drafted by me.

Chapter 1

How Heterogeneous Beliefs Trigger Financial Crises

by Florian Schuster, Marco Wysietzki, and Jonas Zdrzalek

Abstract

We present a theoretical framework to characterize how belief heterogeneity in financial markets interacts with financial crises. To that end, we embed belief heterogeneity in a financial market model featuring a collateral constraint, which introduces a pecuniary externality. This setup allows us to identify individual contributions to financial distress. The main result is that belief disagreements increase the likelihood and the extent of financial distress. Specifically, crises occur under less severe macroeconomic shocks, and the associated loss of efficiency is larger than in an economy populated by homogeneous individuals. This finding rests upon the fact that economic agents contribute to financial distress asymmetrically, with optimistic agents making larger contributions than pessimistic agents. In terms of policy implications, we show that, while corrective policy interventions are generally efficiency-enhancing, type-specific policies generate additional efficiency gains. Against this background, we propose a system of non-linear, i. e. type-specific, macroprudential taxes. This policy outperforms linear taxes, which are typically proposed in the literature, in reducing indebtedness and stabilizing collateral prices.

Key words: financial amplification, pecuniary externalities, collateral constraint, financial crisis, belief heterogeneity, macroprudential policy

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1.1 Introduction

Belief heterogeneity was a contributing factor in prompting the 2007–2009 global financial crisis, underlying the build-up of leverage in financial balance sheets (Cheng et al., 2014; Gennaioli and Shleifer, 2018; Mian and Sufi, 2022). However, from a theory perspective, a question still to be answered is how the occurrence of a crisis and optimal macroprudential policies are impacted by the belief channel.

There is a vast literature on the link between borrowing, investment, and financial crises. An established result is the efficiency-enhancing effect of macroprudential policy, encompassing both corrective taxes and quantitative restrictions on financial decisions (Geanakoplos and Polemarchakis, 1986; Bianchi, 2011; Dávila and Korinek, 2018; Jeanne and Korinek, 2020). However, in the presence of belief heterogeneity, policy instruments would optimally address the individual behavior of market participants, and the extent to which it contributes to financial distress. That requires a characterization of how differentiated beliefs give rise to such individual contributions. Albeit the literature has provided valuable insights into measuring systemic risk contributions, it lacks an explicit consideration of the role of beliefs (Acharya et al., 2012; Adrian and Brunnermeier, 2016; Acharya et al., 2017).

We fill this gap and analyze the belief channel of financial distress. We build upon an established model that features a pecuniary externality, originating from a price-dependent collateral constraint in the credit market. It is augmented by heterogeneity of beliefs across the population. This setup gives rise to differentiated risk taking in financial decisions. The latter are observable, so we may characterize individual contributions to financial distress explicitly. That allows us to derive optimal macroprudential policies which are calibrated to each individual's type.

The main result is that belief disagreements increase the likelihood and the extent of financial distress. Specifically, crises occur under less severe macroeconomic shocks, and the associated loss of efficiency is larger than in an economy populated by homogeneous individuals. This finding rests upon the fact that economic agents contribute to financial distress asymmetrically, with optimistic agents making larger contributions than pessimistic agents. That has notable implications for macroprudential policy. We show that, while corrective policy interventions are generally efficiency-enhancing, type-specific policies generate additional efficiency gains. Against this background, we propose a system of non-linear, i. e. type-specific, macroprudential taxes. This policy outperforms linear taxes, which are typically proposed in the literature, in reducing indebtedness and stabilizing collateral prices.

To the best of our knowledge, we are the first to study the efficiency properties of an economy that features both frictional financial markets and belief heterogeneity. Specifically, our model incorporates a collateral constraint on borrowing as a function of the market-determined collateral price. This type of friction introduces a pecuniary externalitiy, as economic agents do not internalize that their decisions mutually affect borrowing capacities, which, in turn, establishes a financial amplification mechanism. Agents may hold heterogeneous beliefs in the sense of perceiving differentiated probability distributions over the future state of the world. This setup allows us to distinguish relatively more optimistic from pessimistic individuals.

We use this model to analyze the interaction of the collateral constraint and belief heterogeneity. First, we characterize how the latter impacts the probability of distress in the competitive equilibrium, as well as the equilibrium allocation, collateral prices, and externalities. We then perform an efficiency analysis. It allows us to detect inefficiences in the competitive allocation and to show how a social planner achieves a welfare improvement by internalizing the effects of individual investment and borrowing decisions on collateral prices. We characterize her optimal corrective policies numerically, and evaluate how they alter the levels of borrowing, investment, the probability of financial distress, and efficiency.

Theorem 1.1 entails a key results of our analysis, stating that, compared to an economy where agents hold a homogeneous and rational belief, belief heterogeneity raises the likelihood of financial distress. For collateral constraints to be binding, the economy does need to be hit by severe shocks to aggregate investment or net worth, as is typically the case in the literature on pecuniary externalities. Instead, it suffices that some agents' beliefs deviate from the ex post state of the world. This is likely to be the case in the presence of belief heterogeneity, which therefore raises the probability that a financial crisis is triggered.

This finding is brought about by the fact that optimistic and pessimistic agents contribute asymmetrically to systemic distress. Our analysis reveals that optimists overborrow and overinvest, while pessimists underborrow and underinvest. By this behavior, optimists and pessimists exert downward and upward pressure on collateral prices, respectively. However, pessimists prove to make a smaller impact, as their level of investment is bounded from below by the motive to hold collateral. Under the plausible assumption that beliefs are distributed normally across the population, that implies that collateral prices turn out to be lower under heterogeneous beliefs, suggesting that belief heterogeneity precipitates financial distress.

We further study the efficiency implications of the former findings. The competitive allocation is associated with inefficiencies emanating from the fact that economic agents do not internalize how their investment and borrowing decisions impact collateral prices. A social planner, however, albeit herself constrained by the borrowing limit, internalizes these effects. Theorem 1.2 draws upon this insight, formulating policy implications on how to implement an efficient allocation. We show that, even though beliefs are agents' private information and a priori unobservable to the social planner, it can be decentralized by a set of non-linear macroprudential taxes, suitable to address type-specific contributions to financial distress. Our policy proposal goes beyond the existing literature, which takes no account of heterogeneity among agents and, hence, focuses on linear macroprudential taxes. By evaluating efficiency implications numerically, we find that, although either sort of policy intervention enhances efficiency and reduces the probability of financial distress, the non-linear policy we propose produces considerable welfare gains.

This chapter makes several important contributions. We develop a framework that helps to explicitly characterize how different market participants contribute to financial crises. That is decisive to show that the mere presence of belief disagreements poses a source of financial distress. The optimal design of prudential policies thus accounts for belief divergences and is calibrated to individual contributions. This is particularly relevant during different phases of the business cycle, as investors' beliefs prove to fluctuate and diverge largely between booms and busts (Minsky, 1977; Aliber and Kindleberger, 2015; Minsky, 1986; Adam et al., 2017; Kaplan et al., 2020; Mian and Sufi, 2022). On the conceptual level, this chapter provides a formal framework which can be used for further analyses of financial amplification mechanisms in environments where economic agents do not have rational expectations, but potentially feature heterogeneous beliefs.

The remainder of this chapter is organized as follows. We review the related literature in section 1.2. Section 1.3 develops the baseline model, and analyzes the competitive equilibrium. In section 1.4, we describe the externalities present in our model, derive optimal corrective policies, and perform normative analyses numerically. We provide some final remarks in section 1.5.

1.2 Related literature

Financial amplification, pecuniary externalities and systemic risk. The chapter relates to the literature on financial amplification, including studies of pecuniary externalities in particular. This literature originates from Fisher (1933) and was extended by analyses of borrowing constraints and their effects on asset prices by Bernanke and Gertler (1990), Shleifer and Vishny (1992), Kiyotaki and Moore (1997), Brunnermeier and Pedersen (2009), and Acharya et al. (2011). Hart (1975) and Stiglitz (1982) moreover prove the presence of pecuniary externalities in incomplete markets.[1] By modeling a borrowing constraint in an incomplete credit market, our framework builds on the structures of this

[1] For survey articles, see Shleifer and Vishny (2011) and Brunnermeier and Oehmke (2013).

literature.

Welfare implications of pecuniary externalities are examined in Gromb and Vayanos (2002), Caballero and Krishnamurthy (2003), Lorenzoni (2008), and Caballero and Lorenzoni (2014). While these papers focus on externalities affecting borrowers' net worth, Jeanne and Korinek (2010), Bianchi (2011), Bianchi and Mendoza (2018), Dávila and Korinek (2018), and Jeanne and Korinek (2019) explore the collateral channel of financial amplification that can lead to financial crises. Since we are modeling externalities equivalently, we adopt their terminology and basic model structure.

Furthermore, we derive optimal corrective policies implemented by a a constrained social planner, referring to the early contributions of Stiglitz (1982) and Geanakoplos and Polemarchakis (1986). The policy maker in our model applies an ex ante macroprudential tax along the lines of Jeanne and Korinek (2010), Dávila and Korinek (2018), Jeanne and Korinek (2019), and Jeanne and Korinek (2020).[2]

In specifying individual constributions to financial distress, this chapter links to articles that focus on defining measures of systemic risk. Notably, Adrian and Brunnermeier (2016) propose $\Delta CoVar$, a measure capturing the interdependences between specific financial institutions and the entire financial system. Furthermore, Acharya et al. (2012) and Acharya et al. (2017) model individual institutions' exposure to financial crises. For an overview of quantitative measures of systemic risk, see Bisias et al. (2012). As opposed to our analysis, these studies do not account for belief disagreements as potential drivers of systemic risk contributions.

Macroeconomic perspectives on belief heterogeneity. Our work is also part of the literature on macroeconomic perspectives on belief heterogeneity. The idea of belief heterogeneity shaping market outcomes was pioneered by Keynes (1936), Minsky (1977), and Aliber and Kindleberger (2015). Since then, the literature has provided evidence that belief heterogeneity is relevant for asset prices and market volatility, in particular during the recent financial crisis (Harrison and Kreps, 1978; Scheinkman and Xiong, 2003; Reinhart and Rogoff, 2008; Simsek, 2013; Cheng et al., 2014; Gennaioli and Shleifer, 2018; Adam and Nagel, 2022).

Prior research has already combined belief heterogeneity with frictional financial markets, particularly in the context of leveraged speculation.[3] Geanakoplos (1996) was the first to model a general equilibrium with endogenous collateral constraints and heterogeneous beliefs, further developed in subsequent studies (Geanakoplos, 2003, 2010), showing

[2]The social planner in our model has an instrument at hand which could be interpreted as a financial transaction tax. So the interested reader is referred to the literature on financial transaction taxes initiated by Tobin (1978) and extended by Summers and Summers (1989) and Stiglitz (1989).

[3]Xiong (2013) and Simsek (2021) review the literature on asset trading driven by heterogeneous beliefs in more detail.

that heterogeneity of beliefs fosters credit and leverage cycles. Simsek (2013) generalizes the framework by using a continuum of states, and focuses on various degrees of heterogeneity. The contribution of this chapter is that we add an analysis of efficiency implications to this literature, in particular by deriving optimal type-specific macroprudential policies.

As in all normative studies involving heterogeneity of beliefs, we face the challenge of how to aggregate welfare properly. Several approaches have been suggested, such as the welfare criteria put forth by Gilboa et al. (2014), Gayer et al. (2014), Brunnermeier et al. (2014), Blume et al. (2018), and Kim and Kim (2021). We overcome this challenge by an agnostic approach, equipping the social planner with no superior information, but letting her accepting individual beliefs.

Methodological approach. Lastly, our investigation of comparative statics with respect to the economy's belief structure closely relates to Dávila and Walther (2023), who study optimal leverage policies in response to changing beliefs. We follow their approach of applying methods of the calculus of variation to equilibrium variables under belief heterogeneity.

1.3 Model

The aim of this chapter is to explore a financial amplification mechanism in an environment where agents hold heterogeneous beliefs about the future. To that end, we set up a model featuring frictional financial markets and enrich it by belief heterogeneity across agents. We derive the competitive equilibrium of this economy and study how it is impacted by variations in beliefs. The framework allows us to distinguish the respective contributions of optimistic and pessimistic agents to financial amplification, and to evaluate the probability and the extent of distress in economies with different belief structures. Our results lay the ground for the study of optimal corrective policies in the next section.

1.3.1 Setup

We model a small open economy with three periods $t = 0, 1, 2$ and two classes of agents, referred to as lenders and investors. Lenders trade debt securities with investors or save in a zero return storage technology. The interest rate is exogeneous and normalized to zero for simplicity, and lenders are assumed to be risk-neutral. Investors are divided into J groups indexed by $j \in \{1, ...J\}$, each of which consists of a continuum of individuals. Each group has a population share s^j that is common knowledge and derives utility from a single consumption good c_t^j according to a concave and strictly increasing utility function $u\left(c_t^j\right)$. Population shares are collected in the vector $s = \{s^j\}_{j\in\{1,...J\}}$.

In $t = 0$, investors receive an endowment $e > 0$, as well as an initial amount of assets $\bar{a} > 0$. They can borrow or save d_0^j to finance consumption and to further invest into a_0^j units of the asset.[4] The asset is traded at a price q_0 and exists in fixed supply. In $t = 1$, financial investment pays off an a priori uncertain dividend $R \in \left[\underline{R}, \overline{R}\right]$, which different groups of investors hold specific beliefs about. After all uncertainty has been resolved at the beginning of the period, investors repay former debt d_0^j, issue new debt d_1^j, and trade again, purchasing or liquidating l_1^j claims on the asset at price q_1. Debt issuance in $t = 1$ is restricted by a borrowing constraint

$$d_1^j \leq \phi q_1 \left(a_0^j - l_1^j\right).$$

The constraint implies that investors borrow against their asset position at the end of the period.[5] In $t = 2$, net of claims $a_0^j - l_1^j$ materializes and debt d_1^j must be repaid, determining final consumption c_2^j.

Our model features two important components. First, financial markets exhibit a friction, captured by the borrowing constraint. It incorporates a financial amplification mechanism within our framework, and results in a pecuniary externality. Second, we allow investors to hold different beliefs about the asset pay-off R.

Definition 1.1. *Let $F(R)$ be the true cumulative distribution function (cdf) of R, and $F^j(R)$ be the cdf perceived by type-j investors. We refer to heterogeneous beliefs if each type of investors j perceives an idiosyncratic distribution of R, i. e. $F^i(R) \neq F^j(R)$ for all $i \neq j$. We refer to homogeneous beliefs if all types of investors have rational expectations, i. e. $F^j(R) = F(R)$ for all j.*

The vector $\mathcal{F} = \{F^j(R)\}_{j\in\{1,...J\}}$ characterizes the complete set of beliefs existing in the economy, which we assume to be publicly known. Beliefs are distributed discretely

[4] Lenders' endowment is assumed to make the supply of debt securities perfectly elastic to demand. That is, all investors' borrowing preferences can be satisfied by assumption. This includes the possibility of savings $d_0^j < 0$.

[5] To rationalize this constraint, we adopt the mechanism suggested by Jeanne and Korinek (2019). The constraint bases on the presumption that investors lack commitment to repay. When investors renegotiate debt obligations, they make a take-it-or-leave-it offer in order to lower the amount of outstanding debt. If lenders reject the offer, they may seize a fraction ϕ of investors' assets and sell it at the prevailing market price. Lenders will hence accept the offer provided the repayment exceeds the current market value of seizable positions. This being said, we may assume without loss of generality that default and renegotiations never occur in equilibrium. One could further consider a similar restriction of debt issuance in period $t = 0$, which we neglect on the grounds that there is no role for macroprudential interventions in that period. Binding borrowing constraints in $t = 0$ would limit the set of cases when the period-1 constraint is binding, however without altering the results of our analysis, which focuses on states within this set.

across types, so each cdf $F^j(R)$ appears with frequency s^j.

1.3.2 Competitive equilibrium

To derive the competitive equilibrium, we first solve individual optimization problems backwards from $t = 2$ to $t = 0$. We distinguish between state variables of type-j individuals, i. e. $\{a_0^j, d_0^j\}$, and aggregate state variables of group j, denoted by $\left\{\tilde{a}_0^j, \tilde{d}_0^j\right\}$.

Optimization in $\mathbf{t = 1, 2}$. The optimization problem of type-j investors in $t = 1$ reads

$$V_1^j\left(a_0^j, d_0^j \mid \tilde{a}_0, \tilde{d}_0\right) = \max_{c_1^j, c_2^j, d_1^j, l_1^j \le a_0^j} u\left(c_1^j\right) + u\left(c_2^j\right) \quad \text{s.t.}$$

$$\left(\lambda_1^j\right) \quad c_1^j = Ra_0^j + q_1 l_1^j + d_1^j - d_0^j \tag{1.1}$$

$$\left(\lambda_2^j\right) \quad c_2^j = a_0^j - l_1^j - d_1^j \tag{1.2}$$

$$\left(\eta_1^j\right) \quad d_1^j \le \phi q_1 \left(a_0^j - l_1^j\right), \tag{1.3}$$

where investors take group-wide aggregate states $\tilde{a}_0 = \left\{\tilde{a}_0^j\right\}_{j\in\{1,\dots J\}}$ and $\tilde{d}_0 = \left\{\tilde{d}_0^j\right\}_{j\in\{1,\dots J\}}$ as given because they affect the equilibrium asset price q_1. Let λ_1^j and λ_2^j be the Lagrange multipliers for the budget constraints (1.1) and (1.2), respectively, and η_1^j for the borrowing constraint (1.3).

This problem gives rise to the following pair of Euler equations for each j:

$$u'\left(c_1^j\right) - \eta_1^j = u'\left(c_2^j\right) \tag{1.4}$$

$$q_1 u'\left(c_1^j\right) - \eta_1^j \phi q_1 = u'\left(c_2^j\right), \tag{1.5}$$

jointly yielding equilibrium price equations

$$q_1 = \frac{u'\left(c_2^j\right)}{(1-\phi)u'\left(c_1^j\right) + \phi u'\left(c_2^j\right)} \tag{1.6}$$

for each j.

Optimization in $\mathbf{t = 0}$. In $t = 0$, the optimization of a type-j investor is

$$\max_{c_0^j, a_0^j \ge 0, d_0^j} u\left(c_0^j\right) + E^j\left[V_1^j\left(a_0^j, d_0^j \mid \tilde{a}_0, \tilde{d}_0\right)\right] \quad \text{s.t.}$$

$$\left(\lambda_0^j\right) \quad c_0^j = e + d_0^j + q_0\left(\bar{a} - a_0^j\right), \tag{1.7}$$

where the expectation operator is indexed by j, capturing potentially differing beliefs, and λ_0^j denotes the Lagrange multiplier for the period-0 budget constraint. Eliminating

Lagrange multipliers, we obtain the following optimality conditions for each j:

$$q_0 u'\left(c_0^j\right) = E^j\left[Ru'\left(c_1^j\right) + u'\left(c_2^j\right) + \eta_1^j \phi q_1\right] \tag{1.8}$$
$$u'\left(c_0^j\right) = E^j\left[u'\left(c_1^j\right)\right]. \tag{1.9}$$

Equilibrium. In equilibrium, the asset market is cleared in both periods $t = 0$ and $t = 1$, formalized by the conditions

$$\sum_{j=1}^{J} s^j a_0^j = \bar{a} \tag{1.10}$$

and

$$\sum_{j=1}^{J} s^j l_1^j = 0, \tag{1.11}$$

completing the set of equilibrium conditions. In a symmetric equilibrium, investors are identical within each group j, i. e. $x_t^j = \tilde{x}_t^j$ for all j with $x \in \{c, a, d, l, \lambda, \eta\}$. We may thus define the symmetric competitive equilibrium as follows.

Definition 1.2. *A competitive equilibrium consists of an allocation* $\left\{\tilde{c}_0^j, \tilde{c}_1^j, \tilde{c}_2^j, \tilde{a}_0^j, \tilde{d}_0^j, \tilde{d}_1^j, \tilde{l}_1^j\right\}_{j\in\{1,\ldots J\}}$, *a sequence of multipliers* $\tilde{\eta}_1 = \left\{\tilde{\eta}_1^j\right\}_{j\in\{1,\ldots J\}}$, *and prices* $\{q_0, q_1\}$, *satisfying equations* (1.1), (1.2), (1.4), (1.5), (1.7), (1.8), (1.9), *and a complementary slackness condition for all* j, *as well as the market clearing conditions* (1.10) *and* (1.11), *given population shares* s *and beliefs* $\mathcal{F}$.

The competitive equilibrium reflects the two main components of our model: the financial friction and potential belief disagreements. The financial friction introduces a wedge between market prices of the asset as well as debt and investors' marginal rates of substitution across periods. The wedge is formally represented by the multiplier $\tilde{\eta}_1^j$ that appears in equations (1.4), (1.5), and (1.8). In the latter two equations, the term $\tilde{\eta}_1^j \phi q_1$ captures the collateral premium of the asset, as each additional unit of $\tilde{a}_0^j$ and $\tilde{l}_1^j$ relaxes the constraint.

To highlight the impact of belief heterogeneity, we compare the competitive equilibrium under heterogeneous and homogeneous beliefs. If investors have heterogeneous expectations about the return R, they evaluate expected marginal benefits of investment and borrowing differently. Formally, group-specific expectation operators E^j apply in the Euler equations (1.8) and (1.9), resulting in group-specific values of $\tilde{a}_0^j$, $\tilde{d}_0^j$, and of the shadow price of borrowing $\tilde{\eta}_1^j$.

If, in contrast, investors hold a homogeneous belief, their marginal rates of substitution are identical, as is the shadow value of borrowing. Importantly, intertemporal substitution in this case is only possible through debt or savings $\tilde{d}_t^j$. The reason is that investors do not trade in excess of the initial asset endowment neither in $t = 0$ nor in $t = 1$, i. e. $\tilde{a}_0^j = \bar{a}$ and $\tilde{l}_1^j = 0$ for all j.

In the following, we restrict the set of equilibria taken into account in the analysis. Since we are only interested in situations when financial distress occurs, the model parameters, comprising risk aversion A, beliefs $\mathcal{F}$, the realized return $\hat{R}$, as well as the margin requirement ϕ, must satisfy that, in equilibrium, the asset is traded and constraints are binding $(\tilde{\eta}_1^j > 0)$.[6]

Period-1 equilibrium price. Given its impact on the borrowing constraint, the equilibrium collateral price q_1 is a key variable in our model. We show its existence and uniqueness, and how it interacts with the multiplier of the borrowing constraint.

Proposition 1.1.

(i) The equilibrium price q_1 exists.

(ii) If at least one type of investors j receives a return as expected or higher, i. e. $E^j[R] \leq \hat{R}$ for at least one j and any realization $\hat{R}$ of R, the equilibrium price is unique, satisfying $q_1 \leq 1$, and the following two equivalences hold:

(1) $q_1 = 1$ if and only if $\tilde{\eta}_1^j = 0$ for all j,

(2) $q_1 < 1$ if and only if $\tilde{\eta}_1^j > 0$ for at least one j.

Proposition 1.1 first states that the equilibrium exists. Second, assuming that there is positive demand because at least one type makes a profit from investment, it asserts that the equilibrium price is unique and characterizes its relation with the borrowing constraint.[7] The constraint is binding at a price smaller than 1, but slack if $q_1 = 1$. At this price, investors are indifferent between purchasing or selling claims.

The two equivalences in part (ii) of Proposition 1.1 formalize this indifference property. They imply that either all or none of the investors are constrained by the borrowing limit. It is sufficient that only one group of investors is forced to liquidate claims on the market, i. e. $\tilde{l}_1^j > 0$, to reduce the price q_1 to a level below one. This deflation either constrains other investors via a tighter borrowing limit, or it gives them a pecuniary incentive to issue as much debt as possible. They do so to purchase additional claims, i. e. $\tilde{l}_1^j < 0$. To see this, recall the budget constraints (1.1) and (1.2), and note that, provided $q_1 < 1$,

[6] We make parameter restrictions explicit in the derivations of our results, provided in the appendix.

[7] However, the equilibrium price exists even if demand is zero, as this scenario corresponds to all investors being bankrupt, and infinitely many prices satisfy the Walrasian equilibrium definition. Abstracting from this case, we focus on equilibria with positive demand, which turn out to be uniquely determined.

every purchased unit of claims offers a positive return $1 - q_1 > 0$ in the final period. Hence, in order to transfer funds to $t = 2$, solvent investors prefer additional investment $\tilde{l}_1^j < 0$ over savings $\tilde{d}_1^j < 0$. For a price $q_1 = 1$, however, they are indifferent between both ways of intertemporal substitution.[8]

1.3.3 Equilibrium effects of variations in beliefs

In this section, we analyze how variations in beliefs affect the allocation and prices in the competitive equilibrium. We show how the two main ingredients of our model, the financial friction and heterogeneity of beliefs, interact. The results of this comparative statics exercise allow us to specify how different types contribute to financial amplification. We use these insights to evaluate how belief heterogeneity affects the overall probability and extent of financial distress.

To keep the model tractable, we henceforth impose the following assumption without further mention. It is useful to simplify the comparative statics analysis below.

Assumption 1.1. *Investors have exponential preferences of the form* $u\left(c_t^j\right) = -\exp\left(-Ac_t^j\right)$*, where absolute risk aversion* $A = -\frac{u''\left(c_t^j\right)}{u'\left(c_t^j\right)}$ *is constant (CARA).*[9]

We start out by examining the effect of changes in period-0 variables on the equilibrium price in $t = 1$, before analyzing how belief variations impact the equilibrium values of investment and borrowing in period $t = 0$. Note that the period-1 equilibrium price q_1 is no direct function of beliefs $\mathcal{F}$, but only through period-0 choices $\tilde{a}_0(\mathcal{F})$ and $\tilde{d}_0(\mathcal{F})$, i. e. $q_1 = q_1\left(\tilde{a}_0(\mathcal{F}), \tilde{d}_0(\mathcal{F})\right)$. Thus, this two-step procedure allows us to elaborate the relationship between the set of beliefs in the economy and the equilibrium price q_1, which defines the tightness of the borrowing constraint and measures the extent of financial distress.

Period-0 allocation and the equilibrium price. Proposition 1.2 states how the equilibrium price q_1 is linked to period-0 levels of investment and debt.

Proposition 1.2.

(i) If investors hold heterogeneous beliefs $\mathcal{F}$*, the period-1 equilibrium price* q_1 *is decreas-*

[8] Formally, one of the Euler equations (1.4) and (1.5) is redundant in the unconstrained case, i. e. if $q_1 = 1$ and $\tilde{\eta}_1^j = 0$ for all j. Intuitively, investors are indifferent between the instruments $\tilde{l}_1^j$ and $\tilde{d}_1^j$, given that both promise a zero net return. We assume without loss of generality that there is no trade in the unconstrained economy, i. e. $\tilde{l}_1^j = 0$ for all j.

[9] For expositional reasons, we continue using the general notation $u\left(c_t^j\right)$.

ing with period-0 investment and borrowing, i. e., for all j,

$$\frac{\partial q_1}{\partial \tilde{a}_0^j} < 0 \text{ and } \frac{\partial q_1}{\partial \tilde{d}_0^j} < 0.$$

(ii) If investors hold the homogeneous belief $F(R)$, the period-1 equilibrium price q_1 is decreasing with period-0 borrowing, i. e.

$$\frac{\partial q_1}{\partial \tilde{d}_0} < 0.$$

Proposition 1.2 states that more investment and borrowing in period $t = 0$ have a diminishing effect on the future equilibrium asset price. In the homogeneous case, while the former is irrelevant, as trade does not occur, the negative effect of borrowing holds true as well.

The two effects work through different channels, illustrated by the budget constraints (1.1) and (1.2). First, investment in $\tilde{a}_0^j$ increases period-2 consumption $\tilde{c}_2^j$ one-to-one, while $\tilde{c}_1^j$ rises with factor $\hat{R}$. Thus, in a sufficiently adverse state, satisfying $\hat{R} < 1$, consumption in the last period $\tilde{c}_2^j$ increases by more in response to investment than $\tilde{c}_1^j$. To smooth consumption, investors redistribute resources from $t = 2$ to $t = 1$ by liquidating $\tilde{l}_1^j$ units of their asset position (or purchasing less additional units). Second, higher indebtedness $\tilde{d}_0^j$ reduces the initial period-1 wealth $\hat{R}\tilde{a}_0^j - \tilde{d}_0^j$, raising the risk of being constrained and forced to liquidate a fraction of the portfolio. Both channels result in a higher supply (and a lower demand) of claims, which, in turn, reduce the equilibrium price q_1.

Beliefs and the period-0 allocation. We now turn to the relationship between investment $\tilde{a}_0(\mathcal{F})$ and borrowing $\tilde{d}_0(\mathcal{F})$ and investors' beliefs $\mathcal{F}$. To that end, we employ methods from the calculus of variation. We adopt the following procedure, that was first applied to heterogeneous belief environments by Dávila and Walther (2023). Recall that type-j investors' beliefs are characterized by the perceived distribution of R with cdf $F^j(R)$. Consider a perturbation to beliefs of the form $F^j(R) + \epsilon G^j(R)$, where $\epsilon > 0$ is an arbitrary number, and $G^j(R)$ captures the direction of the perturbation. $F^j(R) + \epsilon G^j(R)$ is required to be a valid cdf for small enough ϵ, so we assume it is continuous and differentiable, satisfies $G(\underline{R}) = G(\overline{R}) = 0$, and $\partial (F^j(R) + \epsilon G^j(R)) / \partial R \geq 0$ for sufficiently small ϵ.

This setup allows us to specify the concepts of optimism and pessimism. These terms are defined relative to each other in the sense of first-order stochastic dominance. A perturbation $G^j(R)$ makes type-j investors more optimistic if and only if it satisfies $F^j(R) + \epsilon G^j(R) \leq F^j(R)$ for all R. It is easy to see that a more optimistic belief requires the perturbation to have a non-positive direction, i. e. $G^j(R) \leq 0$ for all R. Analogously, investors of type j are made more pessimistic through a perturbation with direction $G^j(R) \geq 0$ for all R. Intuitively, investors are more optimistic if they assign lower probabilities than pessimists to low returns, so their cdf is shifted downwards.[10]

Using this technique, we show how a variation of a type's belief alters its individual choices of investment and debt issuance. The corresponding functional derivatives are

$$\frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j \text{ and } \frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j,$$

where δ denotes the operator for functional derivatives. Proposition 1.3 summarizes the results.

Proposition 1.3.

(i) Let investors hold heterogeneous beliefs $\mathcal{F}$ and let $G^j(R)$ be the direction of a perturbation of type-j investors' belief $F^j(R)$. More optimistic (pessimistic) investors invest and borrow more (less), i. e.

$$\frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j \begin{cases} \geq 0, & G^j(R) \leq 0 \\ < 0, & G^j(R) \geq 0 \end{cases} \text{ and } \frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j \begin{cases} \geq 0, & G^j(R) \leq 0 \\ < 0, & G^j(R) \geq 0 \end{cases}.$$

(ii) Let investors hold the homogeneous belief $F(R)$ and let $G(R)$ be the direction of a perturbation. The more optimistic (pessimistic) the homogeneous belief is, the more (less) investors borrow, i. e.

$$\frac{\delta \tilde{d}_0}{\delta F} \cdot G \begin{cases} \geq 0, & G(R) \leq 0 \\ < 0, & G(R) \geq 0 \end{cases}.$$

The essential insight from Proposition 1.3 is that investment and borrowing are monotonic functions of beliefs. The more optimistic a group of investors is, the more it invests into the asset and the more debt it issues. The opposite holds true for more pessimistic groups. If investors are homogeneous, only borrowing responds to variations in beliefs, while the asset is not traded.

Beliefs and the equilibrium price. Combining the results from Propositions 1.2 and 1.3, we describe how behavioral responses of investors to changes in beliefs $\mathcal{F}$ impact the period-1 equilibrium price $q_1\left(\tilde{a}_0(\mathcal{F}), \tilde{d}_0(\mathcal{F})\right)$ in Proposition 1.4.

[10] In the case of investors holding a homogeneous belief, a perturbation implies a variation of the true distribution $F(R)$.

Proposition 1.4.

(i) Let investors hold heterogeneous beliefs $\mathcal{F}$.

(1) Let further $G^j(R)$ be the direction of a perturbation of type-j investors' belief $F^j(R)$ and beliefs $F^i(R)$ be constant for all $i \neq j$. If the perturbation makes investors of type j more optimistic (pessimistic), the period-1 equilibrium price q_1 is lower (higher), i. e.

$$\frac{\delta q_1}{\delta F^j} \cdot G^j \begin{cases} \leq 0, & G^j(R) \leq 0 \\ > 0, & G^j(R) \geq 0 \end{cases}.$$

(2) Let further $G^j(R) < 0 < G^i(R)$ with $|G^j(R)| = |G^i(R)|$ for all R be the directions of two perturbations that make investors of type j more optimistic and investors of type i more pessimistic by the same magnitude. The behavioral responses to the perturbation with direction $G^j(R)$ have a stronger impact on the period-1 equilibrium price q_1 than those of the perturbation with direction $G^i(R)$, i. e.

$$\left|\frac{\delta q_1}{\delta F^j} \cdot G^j\right| \geq \left|\frac{\delta q_1}{\delta F^i} \cdot G^i\right|.$$

(ii) Let investors hold the homogeneous belief $F(R)$ and $G(R)$ be the direction of a perturbation. If the perturbation makes investors more optimistic (pessimistic), the period-1 equilibrium price q_1 is lower (higher), i. e.

$$\frac{\delta q_1}{\delta F} \cdot G \begin{cases} \leq 0, & G(R) \leq 0 \\ > 0, & G(R) \geq 0 \end{cases}.$$

Proposition 1.4 comprises a fundamental finding that proves pivotal in the derivation of the results below. Part (i) characterizes the relationship of q_1 and heterogeneous beliefs. The more optimistic investors are, the lower the collateral price is in equilibrium. Conversely, if investors hold more pessimistic beliefs, the equilibrium price is higher. This result originates from the two monotonicities we have established in Propositions 1.2 and 1.3: q_1 responds monotonically to period-0 investment and borrowing, which, in turn, are monotonically driven by beliefs.

However, according to statement (2), the equilibrium price responds asymmetrically to symmetric variations of beliefs. Consider the thought experiment of two distinct perturbations, one making investors of type j more optimistic, the other making investors of type i more pessimistic, both to the very same extent. Formally, this is equivalent to decreasing type j's and increasing type i's probability mass for each realization $\hat{R}$ by the same amount. The statement argues that the perturbation to j dominates the perturbation to i. Thus, the equilibrium price turns out to be lower. More precisely, the perturbation to the optimistic type j exerts a downward effect that outweighs the upward effect from the perturbation to the pessimistic type i, resulting in a lower equilibrium price. The asymmetry between optimistic and pessimistic investors' influence on q_1 is the main result of Proposition 1.4.

Key to understand the asymmetry is the collateral constraint. By the two perturbations, type-j investors become more optimistic, willing to invest and borrow more, while type-i investors become more pessimistic, willing to invest less and save more. Importantly, both types have the incentive to invest into the asset as collateral in $t = 1$. In $t = 0$, this incentive amplifies type j's willingness to extend investment, but it counteracts type i's willingness to reduce investment. Accordingly, it induces type j to increase period-0 borrowing by more than type i increases period-0 savings. Therefore, when the constraint is binding in the following period $t = 1$, type-j investors' supply of liquidated claims will initially exceed type-i investors' demand, which can only be equated for a lower equilibrium price q_1.

Part (ii) of Proposition 1.4 states that the former result holds true in the case of a homogeneous belief as well. A lower equilibrium price will arise if the uniform belief is more optimistic, and q_1 will be higher if it is more pessimistic.

Probability of financial distress. While Proposition 1.4 specifies how different types of investors contribute to financial amplification, we now evaluate how heterogeneity affects the overall probability of financial distress. We apply the method proposed by Dávila and Walther (2023) to prove that financial distress is more likely under heterogeneous beliefs. The probability of financial distress is determined by the lowest possible realization of R such that the constraints are slack.

Definition 1.3. *Let* $\hat{R}^*_{het} \equiv \min\left\{\hat{R} \mid \tilde{\eta}^j_1 = 0 \text{ for all } j\right\}$ *and* $\hat{R}^*_{hom} \equiv \min\left\{\hat{R} \mid \tilde{\eta}_1 = 0\right\}$ *be the lowest possible realizations of* R *such that the borrowing constraints are slack in the competitive equilibrium if investors hold heterogeneous beliefs* $\mathcal{F}$ *or the homogeneous belief* F*, respectively.*

Definition 1.3 translates into the mappings $\hat{R} \mapsto q_1\left(\hat{R}\right)$, where q_1 serves as a measure of financial distress, formally written as

$$q_1 \begin{cases} = 1 & \hat{R} \geq \hat{R}^*_{het} \\ < 1 & \hat{R} < \hat{R}^*_{het} \end{cases} \text{or } q_1 \begin{cases} = 1 & \hat{R} \geq \hat{R}^*_{hom} \\ < 1 & \hat{R} < \hat{R}^*_{hom} \end{cases}.$$

Figure 1.1: Mapping from $\hat{R}$ to q_1 in the competitive equilibrium
This figure shows the mapping from $\hat{R}$ to q_1 for the two cases when investors hold the homogeneous belief $F(R)$ or heterogeneous beliefs $\mathcal{F}$, respectively. The solid line refers to the homogeneous case, and the dashed line refers to the heterogeneous case. $\hat{R}^*_{hom}$ and $\hat{R}^*_{het}$ are thresholds as defined in Definition 1.3. The assumptions underlying this simulation are given in section 1.4.4.

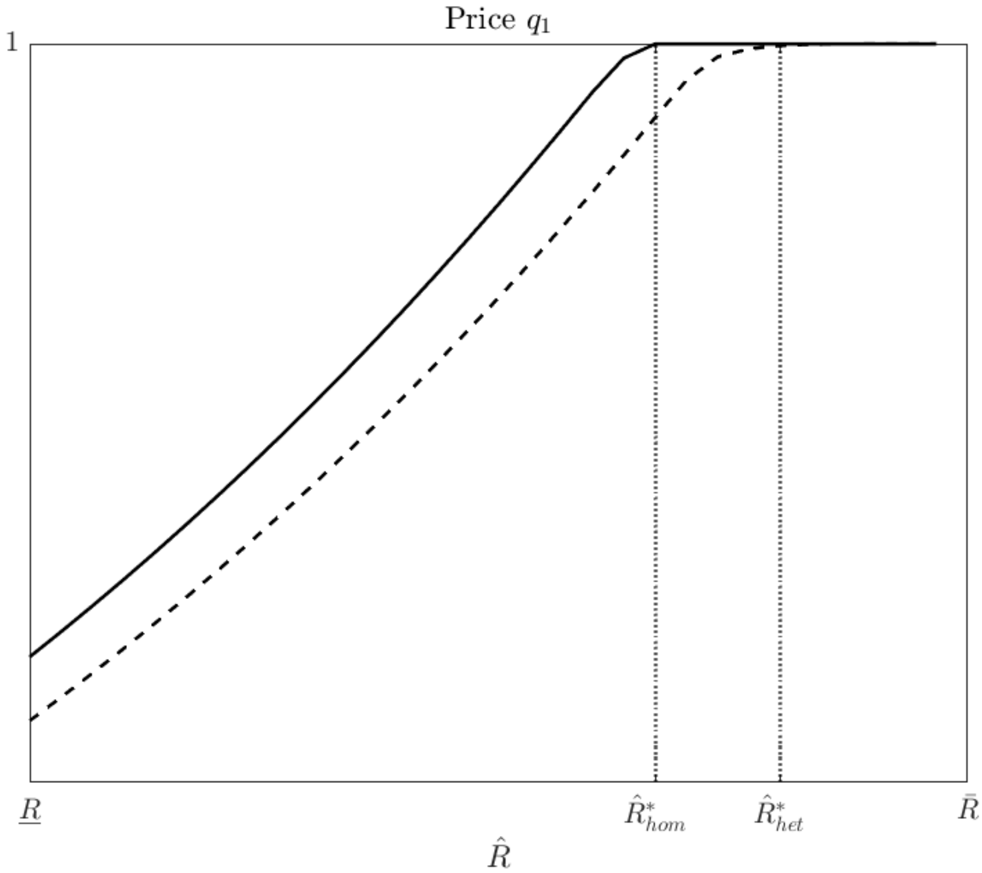


Figure 1.1 portrays an illustration of the two mappings.[11] We show that the the threshold is lower if investors hold a homogeneous belief, compared to a setting of heterogeneous beliefs varying around it.

Theorem 1.1. *Consider two distinct populations with investors holding heterogeneous beliefs $\mathcal{F}$ in one, and the homogeneous belief $F(R)$ in the other. If the homogeneous belief is not more optimistic than any other belief in the heterogeneous case, i. e. $F^j(R) < F(R)$ for all R and at least one j, the probability of financial distress in the competitive equilibrium is higher under heterogeneity than under homogeneity, which is equivalent to*

$$\hat{R}^*_{het} > \hat{R}^*_{hom}.$$

Theorem 1.1 constitutes the first key result of our analysis. In an environment of heterogeneous beliefs, it is more likely that financial distress occurs. In general, it occurs

[11] Figure 1.1 is based on the numerical application provided in section 1.4.4.

whenever the realized return $\hat{R}$ is insufficient so that each investor could comply with her repayment obligations. If investors share a homogeneous belief, each $\hat{R} < \hat{R}^*_{hom}$ will constrain *all* investors. However, if beliefs are heterogeneous, it is enough that $\hat{R}$ is too low for *one* group to make everyone's borrowing constraint binding. In fact, under heterogeneity, the threshold $\hat{R}^*_{het}$ corresponds to the most optimistic type reaching the constraint, as it has built up the highest exposure to low returns.

We find that the most optimistic type is financially distressed even for higher returns than if investors held a homogeneous belief. Consequently, under heterogeneity, financial distress occurs in even more favorable states of the world (as depicted in Figure 1.1) and is hence more likely. It rests on the presumption that the most optimistic belief is sufficiently off the ex post realization. Hence, Theorem 1.1 highlights the role of belief divergences as an additional source of financial distress. As is well known from the literature, a spiral of financial amplification can be initiated by adverse shocks sufficiently strong to drive excessively borrowing agents towards the constraint. Beyond that, we document that the dispersion of beliefs lays the ground for another trigger, namely that some agents' beliefs deviate sufficiently from the true shock distribution.

1.3.4 Discussion

In the previous section, we have shown that belief heterogeneity increases the probability of financial distress and how it affects the equilibrium collateral price. This price, in turn, is the main determinant of the financial friction, as it governs the tightness or slackness of the borrowing limit. Our results jointly allow us to characterize the interaction of the collateral constraint and belief divergence and to specify how different types of agents contribute to financial amplification.

The mechanism emerging from this interaction has two features. The first property is that heterogeneity of beliefs raises the *likelihood* of financial distress relative to the homogeneous benchmark, as stated by Theorem 1.1. The second property refers to the *extent* of financial distress, building upon the differences in individual contributions shown in Proposition 1.4. Principally, during financial distress, optimistic and pessimistic investors drive collateral prices in opposing directions, as the former tend to sell and the latter tend to purchase. However, we find an asymmetry of their contributions, attributing a larger impact to optimistic behavior. Hence, to distinguish the behavior of borrowing constraints in the presence of heterogeneous beliefs from the homogeneous benchmark, we must take into account how beliefs are distributed over the population.

It turns out that the financial friction tends to be more severe under heterogeneity rather than homogeneity. That holds true under the condition that the mean belief coincides with or is more optimistic than the homogeneous belief. Put differently, so long as the belief distribution is symmetric around the homogeneous belief, or skewed towards more optimistic beliefs, heterogeneity exacerbates financial amplification. The reason is that optimistic investors' (negative) contribution more than outweighs pessimistic investors' (positive) contribution.[12]

These results add new insights to the existing literature on financial amplification. It typically presumes rational expectations and establishes mechanisms where financial constraints bind in response to exogenous reductions of aggregate investment or net worth (Bianchi, 2011; Dávila and Korinek, 2018; Jeanne and Korinek, 2020). We extend this approach, and show that belief differences are sufficient to make such constraints binding. We may further quantify how market participants contribute to their tightness on the micro level. In the following section, we turn to the welfare implications of these interactions of heterogeneous beliefs and financial frictions.

1.4 Efficiency analysis

We proceed by exploring the efficiency properties of our baseline economy. Given that the borrowing constraint is price-dependent, investors are subject to a pecuniary externality, as they do not internalize how their decisions affect other agents' individual welfare. We characterize these uninternalized welfare effects and their interplay with belief heterogeneity in the following section. Subsequently, we derive a constrained-efficient allocation as a welfare benchmark to contrast the competitive equilibrium and develop optimal corrective policies. Lastly, we quantify the welfare impact of such policy interventions numerically.

1.4.1 Uninternalized welfare effects

The collateral price q_1 links individual choices and utilities across investors in two ways. First, it changes the value of investors' budgets in $t = 1$. Second, it determines the tightness of the borrowing constraints. Investors do not internalize these price effects. We use the terminology of Dávila and Korinek (2018) of *distributive* and *collateral* externalities.

[12] Belief heterogeneity may mitigate financial amplification compared to the homogeneous benchmark, on the contrary, provided that the distribution is sufficiently skewed towards more pessimistic beliefs. The skewness would have to be large enough to reverse the relation of optimistic and pessimistic investors' influence on the collateral price. However, we argue that the presumption of a symmetric distribution is likely to prevail in financial markets. A range of studies provides both empirical and theoretical evidence that financial market participants' beliefs are distributed symmetrically, if not (close to) normally (Söderlind, 2009; Cvitanic and Malamud, 2011; Atmaz, 2014; Atmaz and Basak, 2016). Under this premise, extreme beliefs are either sufficiently improbable or counteracted by an equiprobable set of contrasting beliefs.

Definition 1.4. *The uninternalized effects of changes in any type j's aggregate state variables* $\left\{\tilde{a}_0^j, \tilde{d}_0^j\right\}$ *on any i's individual welfare in periods* $t = 1, 2$ *can be written as*

$$\frac{\partial V_1^i}{\partial \tilde{a}_0^j} = \tilde{\lambda}_1^i D^i_{\tilde{a}_0^j} + \tilde{\eta}_1^i C^i_{\tilde{a}_0^j}$$
$$\frac{\partial V_1^i}{\partial \tilde{d}_0^j} = \tilde{\lambda}_1^i D^i_{\tilde{d}_0^j} + \eta_1^i C^i_{\tilde{d}_0^j},$$

where $D^i_{\tilde{a}_0^j}$ *and* $D^i_{\tilde{d}_0^j}$ *are referred to as distributive externalities, and* $C^i_{\tilde{a}_0^j}$ *and* $C^i_{\tilde{d}_0^j}$ *are referred to as collateral externalities.*

(i) If investors hold heterogeneous beliefs $\mathcal{F}$*, distributive externalities are given by*

$$D^i_{\tilde{a}_0^j} = \frac{\partial q_1}{\partial \tilde{a}_0^j} \tilde{l}_1^i$$
$$D^i_{\tilde{d}_0^j} = \frac{\partial q_1}{\partial \tilde{d}_0^j} \tilde{l}_1^i,$$

and collateral externalities are given by

$$C^i_{\tilde{a}_0^j} = \phi \frac{\partial q_1}{\partial \tilde{a}_0^j} \left(\tilde{a}_0^i - \tilde{l}_1^i\right)$$
$$C^i_{\tilde{d}_0^j} = \phi \frac{\partial q_1}{\partial \tilde{d}_0^j} \left(\tilde{a}_0^i - \tilde{l}_1^i\right).$$

(ii) If investors hold the homogeneous belief $F(R)$*, distributive externalities are zero, and collateral externalities are given by*

$$C_{\tilde{a}_0} = \phi \frac{\partial q_1}{\partial \tilde{a}_0} \bar{a}$$
$$C_{\tilde{d}_0} = \phi \frac{\partial q_1}{\partial \tilde{d}_0} \bar{a}.$$

Distributive effects describe the price-induced redistribution between trading agents, altering their marginal rates of substitution. Collateral effects measure the price-induced change in an agent's capacity to borrow. In an environment of heterogeneous beliefs, it turns out that, the more optimistic investors are, the more likely it is that they will sell claims on the asset in $t = 1$ ($\tilde{l}_1^j \geq 0$). Accordingly, more pessimistic investors will more probably enter the market as buyers ($\tilde{l}_1^j < 0$). The reason is that a group's exposure to adverse states, reflected by its position $\tilde{a}_0^j$, is a monotonic function of beliefs (see Proposition 1.3). We use this fact, as well as Proposition 1.2, to characterize the direction of distributive and collateral externalities.

Proposition 1.5.

(i) If investors hold heterogeneous beliefs $\mathcal{F}$, distributive externalities are non-positive for period-1 sellers, i. e. $D^i_{\tilde{a}^j_0} \leq 0$ *and* $D^i_{\tilde{d}^j_0} \leq 0$ *if* $\tilde{l}^i_1 \geq 0$*, and non-negative for period-1 buyers, i. e.* $D^i_{\tilde{a}^j_0} \geq 0$ *and* $D^i_{\tilde{d}^j_0} \geq 0$ *if* $\tilde{l}^i_1 \leq 0$*. If investors hold the homogeneous belief* $F(R)$*, distributive externalities are zero.*

(ii) Collateral externalities have are non-positive for any type i and irrespective of beliefs, i. e. $C^i_{\tilde{a}^j_0} \leq 0$ *and* $C^i_{\tilde{d}^j_0} \leq 0$ *for each i.*

Distributive externalities are signed reflective of the fact that a decline of the equilibrium price q_1 benefits buyers and harms sellers in $t = 1$. Collateral externalities, in turn, are unambiguously adverse to each type of agent, as more investment and borrowing reduce the collateral value, cutting any investor's borrowing capacity. Combining Proposition 1.5 with our results from section 1.3 allows us to evaluate the welfare implications of the interaction mechanism between beliefs and the equilibrium price q_1.

Proposition 1.6.

(i) Let investors hold heterogeneous beliefs $\mathcal{F}$.

(1) Let further $G^j(R)$ be the direction of a perturbation of type-j investors' belief $F^j(R)$ and beliefs $F^i(R)$ be constant for all $i \neq j$. If the perturbation makes investors of type j more optimistic (pessimistic), uninternalized welfare effects of any type-i investor are larger (smaller) in absolute value, i. e., for each $i \neq j$ and $x \in \{a, d\}$,

$$\left| \frac{\delta D^i_{\tilde{x}^j_0}}{\delta F^j} \cdot G^j \right| \begin{cases} \geq 0, & G^j(R) \leq 0 \\ \leq 0, & G^j(R) \geq 0 \end{cases} \quad \text{and} \quad \frac{\delta C^i_{\tilde{x}^j_0}}{\delta F^j} \cdot G^j \begin{cases} \leq 0, & G^j(R) \leq 0 \\ \geq 0, & G^j(R) \geq 0 \end{cases}.$$

(2) Let further $G^j(R) < 0 < G^k(R)$ with $|G^j(R)| = |G^k(R)|$ for all R be the directions of two perturbations that make investors of type j more optimistic, and investors of type k more pessimistic by the same magnitude. Uninternalized welfare effects under the perturbation with direction $G^j(R)$ are stronger than those under the perturbation with direction $G^k(R)$, i. e., for each $i \neq j, k$ and $x \in \{a, d\}$,

$$\left| \frac{\delta D^i_{\tilde{x}^j_0}}{\delta F^j} \cdot G^j \right| \geq \left| \frac{\delta D^i_{\tilde{x}^k_0}}{\delta F^k} \cdot G^k \right| \quad \text{and} \quad \left| \frac{\delta C^i_{\tilde{x}^j_0}}{\delta F^j} \cdot G^j \right| \geq \left| \frac{\delta C^i_{\tilde{x}^k_0}}{\delta F^k} \cdot G^k \right|.$$

(ii) *Let investors hold the homogeneous belief $F(R)$ and $G(R)$ be the direction of a perturbation. If the perturbation makes investors more optimistic (pessimistic), collateral externalities are larger (smaller) in absolute value, i. e., for $x \in \{a, d\}$*

$$\frac{\delta C_{\tilde{x}_0}}{\delta F} \cdot G \begin{cases} \leq 0, & G(R) \leq 0 \\ \geq 0, & G(R) \geq 0 \end{cases}.$$

Proposition 1.6 describes the welfare effects associated with the interaction of beliefs and the equilibrium price q_1. It states that more optimistic types, exerting downward pressure on the collateral price due to large investment and borrowing, impose more intense negative distributive externalities on sellers ($\tilde{l}_1^i > 0$) and more intense positive ones on buyers ($\tilde{l}_1^i < 0$). In contrast, more pessimistic types' choices have an increasing impact on the collateral price, by this causing the reverse response of distributive externalities.

By the same logic, collateral externalities, being non-positive in general, turn out to be more or less pronounced in the case of more optimistic or pessimistic groups, respectively. This result holds true analogously in the homogeneous case.

Importantly, the asymmetry between optimistic and pessimistic investors' influence on q_1 translates into asymmetric welfare effects, as we formalize in statement (2) of part (i). Since the price responds more markedly to optimistic than to pessimistic behavior, the former further dominates in welfare terms. If the two groups j's and k's beliefs are made more optimistic and pessimistic to the same extent, respectively, any further type i's group-wide welfare losses from j's high investment and borrowing exceed the gains from k's precaution.

1.4.2 Constrained efficiency

Investors do not internalize the distributive or collateral side effects of their behavior which materialize through the collateral price q_1. These externalities render the competitive equilibrium allocation inefficient. To evaluate its welfare properties, we employ the concept of constrained efficiency.

The constrained-efficient allocation solves the problem of a constrained social planner who chooses investment and borrowing in period $t = 0$ while leaving all later choices to private agents. Specifically, she maximizes social welfare subject to all resource constraints, technological constraints, market clearing conditions, and financial frictions, respecting the competitive equilibrium price formation (see equation (1.6)).

Social welfare is evaluated by aggregating investors' expected lifetime utilities, and applying arbitrary Pareto weights $\omega = \{\omega^j\}_{j \in \{1,\ldots,J\}}$. A relevant question in this setting is the planner's belief (Blume et al., 2018; Dávila, 2023; Kim and Kim, 2021). If we assigned a specific belief to the planner, she would naturally disagree with investors upon their beliefs. Abstracting from this trivial motive of correction, we aim at isolating ex ante corrective policies related to the financial friction, and, thus, make the following assumption.

Assumption 1.2. *The constrained social planner has no superior information and respects individual beliefs for each type j.*

We solve the following social planner problem.

$$\max_{\left\{\tilde{c}_0^j,\tilde{a}_0^j,\tilde{d}_0^j\right\}_{j\in\{1,\dots J\}}} \sum_{j=1}^{J} \omega^j s^j \left[u\left(\tilde{c}_0^j\right) + E^j\left[V_1^j\left(\tilde{a}_0^j, \tilde{d}_0^j|\tilde{a}_0, \tilde{d}_0\right)\right]\right] \quad \text{s.t.}$$
$$(\tilde{\lambda}_0) \quad \sum_{j=1}^{J} s^j \tilde{c}_0^j = \sum_{j=1}^{J} s^j \left[e + \tilde{d}_0^j\right] \tag{1.12}$$
$$(\tilde{\psi}) \quad \sum_{j=1}^{J} s^j \tilde{a}_0^j = \bar{a}.$$

With the first order conditions for consumption, $\tilde{\lambda}_0 = \omega^j u'\left(\tilde{c}_0^j\right)$, the planner's optimality conditions for each j are

$$0 = E^j\left[Ru'\left(\tilde{c}_1^j\right) + u'\left(\tilde{c}_2^j\right) + \tilde{\eta}_1^j \phi q_1\right] - \frac{\tilde{\psi}}{\omega^j} + \sum_{i=1}^{J} \frac{\omega^i}{\omega^j}\frac{s^i}{s^j} E^i\left[D^i_{\tilde{a}_0^j} u'\left(\tilde{c}_1^i\right) + \tilde{\eta}_1^i C^i_{\tilde{a}_0^j}\right] \tag{1.13}$$
$$0 = u'\left(\tilde{c}_0^j\right) - E^j\left[u'\left(\tilde{c}_1^j\right)\right] + \sum_{i=1}^{J} \frac{\omega^i}{\omega^j}\frac{s^i}{s^j} E^i\left[D^i_{\tilde{d}_0^j} u'\left(\tilde{c}_1^i\right) + \tilde{\eta}_1^i C^i_{\tilde{d}_0^j}\right]. \tag{1.14}$$

We can now define the constrained-efficient allocation.

Definition 1.5. *The period-0 allocation $\left\{\tilde{c}_0^j, \tilde{a}_0^j, \tilde{d}_0^j\right\}_{j\in\{1,\dots J\}}$ is constrained-efficient if and only if there are shadow prices $\tilde{\lambda}_0$, $\tilde{\psi}$, $\left\{\tilde{\eta}_1^j\right\}_{j\in\{1,\dots J\}}$ and a set of Pareto weights $\{\omega^j\}_{j\in\{1,\dots J\}}$ such that it satisfies the price relation* (1.6) *for each j, the market clearing condition* (1.10)*, and the resource constraint* (1.12)*, as well as equations* (1.13)*,* (1.14)*, and $\tilde{\lambda}_0 = \omega^j u'\left(\tilde{c}_0^j\right)$ for each j, given population shares s and beliefs $\mathcal{F}$.*

Equations (1.13) and (1.14) differ from the competitive equilibrium conditions (1.8) and (1.9) by the aggregate terms of externalities on the right-hand side. They indicate formally that the competitive allocation is not constrained-efficient, whereas the social planner takes distributive and collateral externalities into account. Furthermore, she accounts for market clearing in $t = 0$, represented by the multiplier $\tilde{\psi}$.

1.4.3 Optimal corrective policies

The constrained-efficient allocation can be achieved in a decentralized market using a set of adequate policy instruments. We start out by characterizing optimal macroprudential taxes under both heterogeneous and homogeneous beliefs. We contrast a system of non-linear taxes under heterogeneity with a linear tax. The latter allows us to quantify differences in the efficiency-enhancing effects of our approach and existing policy proposals in the following section.

Decentralization. To decentralize the constrained-efficient allocation, we provide the social planner with access to macroprudential taxes, available to manipulate agents' investment and borrowing decisions, and lump-sup transfers. These instruments satisfy the conditions stated in the following proposition.

Proposition 1.7.

(i) If investors hold heterogeneous beliefs $\mathcal{F}$, the social planner can implement the constrained-efficient allocation by taxing investment and borrowing, satisfying

$$\tau_a^j = \operatorname{sgn}\left(\bar{a} - \tilde{a}_0^j\right)\left(s^j q_0 \tilde{\lambda}_0\right)^{-1} \sum_{i=1}^{J} \omega^i s^i E^i \left[D^i_{\tilde{a}_0^j} u'\left(\tilde{c}_1^i\right) + \tilde{\eta}_1^i C^i_{\tilde{a}_0^j}\right] \tag{1.15}$$

$$\tau_d^j = -\operatorname{sgn}\left(\tilde{d}_0^j\right)\left(s^j \tilde{\lambda}_0\right)^{-1} \sum_{i=1}^{J} \omega^i s^i E^i \left[D^i_{\tilde{d}_0^j} u'\left(\tilde{c}_1^i\right) + \tilde{\eta}_1^i C^i_{\tilde{d}_0^j}\right] \tag{1.16}$$

for each j and rebating revenues through type-specific lump-sum transfers $T^j = \tau_a^j \operatorname{sgn}\left(\bar{a} - \tilde{a}_0^j\right) q_0 \left(\bar{a} - \tilde{a}_0^j\right) + \tau_d^j \operatorname{sgn}\left(\tilde{d}_0^j\right) \tilde{d}_0^j$.[13]

(ii) If investors hold the homogeneous belief $F(R)$, the social planner can implement the constrained-efficient allocation by taxing borrowing, satisfying

$$\tau_d = -\tilde{\lambda}_0^{-1} E\left[\tilde{\eta}_1 C_{\tilde{d}_0}\right] \tag{1.17}$$

and rebating revenues through lump-sum transfers $T = \tau_d \tilde{d}_0$, while the tax on investment is arbitrary.

In the heterogeneous case, optimal macroprudential taxes are characterized by a range of sufficient statistics related to distributive and collateral externalities, aggregated in the squared brackets in equations (1.15) and (1.16).[14]

[13] We use a sign operator for an easier interpretation of taxes and subsidies, given the fact that investors can take short and long positions in the asset as well as borrow and save.

[14] For a more detailed description of sufficient statistics, see Dávila and Korinek (2018).

Three components determine distributive effects. First, when price movements induce a redistribution of funds between period-1 buyers and sellers, this affects their marginal rates of substitution. Second, price movements themselves measure the intensity of redistribution. Third, the direction of redistribution depends on whether an investor is a seller ($\tilde{l}_1^j > 0$) or a buyer ($\tilde{l}_1^j < 0$) in $t = 1$. The latter two components are captured by the distributive externalities $D^i_{\tilde{a}_0^j}$ and $D^i_{\tilde{d}_0^j}$, given in Definition 1.4.

Collateral effects are driven by another three components. First, the multiplier $\tilde{\eta}_1^j$ measures the welfare gain (loss) when the constraint is relaxed (tightened) by one unit. Second, price movements describe the change in an investor's borrowing capacity per unit of collateral, whose total magnitude available matters third. The last two elements are incorporated in the collateral externalities $C^i_{\tilde{a}_0^j}$ and $C^i_{\tilde{d}_0^j}$ from Definition 1.4.

If, however, investors hold the homogeneous and rational belief, these sufficient statistics turn out to be simpler. Since investors do not trade the asset under homogeneity, the social planner cannot manipulate investment decisions. The resulting tax on investment is arbitrary. Moreover, for the very same reason, distributive externalities are zero, rendering the tax on borrowing responsive solely to collateral externalities (see equation (1.17)).

Notably, the instruments derived in Proposition 1.7 may well be subsidies instead of taxes, depending on the extent of externalities induced by type j and its specific choices of investment and borrowing. Taxes/subsidies turn out to be zero only provided that *all* investors expect their collateral constraints to be slack. To put it another way, it suffices that one group of investors expects to be constrained to let taxes/subsidies take on either sign for the entire population. We will return to the signing of policy instruments in the next section.

Incentive compatibility. In an environment of heterogeneous agents, whose type is their private information, corrective policies may not be incentive-compatible. The instruments we have derived in Proposition 1.7 are type-specific, raising the question of knowledge required by the social planner to impose taxes in an incentive-compatible way.

Importantly, the optimal non-linear taxes in equations (1.15) and (1.16) incorporate no more than publicly known objects. To be precise, to set group-specific taxes, the social planner must be informed about the set of beliefs $\mathcal{F}$ in the economy, each type's respective population share s^j, as well as investment and borrowing choices $\tilde{a}_0$ and $\tilde{d}_0$, which are publicly observable in the market. Since the latter are monotonic functions of beliefs, as we have shown in Proposition 1.3, they perfectly reveal any investor's belief.

Therefore, the constrained-efficient allocation can be implemented by means of the following system of non-linear macroprudential taxes.

Theorem 1.2. *If investors hold heterogeneous beliefs $\mathcal{F}$, the social planner can implement* *the constrained-efficient allocation by taxing investment and borrowing according to the tax system* $(\tilde{\tau}_a, \tilde{\tau}_d)$*, satisfying*

$$\tilde{\tau}_a: \quad \tilde{a}_0^k \mapsto \tilde{\tau}_a(\tilde{a}_0^k) \ s.t. \ \tilde{\tau}_a(\tilde{a}_0^k) = \begin{cases} RHS \ of \ (1.15) & if \ \tilde{a}_0^k = \tilde{a}_0^j \ for \ any \ j \ with \ \tilde{a}_0^j \in \tilde{a}_0 \\ \infty & if \ \tilde{a}_0^k \notin \tilde{a}_0 \end{cases} \tag{1.18}$$

$$\tilde{\tau}_d: \quad \tilde{d}_0^k \mapsto \tilde{\tau}_d(\tilde{d}_0^k) \ s.t. \ \tilde{\tau}_d(\tilde{d}_0^k) = \begin{cases} RHS \ of \ (1.16) & if \ \tilde{d}_0^k = \tilde{d}_0^j \ for \ any \ j \ with \ \tilde{d}_0^j \in \tilde{d}_0 \\ \infty & if \ \tilde{d}_0^k \notin \tilde{d}_0, \end{cases} \tag{1.19}$$

and corresponding lump-sum transfers.

The essential point of Theorem 1.2 is that the social planner does not rely on knowledge of individual beliefs. The peculiar nature of our optimal macroprudential taxes ensures that the constrained-efficient allocation is indeed decentralizable, even in a setting of heterogeneous beliefs.

Our results on optimal corrective policies give rise to several issues linked to the welfare implications of the interplay between belief heterogeneity and the financial friction. First, analyzing the responses of group-specific taxes/subsidies to variations of beliefs is informative on different types' contributions to changes in social welfare. Second, we seek to compare the efficiency properties of our economy under homogeneity and heterogeneity of beliefs. Third, it is enlightening to evaluate how the probability of financial distress is altered through a planner intervention of the kind sketched above. Moreover, we aim at quantifying the welfare impact of the non-linear tax instruments we propose in contrast to a linear macroprudential tax on borrowing. The latter is an instrument which has gained much attention in the literature (Bianchi, 2011; Dávila and Korinek, 2018; Jeanne and Korinek, 2019, 2020). In our model, it corresponds to equation (1.17), being a tax on borrowing calibrated to the case of homogeneous and rational expectations.

Examining these questions is analytically intractable. The clear signing of tax instruments depends on the specific belief distribution, which we have kept general thus far. To gain insights into the welfare implications of our policy proposals, we provide a numerical application of our model in the following.

1.4.4 Numerical application

The numerical analysis requires a simplified version of our model. In this section, we first describe the simplifications applied to make the baseline model numerically tractable, and briefly characterize the resulting equilibrium allocations, prices, and, importantly, optimal corrective policies for different levels of belief heterogeneity. Subsequently, we quantify the welfare implications of such policies. The final exercise of this section is an assessment of how these interventions impact the probability of financial distress.

Table 1.1: Parametrization
This table provides a summary of model parameter values chosen.

Parameter		Value
Margin requirement	ϕ	0.35
Good state	R^g	2
Bad state	R^b	0
Initial endowment of consumption goods	e	1
Initial asset endowment	$\bar{a}$	2
Risk aversion	A	0.5
Heterogeneity step	μ	0.025
Initial belief	π^g	0.5

Simplifications. Suppose the economy is populated by two groups of investors, called optimists and pessimists, indexed by o and p. We let both groups be of equal mass, i. e. $s^o = s^p = 1$, and differ in terms of their return expectations, i. e. $E^o[R] > E^p[R]$. Furthermore, there are only two states of the world. To be precise, R may take on either a *good* or a *bad* value, denoted by $R^g > R^b$.

We choose parameters in line with the assumptions underlying our theoretical analysis, simulating equilibria with significant trade volumes and binding financial constraints. Table 1.1 summarizes the parameter values chosen in the application.

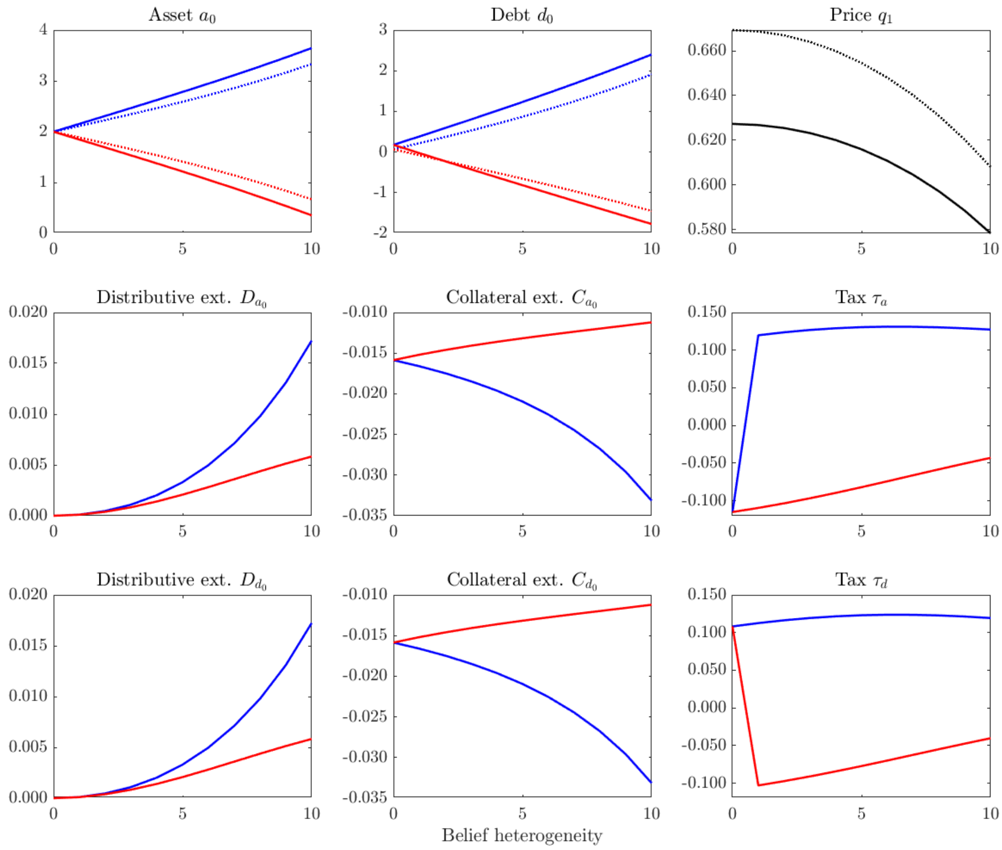
The parameter ϕ, capturing the margin requirement for borrowing, is selected following Mendoza (2002) and Bianchi (2011), who suggest that debt is required to not exceed a fraction of 30 to 40 percent of tradable assets. Averaging these values, we set $\phi = 0.35$. The two states R^g and R^b are chosen with the aim to make trading incentives strong enough, which, in turn, ensures a significant trade volume. This condition is met for $R^g = 2$ and $R^b = 0$. For the same argument, we set initial endowments of consumption goods e and assets $\bar{a}$ to $e = 1$ and $\bar{a} = 2$ and choose a moderate degree of risk aversion $A = 0.5$.

Heterogeneity itself is defined as the linear distance between the probabilities that the two types assign to the good state, i. e. $\pi^{j,g} = 1 - \pi^{j,b}$. We increase this distance symmetrically by N steps of size $\mu = 0.025$ (see Simsek (2013) for comparison). The multiples N thus serve as a measure of belief heterogeneity. The benchmark case is a population with homogeneous beliefs, where $\pi^{o,g} = \pi^{p,g} \equiv \pi^g$, which we set to $\pi^g = 0.5$. Finally, the two types' beliefs at any given level of heterogeneity N are given by

$$E^o[R] = (\pi^g + N\mu)R^g + (\pi^b - N\mu)R^b$$
$$E^p[R] = (\pi^g - N\mu)R^g + (\pi^b + N\mu)R^b.$$

Notably, we let the social planner apply Pareto weights ω such that the constrained-

Figure 1.2: Equilibrium allocations, prices, and optimal corrective policies
The three upper panels show period-0 choices of investment and borrowing as well as the period-1 asset price. The three middle panels show optimal taxes on investment and aggregate distributive and collateral externalities therein. The three middle panels show optimal taxes on borrowing and aggregate distributive and collateral externalities therein. The blue and red lines refer to the optimistic and the pessimistic type, respectively. Solid lines refer to variables from the competitive equilibrium, while dotted lines refer to the constrained-efficient equilibrium. Each number on the x-axis relates to the N-th heterogeneity step, where $N = 0$ stands for the benchmark case of homogeneous beliefs.



efficient allocation replicates the unconstrained competitive allocation, i. e. when the collateral constraints are slack. This choice ensures that the simulated corrective interventions by the planner are solely related to inefficiencies from the financial friction, but not to differences in the aggregation of social welfare.

Allocations, prices, and corrective policies. Figure 1.2 displays the responses of key variables to different levels of heterogeneity. Specifically, it shows the equilibrium values of period-0 investment and borrowing, the period-1 price q_1 – the main determinant of the collateral constraint – as well as taxes and the externalities therein. The two beliefs diverge increasingly the further one follows the x-axis. The blue and red lines refer to the optimists and pessimists, respectively. Solid lines refer to variables from the competitive equilibrium, while dotted lines refer to the constrained-efficient equilibrium.

The top-left and top-central panels illustrate the monotonicity of period-0 investment and borrowing in beliefs. Starting from a no-trade equilibrium under homogeneous beliefs, where investors keep their initial asset position constant, investment and borrowing increase (decrease) the more optimistic (pessimistic) they become. Contrasting the competitive allocation, the social planner induces agents to trade, borrow, and save less. Importantly, the planner reduces optimists' borrowing by more than pessimists' saving, reflecting the asymmetry between optimistic and pessimistic types' contributions to financial distress, formalized in Proposition 1.4.

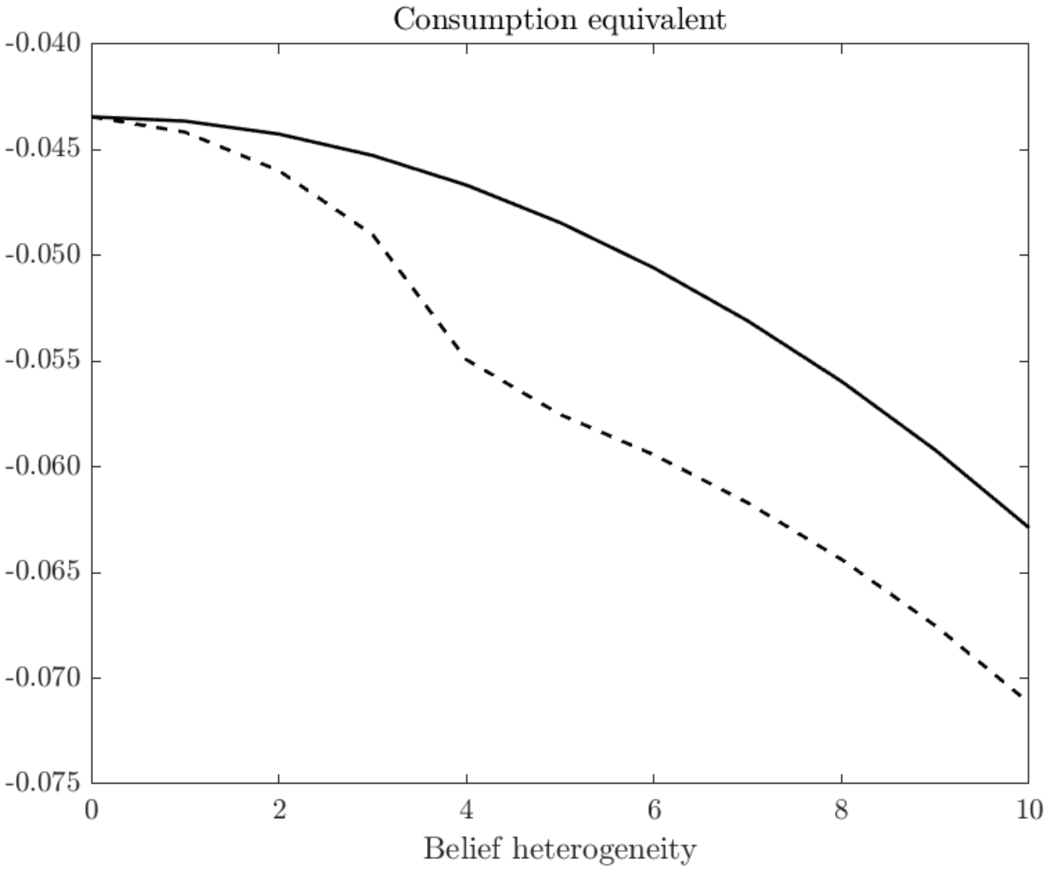
In the top-right panel, this asymmetry becomes evident in the response of the equilibrium price q_1 to increasing belief heterogeneity. Given that the influence of optimistic behavior is dominant, the equilibrium price declines even though we have not altered the economy's mean belief, but made the two types more heterogeneous in a symmetric manner. The fact that the equilibrium price q_1 is constantly lower under heterogeneity than under homogeneity further implies that financial distress is aggravated by belief disagreements. The social planner improves on the competitive allocation by sustaining a higher price, alleviating the tightness of the financial friction.

The panels in the second row of Figure 1.2 depict the aggregate distributive and collateral externalities associated with each type's investment and the corresponding corrective policies, formalized in equation (1.15). To achieve constrained efficiency, the planner taxes investment by optimists ($\tau_a^o > 0$), and subsidizes asset purchases by pessimists ($\tau_a^p < 0$). The interplay of aggregate distributive and collateral externalities determine the signs of the instruments. The tax on optimists' investment is driven by negative collateral externalities clearly outweighing positive distributive externalities. The latter arise because pessimists, buying claims in $t = 1$, benefit from the price decline induced by optimists' behavior. However, as the collateral price continues falling with increasing heterogeneity, optimists pass over more intense collateral externalities to pessimists. Pessimists, in contrast, are subsidized because their cautious investment decisions tend to mitigate the price decline, benefiting optimists' budget in $t = 1$, and reducing collateral externalities. Since they behave with more precaution the more pessimistic they become, the social planner is less inclined to correct their behavior, and the subsidy reverts to zero.

The lower panels of Figure 1.2 refer to aggregate externalities associated with borrowing and saving and the respective policy instruments, captured by equation (1.16). By the same mechanisms as for the correction of investment, borrowing by optimists is increasingly taxed ($\tau_d^o > 0$), and borrowing by pessimists is subsidized ($\tau_d^p < 0$).[15] If the two types of investors hold the homogeneous belief, their borrowing is slightly taxed.

[15] Aggregate distributive and collateral externalities from borrowing turn out to be equal to those from investment in this example due to our assumption $R^b = 0$. In this case, price effects are identical, and so are type-specific externalities (see Definition 1.4).

Figure 1.3: Welfare effects of linear and non-linear corrective taxes
This figure shows the consumption equivalents of two types of allocations relative to the unconstrained competitive allocation. The solid line refers to constrained-efficient allocations, which are implemented by means of the system of non-linear taxes proposed in Theorem 1.2. The dotted line refers to allocations implemented by means of the system of linear taxes proposed in part (*ii*) of Proposition 1.7. Each number on the x-axis relates to the N-th heterogeneity step, where $N = 0$ stands for the benchmark case of homogeneous beliefs.



Welfare effects. Thus far, we have qualified both the direction and the extent of corrective taxes. In the following, we turn to the normative question of how the macroprudential correction translates into social welfare. We are particularly interested in measuring welfare gains from the non-linear tax policy, addressing individual contributions to financial distress, as opposed to a linear tax system, which is the most frequently proposed instrument in the literature on pecuniary externalities and prudential policy responses, (Bianchi, 2011; Dávila and Korinek, 2018; Jeanne and Korinek, 2019, 2020). This literature typically presumes rational expectations.

In our model, this policy corresponds to the system of linear corrective taxes in the case of homogeneous beliefs (see part (*ii*) of Proposition 1.7). This is when investors feature rational expectations, and the social planner optimally taxes borrowing, while any correction of investment decisions is ineffective. Figure 1.3 displays the welfare effects of this policy in comparison to the non-linear tax system.

We employ consumption equivalents relative to the unconstrained competitive allocation, which is when no policy intervention is required, as an ex ante social welfare measure. In Figure 1.3, the solid line depicts consumption equivalents of allocations with non-linear corrective taxes, while the dotted line refers to allocations with linear corrective taxes. Each point on the x-axis indicates a specific belief distribution, with beliefs becoming increasingly heterogeneous along the axis.

We find significant efficiency gains of non-linear over linear macroprudential taxes. The planner's intervention contains welfare losses at a level of about four to six percent relative to the unconstrained economy. However, if linear taxes are applied to a heterogeneous population, welfare is well below. As a linear policy cannot address individual contributions to financial distress, the corresponding allocations result in welfare losses which are by up to 14 percent larger than compared to allocations under a non-linear policy.

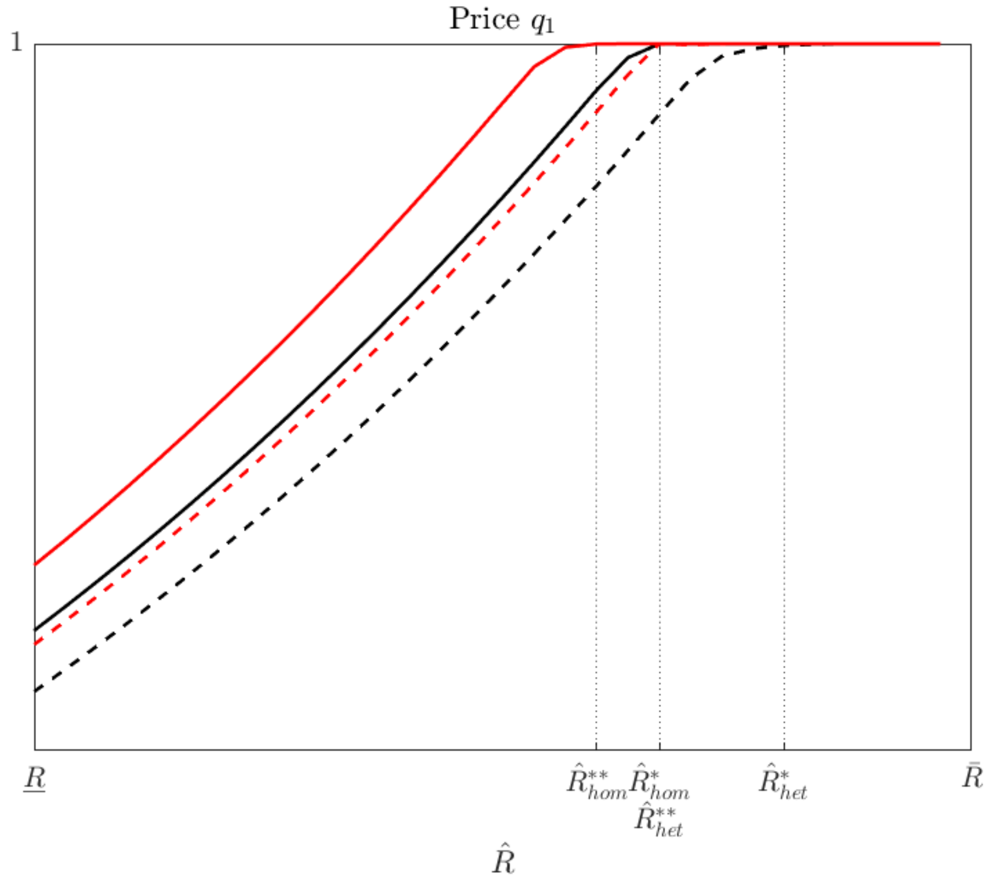
Probability of financial distress. The last numerical exercise we provide is related to the above evaluation how probable financial distress is in the competitive equilibrium. We have found that belief disagreements across investors do indeed raise the probability that financial distress occurs, relative to the case of rational and homogeneous beliefs. We repeat the simulation from above, but further account for the constrained-efficient allocation. To that end, we first define the lowest possible realization of R such that collateral constraints in the constrained-efficient allocation are slack.

Definition 1.6. *Let $\hat{R}^{**}_{het} \equiv \min\left\{\hat{R} \mid \tilde{\eta}^j_1 = 0 \text{ for all } j\right\}$ and $\hat{R}^{**}_{hom} \equiv \min\left\{\hat{R} \mid \tilde{\eta}_1 = 0\right\}$ be the lowest possible realizations of R such that the borrowing constraints are slack in the constrained-efficient equilibrium if investors hold heterogeneous beliefs $\mathcal{F}$ or the homogeneous belief F, respectively.*

Figure 1.4 illustrates the mapping from the realization $\hat{R}$ to q_1 for both the competitive (black lines) and the constrained-efficient equilibrium (red lines). The probability of financial distress is indeed lower under constrained efficiency than in the competitive equilibrium. By manipulating investors' behavior through non-linear taxes, the social planner manages to reduce the thresholds of $\hat{R}$, implying that financial distress in the constrained-efficient equilibrium would only arise in markedly more unfavorable states. Our previous finding that financial distress is generally less likely under the homogeneous belief than under heterogeneity is further robust to the planner intervention.

Figure 1.4: Mapping from $\hat{R}$ to q_1 in the constrained-efficient equilibrium

This figure shows the mapping from $\hat{R}$ to q_1 for the two cases when investors hold the homogeneous belief $F(R)$ or heterogeneous beliefs $\mathcal{F}$, respectively. Solid lines refer to the homogeneous case, and dashed lines refer to the heterogeneous case. Black lines refer to the competitive equilibrium, and red lines refer to the constrained-efficient equilibrium. $\hat{R}^*_{hom}$, $\hat{R}^*_{het}$, $\hat{R}^{**}_{hom}$, and $\hat{R}^{**}_{het}$ are thresholds as defined in Definitions 1.3 and 1.6.



1.5 Conclusion

This chapter presents a theoretical framework to study the belief channel of financial distress. We build on a model incorporating financial frictions, and enrich it by the heterogeneity of beliefs across economic agents. This framework allows us to characterize individual contributions to financial distress, which is the basis for the subsequent analysis. We employ the model to analyze the competitive equilibrium, its sensitivity to changes in the underlying set of beliefs, as well as its efficiency properties. We derive optimal corrective policies, which are furthermore quantified in a numerical application.

The main result is that belief disagreements increase the likelihood and the extent of financial distress. Specifically, crises occur under less severe macroeconomic shocks, and the associated loss of efficiency is larger than in an economy populated by homogeneous individuals. This finding rests upon the fact that economic agents contribute to financial distress asymmetrically, with optimistic agents making larger contributions than pessimistic agents. That has notable implications for macroprudential policy. We show that, while corrective policy interventions are generally efficiency-enhancing, type-specific policies generate additional efficiency gains. Against this background, we propose a system of non-linear, i. e. type-specific, macroprudential taxes. This policy outperforms linear taxes, which are typically proposed in the literature, in reducing indebtedness and stabilizing collateral prices.

These results add to the literature on financial crises in several ways. We characterize explicitly how financial market participants contribute to distress states. Moreover, in our setting, financial constraints may be binding through ex ante return expectations sufficiently off the ex post realization. This differs from former studies, focusing on financial distress in response to aggregate shocks to investment or net worth. Hence, our framework formalizes a further source of financial distress. Ultimately, our policy proposal improves on linear macroprudential taxes in an economy featuring heterogeneity of beliefs. The latter point is especially relevant when studying optimal financial regulation in booms and busts, which typically go along with high belief divergence and fluctuations.

Our work lays the ground for further research. Whereas we study optimal ex ante policies in a prudential sense, it may be worthwhile examining optimal ex post policies, such as central bank liquidity injections, under belief heterogeneity. In addition, several types of financial frictions are considered in the literature on prudential policies. The collateral constraints used in this chapter link debt issuance to market-valued collateral. However, pecuniary externalities and corrective policies have further been studied in environments with flow constraints, relating to household income or firm cash flows. Their interaction with belief disagreements must still be examined. Ultimately, our three period model may be extended to a dynamic framework, allowing for a more profound quantitative exploration of the effects documented in this chapter.

1.A Appendix

1.A.1 Proofs and derivations

Proof of Proposition 1.1

Models with price-dependent collateral constraints like ours bear the risk that equilibrium prices do not exist. The reason is that these models face downward-sloping supply functions. Constraint agents must sell more if the collateral price is low, but less if it high, and the constraint is less tight.

Existence. We first prove the existence of the equilibrium price. Let

$$S(q_1) = \sum_{j=1}^{J} \mathbb{1}_{\left\{\tilde{l}_1^j(q_1)>0\right\}} s^j \tilde{l}_1^j(q_1)$$

denote the supply of claims as a function of q_1. Analogously, define demand as

$$D(q_1) = -\sum_{j=1}^{J} \mathbb{1}_{\left\{\tilde{l}_1^j(q_1)<0\right\}} s^j \tilde{l}_1^j(q_1).$$

Let $D(q_1)$ and $S(q_1)$ be continuous and differentiable functions on the interval $(0,1]$. Note that $S(q_1)$ is bounded from above for any q_1. This follows from the fact that investors cannot sell more claims than they possess, i. e. $\tilde{l}_1^j \leq \tilde{a}_0^j$, and, hence, for any q_1

$$S(q_1) = \sum_{j=1}^{J} \mathbb{1}_{\left\{\tilde{l}_1^j(q_1)>0\right\}} s^j \tilde{l}_1^j(q_1) \leq \sum_{j=1}^{J} s^j \tilde{a}_0^j = \bar{a}.$$

Specifically, it follows that $\lim_{q_1\to 0} S(q_1) \leq \bar{a}$.

We consider two cases when characterizing the demand curve. First, if demand is zero, there is still excess supply. According to the Walrasian equilibrium definition, all prices q_1 are equilibrium prices. Second, if demand is positive, we ensure the existence of an equilibrium price q_1 by showing that demand is infinite as the price approaches zero, i. e. $\lim_{q_1\to 0} D(q_1) = \infty$. First, note that buyers will exhaust their entire borrowing limit as they trade, i. e. $\tilde{d}_1^j = \phi q_1 \left(\tilde{a}_0^j - \tilde{l}_1^j\right)$, because any price $q_1 < 1$ grants them a pecuniary benefit. From the period-2 budget constraint (1.2), we obtain

$$\tilde{c}_2^j = (1-\phi q_1)\left(\tilde{a}_0^j - \tilde{l}_1^j\right). \tag{1.20}$$

Suppose the price approaches its lower limit of zero, i. e. $q_1 \to 0$. From the price equation (1.6), it follows that either the numerator tends to zero, i. e. $u'\left(\tilde{c}_2^j\right) \to 0$, or the denominator tends to infinity, i. e. $(1-\phi)u'\left(\tilde{c}_1^j\right) + \phi u'\left(\tilde{c}_2^j\right) \to \infty$, or both. If the numerator tends to zero, the concavity of $u\left(\tilde{c}_t^j\right)$ implies that $\tilde{c}_2^j$ becomes infinitely large, i. e. $\tilde{c}_2^j \to \infty$, and, by (1.20), so does the demand for claims, i. e. $\tilde{l}_1^j \to -\infty$. If, in contrast, the denominator tends to infinity, this can be caused by consumption in $t=1$ and $t=2$ approaching zero, i. e. either $\tilde{c}_1^j \to 0$ or $\tilde{c}_2^j \to 0$. In the first case, all consumption is shifted to the final period, i. e. $\tilde{c}_2^j \to \infty$, from which an infinite demand for claims, i. e. $\tilde{l}_1^j \to -\infty$, follows again. In the second case, both numerator and denominator of the pricing equation (1.6) would tend to infinity, yet the numerator at a faster pace as $\phi < 1$, and, consequently, the assumption $q_1 \to 0$ would be violated. Thus, at the minimum price of $q_1 \to 0$, period-2 consumption $\tilde{c}_2^j$ will tend to infinity and $\tilde{l}_1^j$ will tend to minus infinity for all j with $\tilde{l}_1^j < 0$. We conclude that overall demand for claims becomes infinitely large, i. e. $\lim_{q_1 \to 0} D(q_1) = \infty$.

All in all, for $q_1 \to 0$, we obtain a bounded supply and an infinitely high demand. It is only required to ensure that this demand exists. We ensure a positive mass of $D(0)$ through assuming that at least one type of investors has had correct expectations ex post, receiving a return that is as high as expected or higher. Formally, $E^j[R] \leq \hat{R}$ for at least one j and all realizations $\hat{R}$ of R ensures that there is at least one group that has sufficient funds available in period $t=1$ to demand claims on the asset.

There are different possibilities how supply and demand can intersect. Either $D(q_1)$ and $S(q_1)$ intersect on $(0,1]$ at (possibly multiple) price(s). Then, all prices in this set are equilibrium prices. Or they do not have an intersection on the interval. We have shown that, in this case, demand is permanently larger than supply, i. e. $D(q_1) > S(q_1)$ for any $q_1 \in (0,1]$ as $D(0) > S(0)$ and there is no intersection on $(0,1]$. Hence, $q_1 = 1$ is the equilibrium price since, for this price, buying investors are indifferent between all levels of feasible demand, and the bounded supply $S(1) < D(1)$ can be fully met. In conclusion, we have shown that the equilibrium price exists.

Uniqueness. Second, we prove that the equilibrium price is unique and satisfies $q_1 \leq 1$ in the case of positive demand. Uniqueness is ensured if, first, $\lim_{q_1 \to 0} D(q_1) = \infty$, second, $D(1) = S(1) = 0$, and third, if $D(q_1)$ and $S(q_1)$ are monotonically decreasing functions on $(0,1]$ with $\frac{\partial D(1)}{\partial q_1} = \frac{\partial S(1)}{\partial q_1} = 0$. We continue assuming their continuity and differentiability.

Regarding the first two conditions, we have shown $\lim_{q_1 \to 0} D(q_1) = \infty$ in the previous part, and $D(1) = S(1) = 0$ follows from our assumption $\tilde{l}_1^j(1) = 0$ for all j. Next, we prove that both supply and demand are monotonic functions on $(0,1]$. Specifically, we determine the signs of

$$\frac{\partial S\left(q_1\right)}{\partial q_1} = \sum_{j=1}^{J} \mathbb{1}_{\left\{\tilde{l}_1^j(q_1)>0\right\}} s^j \frac{\partial \tilde{l}_1^j}{\partial q_1} \tag{1.21}$$

$$\frac{\partial D\left(q_1\right)}{\partial q_1} = -\sum_{j=1}^{J} \mathbb{1}_{\left\{\tilde{l}_1^j(q_1)<0\right\}} s^j \frac{\partial \tilde{l}_1^j}{\partial q_1}. \tag{1.22}$$

Using the period-1 equilibrium conditions (1.1), (1.2), (1.3), and (1.9), and applying the implicit function theorem to (1.5), we obtain

$$\frac{\partial \tilde{l}_1^j}{\partial q_1} = \frac{1}{1+(1-2\phi)\, q_1}\left[\frac{1}{(1-\phi q_1)\, A q_1} - 2\phi \tilde{a}_0^j + (2\phi-1)\tilde{l}_1^j\right] \tag{1.23}$$

Inserting (1.23) into (1.21) and (1.22) yields

$$\frac{\partial S\left(q_1\right)}{\partial q_1} = \frac{1}{1+(1-2\phi)\, q_1}\left[\frac{J^S}{(1-\phi q_1)\, A q_1} - 2\phi \sum_{j=1}^{J} \mathbb{1}_{\left\{\tilde{l}_1^j(q_1)>0\right\}} s^j \tilde{a}_0^j + (2\phi-1) S\left(q_1\right)\right] \tag{1.24}$$

$$\frac{\partial D\left(q_1\right)}{\partial q_1} = -\frac{1}{1+(1-2\phi)\, q_1}\left[\frac{J^D}{(1-\phi q_1)\, A q_1} - 2\phi \sum_{j=1}^{J} \mathbb{1}_{\left\{\tilde{l}_1^j(q_1)<0\right\}} s^j \tilde{a}_0^j + (2\phi-1) D\left(q_1\right)\right], \tag{1.25}$$

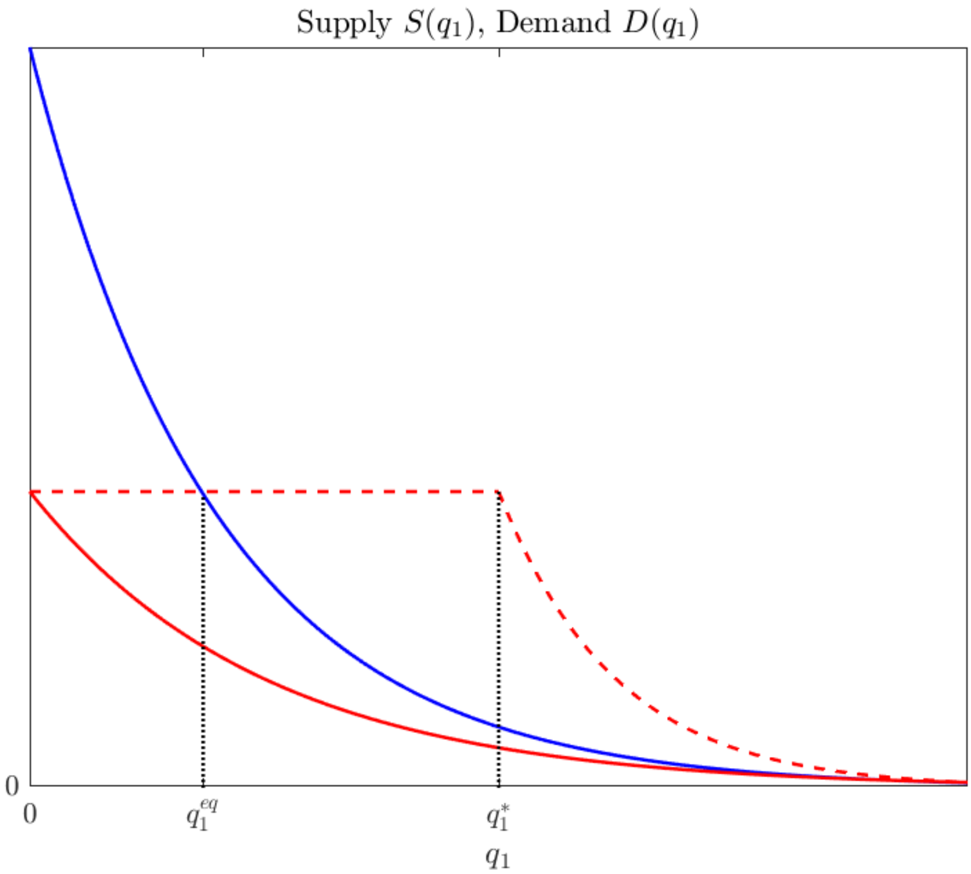
where J^S and J^D are the number of types that are on the supply and the demand side of the market, respectively. We assume that the margin requirement is sufficiently tight, i. e. $\phi < 1/2$.

We first show that the supply curve is a weakly decreasing function of q_1. Recall that $S\left(q_1\right)$ is continuous on $(0,1]$, $\lim_{q_1 \to 1} S\left(q_1\right) = 0$, and an equilibrium with positive demand $D\left(q_1\right) > 0$ requires that there is a q_1 such that $S\left(q_1\right) > 0$. Hence, there must further be a $q_1^* \equiv \min\left\{q_1 \mid \frac{\partial S(q_1)}{\partial q_1} < 0 \textit{ for all } q_1 > q_1^*\right\}$.

Now we distinguish two cases. If $\frac{\partial S\left(q_1^*\right)}{\partial q_1} \neq 0$, there is no $q_1 < q_1^*$ such that $\frac{\partial S(q_1)}{\partial q_1} > 0$, and it follows $\frac{\partial S(q_1)}{\partial q_1} \leq 0$ for all $q_1 \in (0,1]$, making the supply curve monotonically decreasing. If, however, $\frac{\partial S\left(q_1^*\right)}{\partial q_1} = 0$, this is equivalent to $S\left(q_1^*\right) = \frac{1}{2\phi-1}\left[2\phi \sum_{j=1}^{J} \mathbb{1}_{\left\{\tilde{l}_1^j\left(q_1^*\right)\geq 0\right\}} s^j \tilde{a}_0^j - \frac{J^S}{\left(1-\phi q_1^*\right) A q_1^*}\right]$. For $q_1 < q_1^*$, we prove by contradiction that supply is constant.

First suppose that $\frac{\partial S(q_1)}{\partial q_1} > 0$. From (1.24), it follows that $S\left(q_1\right) > S\left(q_1^*\right)$ in this case, which would imply $\frac{\partial S(q_1)}{\partial q_1} < 0$, violating the assumption. Now suppose that $\frac{\partial S(q_1)}{\partial q_1} < 0$. From (1.24), it follows that $S\left(q_1\right) < S\left(q_1^*\right)$ in this case, which would imply $\frac{\partial S(q_1)}{\partial q_1} > 0$, violating the assumption. Therefore, we obtain $\frac{\partial S(q_1)}{\partial q_1} = 0$ for all $q_1 < q_1^*$. The constancy of supply for low collateral prices reflects the fact that supply is bounded from above by the amount invested in $t = 0$. q_1^* is thus the price below which distressed investors are

Figure 1.5: Supply and demand in $t = 1$
This figure sketches two possible supply curves and a demand curve in period $t = 1$. Supply curves are depicted in red, while the demand curve is depicted in blue. q_1^{eq} is the equilibrium price, and q_1^* is defined as in the proof of Proposition 1.1.



willing to liquidate their entire position.

The slope of the demand curve, i. e. the sign of the left-hand side of equation (1.25), is determined by the term in brackets. Under the assumption of $\phi < 1/2$, and restricting the initial endowment to $\bar{a} \leq 2$, the term in brackets is positive, yielding $\frac{\partial D(q_1)}{\partial q_1} < 0$ for any $q_1 \in (0, 1]$.

Lastly, equations (1.24) and (1.25) reveal that $\frac{\partial D(1)}{\partial q_1} = \frac{\partial S(1)}{\partial q_1} = 0$ because $J^S = J^D = \mathbb{1}_{\left\{\tilde{l}_1^j(1)>0\right\}} = \mathbb{1}_{\left\{\tilde{l}_1^j(1)<0\right\}} = S(1) = D(1) = 0$ at $q_1 = 1$.

Since all the conditions for uniqueness are satisfied, we deduce that the equilibrium price is unique (see Figure 1.5 for illustration).

Equivalences. Third, we show the two equivalences in part (ii). For part (i), suppose $q_1 = 1$. Combining equations (1.4) and (1.5) yields $\tilde{\eta}_1^j = \tilde{\eta}_1^j \phi$. The only solution for the latter condition is $\tilde{\eta}_1^j = 0$. Now, suppose $\tilde{\eta}_1^j = 0$. Equation (1.4) then becomes $u'\left(\tilde{c}_1^j\right) = u'\left(\tilde{c}_2^j\right)$. Substituting out $u'\left(\tilde{c}_2^j\right)$ in equation (1.5) yields $q_1 = 1$.

For part (ii), the equivalence is shown formally:

$$\begin{aligned} q_1 &= \frac{u'\left(\tilde{c}_2^j\right)}{(1-\phi)u'\left(\tilde{c}_1^j\right)+\phi u'\left(\tilde{c}_2^j\right)} < 1 \\ \iff & (1-\phi)u'\left(\tilde{c}_2^j\right) < (1-\phi)u'\left(\tilde{c}_1^j\right) \\ \iff & 0 < u'\left(\tilde{c}_1^j\right) - u'\left(\tilde{c}_2^j\right) = \tilde{\eta}_1^j. \end{aligned}$$

□

Proof of Proposition 1.2

For the proof of part (i), recall that the period-1 equilibrium price satisfies equation (1.6), where $\tilde{c}_1^j$ and $\tilde{c}_2^j$ are given by equations (1.1) and (1.2) for all j. Since the equilibrium price equals one if $\tilde{\eta}_1^j = 0$, we restrict ourselves to price effects in the case of $\tilde{\eta}_1^j > 0$. For the borrowing constraint to be binding, assume that the realization $\hat{R}$ is sufficiently adverse, satisfying $\hat{R} < 1$. Using CARA $A = -\frac{u''\left(\tilde{c}_t^j\right)}{u'\left(\tilde{c}_t^j\right)}$ for all j and t, we obtain the following equilibrium price derivatives:

$$\frac{\partial q_1}{\partial \tilde{a}_0^j} = \frac{(1-\phi)(1-R)\left(q_1\right)^2}{\frac{u'\left(\tilde{c}_2^j\right)}{u''\left(\tilde{c}_1^j\right)} + (1-\phi)\left(q_1\right)^2 \tilde{l}_1^j} \tag{1.26}$$

$$\frac{\partial q_1}{\partial \tilde{d}_0^j} = \frac{(1-\phi)\left(q_1\right)^2}{\frac{u'\left(\tilde{c}_2^j\right)}{u''\left(\tilde{c}_1^j\right)} + (1-\phi)\left(q_1\right)^2 \tilde{l}_1^j}. \tag{1.27}$$

The numerators of equations (1.26) and (1.27) are positive, and the denominator is negative. To see this, note that $\frac{\partial q_1}{\partial \tilde{c}_1^j} = -(1-\phi)\frac{u''\left(\tilde{c}_1^j\right)}{u'\left(\tilde{c}_2^j\right)}\left(q_1\right)^2 > 0$. For the denominator, it follows

$$\begin{aligned} & \frac{u'\left(\tilde{c}_2^j\right)}{u''\left(\tilde{c}_1^j\right)} + (1-\phi)\left(q_1\right)^2 \tilde{l}_1^j \le 0 \\ \iff & 1 \ge \frac{\partial q_1}{\partial \tilde{c}_1^j}\tilde{l}_1^j, \end{aligned} \tag{1.28}$$

which is always satisfied. If $\tilde{l}_1^j \le 0$, the left-hand side of (1.28) is negative. But it is exceeded by one even if $\tilde{l}_1^j > 0$. The reason is that $1 \ge \frac{\partial q_1}{\partial \tilde{c}_1^j}\tilde{l}_1^j$ is the condition for finite consumption $\tilde{c}_1^j$. Consider the period-1 budget constraint $\tilde{c}_1^j = R\tilde{a}_0^j + q_1\tilde{l}_1^j + \tilde{d}_1^j - \tilde{d}_0^j$. Increasing the budget by one unit of the consumption good has two effects. First, it directly increases consumption by one unit. Second, it raises q_1, and further increases consumption by $\frac{\partial q_1}{\partial \tilde{c}_1^j}\tilde{l}_1^j$. Suppose $1 < \frac{\partial q_1}{\partial \tilde{c}_1^j}\tilde{l}_1^j$. In this case, the latter effect via q_1 dominates the direct effect, and the initial stimulus initiated an upward loop towards infinite consumption $\tilde{c}_1^j$.

Hence, a finite solution requires $1 \geq \frac{\partial q_1}{\partial \tilde{c}_1^j} \tilde{l}_1^j$, concluding the proof of part (i).

Turning to part (ii), for the equilibrium price derivative with respect to borrowing under a homogeneous belief, we obtain

$$\frac{\partial q_1}{\partial \tilde{d}_0} = \frac{(1-\phi)\,(q_1)^2}{\frac{u'(\tilde{c}_2)}{u''(\tilde{c}_1)}},$$

which is negative for a concave utility function. □

Proof of Proposition 1.3

For the proof of part (i), let investors hold heterogeneous beliefs $\mathcal{F}$. The individual type-j decisions for investment and borrowing are governed by equations (1.8) and (1.9), that we rewrite as functions of its belief $F^j(R)$ in the following way:

$$q_0 u'\left(\tilde{c}_0^j\left(\tilde{a}_0^j\left(F^j(R)\right), \tilde{d}_0^j\left(F^j(R)\right)\right)\right) = \int_{\underline{R}}^{\overline{R}} R u'\left(\tilde{c}_1^j\left(\tilde{a}_0^j\left(F^j(R)\right), \tilde{d}_0^j\left(F^j(R)\right)\right)\right) \ldots$$
$$\ldots + u'\left(\tilde{c}_2^j\left(\tilde{a}_0^j\left(F^j(R)\right)\right)\right) + \tilde{\eta}_1^j\left(\tilde{a}_0^j\left(F^j(R)\right), \tilde{d}_0^j\left(F^j(R)\right)\right)\phi q_1 dF^j(R) \tag{1.29}$$
$$u'\left(\tilde{c}_0^j\left(\tilde{a}_0^j\left(F^j(R)\right), \tilde{d}_0^j\left(F^j(R)\right)\right)\right) = \int_{\underline{R}}^{\overline{R}} u'\left(\tilde{c}_1^j\left(\tilde{a}_0^j\left(F^j(R)\right), \tilde{d}_0^j\left(F^j(R)\right)\right)\right) dF^j(R). \tag{1.30}$$

Notably, period-0 choices $\tilde{a}_0^j\left(F^j(R)\right)$ and $\tilde{d}_0^j\left(F^j(R)\right)$ are direct functions of type j's belief, while period-1 and period-2 variables are both indirect functions of $F^j(R)$ via $\tilde{a}_0^j\left(F^j(R)\right)$ and $\tilde{d}_0^j\left(F^j(R)\right)$ direct functions of it through the expectation operator.

In the following, we apply the calculus of variation, as explained in the main text. Consider a perturbation to beliefs of the form $F^j(R)+\epsilon G^j(R)$, where $\epsilon > 0$ is an arbitrary number, and $G^j(R)$ captures the direction of the perturbation. $F^j(R)+\epsilon G^j(R)$ is required to be a valid cdf for small enough ϵ, so we assume it is continuous and differentiable, it satisfies $G(\underline{R}) = G(\overline{R}) = 0$, and $\partial\left(F^j(R) + \epsilon G^j(R)\right)/\partial R \geq 0$ for sufficiently small ϵ. Lastly, let δ denote the operator for functional derivatives.

We characterize the variational derivatives of investment and borrowing choices when beliefs $F^j(R)$ are perturbed with direction $G^j(R)$, i. e. $\frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j$ and $\frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j$. Optimism and pessimism are measured relative to each other in the sense of first order stochastic dominance. A perturbation $G^j(R)$ makes type-j investors more optimistic if and only if it satisfies $F^j(R)+\epsilon G^j(R) \leq F^j(R)$ for all R. It is easy to see that more optimism requires the perturbation to have a negative direction, i. e. $G^j(R) \leq 0$ for all R. Analogously, investors of type j are made more pessimistic through a perturbation with direction $G^j(R) \geq 0$ for all R.

Applying the implicit function theorem to (1.29) and (1.30), and combining the resulting expressions yield

$$\frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j = \frac{\int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1^j\right) \tilde{a}_0^j G^j(R) dR \cdot \left(\int_{\underline{R}}^{\overline{R}} (1+\phi) u''\left(\tilde{c}_1^j\right) dF^j(R) + q_0 u''\left(\tilde{c}_0^j\right)\right)}{\left(\int_{\underline{R}}^{\overline{R}} R u''\left(\tilde{c}_1^j\right) dF^j(R) + q_0 u''\left(\tilde{c}_0^j\right)\right) \cdot \left(\int_{\underline{R}}^{\overline{R}} (1+\phi) u''\left(\tilde{c}_1^j\right) dF^j(R) + q_0 u''\left(\tilde{c}_0^j\right)\right)} \cdots$$
$$\cdots \frac{-\int_{\underline{R}}^{\overline{R}} \left(u'\left(\tilde{c}_1^j\right) + (R+\phi q_1) u''\left(\tilde{c}_1^j\right) \tilde{a}_0^j\right) G^j(R) dR \cdot \left(\int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1^j\right) dF^j(R) + u''\left(\tilde{c}_0^j\right)\right)}{-\left(\int_{\underline{R}}^{\overline{R}} (R+\phi q_1) R u''\left(\tilde{c}_1^j\right) + (1-\phi q_1) u''\left(\tilde{c}_2^j\right) dF^j(R)\right) \cdot \left(\int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1^j\right) dF^j(R) + u''\left(\tilde{c}_0^j\right)\right)} \quad (1.31)$$

$$\frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j = \frac{-\int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1^j\right) \tilde{a}_0^j G^j(R) dR}{u''\left(\tilde{c}_0^j\right) + \int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1^j\right) dF^j(R)} + \frac{\int_{\underline{R}}^{\overline{R}} R u''\left(\tilde{c}_1^j\right) dF^j(R) + q_0 u''\left(\tilde{c}_0^j\right)}{u''\left(\tilde{c}_0^j\right) + \int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1^j\right) dF^j(R)} \cdot \frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j. \quad (1.32)$$

First, we further investigate equation (1.31). Assuming that the choice of parameters ensures a non-zero trading volume, i. e. $A < 1$ and beliefs $\mathcal{F}$ sufficiently divergent such that $\bar{a} - \tilde{a}_0^j \neq 0$ for some j, and that the borrowing constraints bind in response to the adverse shock, i. e. $\hat{R} < 1$ and $\phi < \frac{1}{2}$ such that $\tilde{\eta}_1^j > 0$ for all j, the numerator is negative for $G^j(R) \leq 0$, and positive for $G^j(R) \geq 0$. The denominator is always negative. Hence, the functional derivative $\frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j$ is positive for $G^j(R) \leq 0$ and negative for $G^j(R) \geq 0$.

Given the signs of the components in (1.32), it follows that $\frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j$ and $\frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j$ have the same sign for each $G^j(R)$. Consequently, the two variational derivatives in (1.31) and (1.32) turn out to be positive if investors are more optimistic ($G^j(R) \leq 0$), and negative if they are more pessimistic ($G^j(R) \geq 0$).

Proving part (ii), we employ the identical procedure as above. Let investors hold the homogeneous belief $F(R)$. Let further $G(R)$ be the direction of a perturbation of the homogeneous belief. We obtain as the functional derivative of borrowing

$$\frac{\delta \tilde{d}_0}{\delta F} \cdot G = \frac{-\int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1\right) \bar{a} G(R) dR}{u''\left(\tilde{c}_0\right) + \int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1\right) dF(R)},$$

which is as well positive for more optimistic investors ($G^j(R) \leq 0$) and negative for more pessimistic investors ($G^j(R) \geq 0$). □

Proof of Proposition 1.4

With regard to part (i), let investors hold heterogeneous beliefs $\mathcal{F}$. Let further $G^j(R)$ be the direction of a perturbation of type-j investors' belief $F^j(R)$, and beliefs $F^i(R)$ be constant for all $i \neq j$.

Recall that the functional derivative $\frac{\delta}{\delta F^j} \cdot G^j$ describes a gradient, so it is identical to a partial derivative if the functional argument is one-dimensional. We write the period-1 equilibrium price as a function of beliefs, i. e. $q_1 = q_1\left(\tilde{a}_0(\mathcal{F}), \tilde{d}_0(\mathcal{F})\right)$. It follows

$$\frac{\delta q_1}{\delta F^j} \cdot G^j = \frac{\delta q_1}{\delta \tilde{a}_0^j} \cdot \frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j + \frac{\delta q_1}{\delta \tilde{d}_0^j} \cdot \frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j = \frac{\partial q_1}{\partial \tilde{a}_0^j} \cdot \frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j + \frac{\partial q_1}{\partial \tilde{d}_0^j} \cdot \frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j. \quad (1.33)$$

Using Propositions 1.2 and 1.3, we obtain statement (1) of part (i).

For statement (2), let $G^j(R) < 0 < G^i(R)$ with $|G^j(R)| = |G^i(R)|$ for all R be the directions of two perturbations that make investors of type j more optimistic and investors of type i more pessimistic by the same magnitude. We investigate each factor in the two summands on the right-hand side of equation (1.33) separately. First, note that equations (1.31) and (1.32) imply that

$$\left|\frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j\right| = \left|\frac{\delta \tilde{a}_0^i}{\delta F^i} \cdot G^i\right| \text{ and } \left|\frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j\right| = \left|\frac{\delta \tilde{d}_0^i}{\delta F^i} \cdot G^i\right|.$$

Second, taking the derivatives of equations (1.26) and (1.27) shows that q_1 is a (decreasing and) concave function of investment and borrowing, i. e. $\frac{\partial^2 q_1}{\partial^2 \tilde{a}_0^j} \leq 0$ and $\frac{\partial^2 q_1}{\partial^2 \tilde{d}_0^j} \leq 0$. As for any concave function, it follows that

$$\left|\frac{\delta q_1}{\delta \tilde{a}_0^j}\right| > \left|\frac{\delta q_1}{\delta \tilde{a}_0^i}\right| \text{ and } \left|\frac{\delta q_1}{\delta \tilde{d}_0^j}\right| > \left|\frac{\delta q_1}{\delta \tilde{d}_0^i}\right|.$$

Inserting the two former results in equation (1.33) yields statement (2).

To prove part (ii), let investors hold the homogeneous belief $F(R)$. Let further $G(R)$ be the direction of a perturbation of the homogeneous belief. Equation (1.33) simplifies to

$$\frac{\delta q_1}{\delta F} \cdot G = \frac{\partial q_1}{\partial \tilde{d}_0} \cdot \frac{\delta \tilde{d}_0}{\delta F} \cdot G,$$

which is negative for $G(R) \leq 0$ and positive for $G(R) \geq 0$ by the same arguments as in statement (1) of part (i). □

Proof of Theorem 1.1

We start out by proving that $\hat{R}^*_{het} > \hat{R}^*_{hom}$, where $\hat{R}^*_{het}$ and $\hat{R}^*_{hom}$ are defined in Definition 1.3. Consider a population with investors holding heterogeneous beliefs $\mathcal{F}$. Let $\hat{R}^{*j}_{het}$ denote the lowest possible realization $\hat{R}$ such that the collateral constraint of type-j investors is slack, i. e. $\tilde{\eta}_1^j = 0$ and $q_1 = 1$, which are equivalent to $\tilde{c}_1^j = \tilde{c}_2^j$. At this point, the borrowing constraint yields $\tilde{d}_1^j = \phi \tilde{a}_0^j$. Using this, and equating the budget constraints (1.1) and (1.2), one obtains $\hat{R}^{*j}_{het} = 1 - 2\phi + \frac{\tilde{d}_0^j}{\tilde{a}_0^j}$.

Given the result from Proposition 1.1, it suffices that one type of investors is constrained to make all investors constrained. We refer to this situation as financial distress, and it follows that $\hat{R}^*_{het} = \max\left\{\hat{R}^{*j}_{het}\right\}_{j \in \{1,\dots,J\}}$. Assuming without loss of generality that investors are ordered from more to less optimistic types, i. e. $F^1(R) < \dots < F^J(R)$ for all R, we obtain $\hat{R}^*_{het} = \hat{R}^{*1}_{het}$. For the homogeneous case, we derive $\hat{R}^*_{hom} = 1 - 2\phi + \frac{\tilde{d}_0}{\tilde{a}}$ equivalently.

To show that $\hat{R}^*_{het} > \hat{R}^*_{hom}$, it is sufficient to prove that $\frac{\tilde{d}_0^1}{\tilde{a}_0^1} > \frac{\tilde{d}_0}{\tilde{a}}$. Since type $j = 1$ is the most optimistic type, we know that $\tilde{a}_0^1 > \bar{a}$ and $\tilde{d}_0^1 > \tilde{d}_0$. To prove that $\frac{\tilde{d}_0^1}{\tilde{a}_0^1} > \frac{\tilde{d}_0}{\bar{a}}$, we show that $\tilde{d}_0^1 - \tilde{d}_0 > \tilde{a}_0^1 - \bar{a}$.

The latter statement would follow if a perturbation, making a specific belief more optimistic, i. e. $G^1(R) < 0$ for all R, always increased borrowing by more than investment, i. e. $\frac{\delta \tilde{d}_0^1}{\delta F^1} \cdot G^1 > \frac{\delta \tilde{a}_0^1}{\delta F^1} \cdot G^1$. We deduce from equation (1.32) that this condition is satisfied provided that

$$\frac{\int_{\underline{R}}^{\overline{R}} R u''\left(\tilde{c}_1^1\right) dF^1 + q_0 u''\left(\tilde{c}_0^1\right)}{u''\left(\tilde{c}_0^1\right) + \int_{\underline{R}}^{\overline{R}} u''\left(\tilde{c}_1^j\right) dF^1} > 1. \tag{1.34}$$

Under the presumption made in Theorem 1.1, requiring the homogeneous belief $F(R)$ to be less optimistic than at least one type's belief in the heterogeneous case, implying $F^1(R) < F(R)$ for all R, inequality (1.34) is satisfied for any type-1 belief F^1 sufficiently optimistic. Hence, under this assumption, we obtain $\hat{R}^*_{het} > \hat{R}^*_{hom}$.

Ultimately, we derive the corresponding probabilities of financial distress. In our setting, it is for the heterogeneous and the homogeneous case, respectively

$$\begin{aligned}
\Pr\left(\tilde{\eta}_1^1 > 0\right) &= \Pr\left(R \leq \hat{R}^*_{het}\right) = F\left(\hat{R}^*_{het}\right) \\
\Pr\left(\eta_1 > 0\right) &= \Pr\left(R \leq \hat{R}^*_{hom}\right) = F\left(\hat{R}^*_{hom}\right).
\end{aligned}$$

Given $\hat{R}^*_{het} > \hat{R}^*_{hom}$ and the strict monotonicity of the cdf F, it follows that $F\left(\hat{R}^*_{het}\right) > F\left(\hat{R}^*_{hom}\right)$. □

Proof of Proposition 1.5

Proposition 1.5 follows from Definition 1.4 and Proposition 1.2. □

Proof of Proposition 1.6

With regard to part (i), let investors hold heterogeneous beliefs $\mathcal{F}$. Let further $G^j(R)$ be the direction of a perturbation of type-j investors' belief $F^j(R)$, and beliefs $F^i(R)$ be constant for all $i \neq j$. We calculate the functional derivatives of distributive and collateral externalities with respect to beliefs in the following way:

$$\frac{\delta D^i_{\tilde{a}_0^j}}{\delta F^j} \cdot G^j = \frac{\delta\left(\frac{q_1}{\partial \tilde{a}_0^j}\right)}{\delta F^j} \cdot G^j \cdot \tilde{l}_1^j = \left(\frac{\partial^2 q_1}{\partial \tilde{a}_0^j \partial \tilde{a}_0^j} \frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j + \frac{\partial^2 q_1}{\partial \tilde{a}_0^j \partial \tilde{d}_0^j} \frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j\right) \tilde{l}_1^j,$$

and analogously for $D^i_{\tilde{d}_0^j}$, $C^i_{\tilde{a}_0^j}$, and $C^i_{\tilde{d}_0^j}$. Since q_1 is strictly decreasing and concave in both $\tilde{a}_0^j$ and $\tilde{d}_0^j$, and using our results from above on the sign of the functional derivatives $\frac{\delta \tilde{a}_0^j}{\delta F^j} \cdot G^j$ and $\frac{\delta \tilde{d}_0^j}{\delta F^j} \cdot G^j$, it follows that the term in brackets is unambiguously negative for

$G^j(R) < 0$ and positive for $G^j(R) > 0$. This proves the first statement of part (i).

Statement (2) of part (i), as well as part (ii), follow from the same arguments as those used in the proof of Proposition 1.4. □

Proof of Proposition 1.7

First, we derive the tax formulas in part (i). Consider the period-0 optimization problem of a type-j agent with taxes:

$$\max_{c_0^j, a_0^j \geq 0, d_0^j} u\left(c_0^j\right) + E^j\left[V_1^j\left(a_0^j, d_0^j | \tilde{a}_0, \tilde{d}_0\right)\right] \quad \text{s.t.}$$

$$\left(\lambda_0^j\right) \quad c_0^j = e + \left(1 - \tau_d^j \operatorname{sgn}\left(\tilde{d}_0^j\right)\right) d_0^j + \left(1 - \tau_a^j \operatorname{sgn}\left(\bar{a} - \tilde{a}_0^j\right)\right) q_0 \left(\bar{a} - a_0^j\right) + T^j.$$

This problem gives rise to the following optimality conditions:

$$\left(1 - \tau_a^j \operatorname{sgn}\left(\bar{a} - \tilde{a}_0^j\right)\right) q_0 u'\left(c_0^j\right) = E^j\left[R u'\left(c_1^j\right) + u'\left(c_2^j\right) + \eta_1^j \phi q_1\right] \tag{1.35}$$

$$\left(1 - \tau_d^j \operatorname{sgn}\left(\tilde{d}_0^j\right)\right) u'\left(c_0^j\right) = E^j\left[u'\left(c_1^j\right)\right]. \tag{1.36}$$

In a symmetric equilibrium, it will always be the case that $c_0^j = \tilde{c}_0^j$, $a_0^j = \tilde{a}_0^j$ and $d_0^j = \tilde{d}_0^j$ for each j. Combining the latter two conditions with their counterparts from the social planner problem, i. e. equations (1.13) and (1.14), respectively, using the planner's pricing relation $\tilde{\psi} = q_0 \omega^j u'\left(\tilde{c}_0^j\right)$, and solving for the taxes yields the tax formulas (1.15) and (1.16).

Second, it follows that, using these taxes, the competitive allocation is constrained-efficient. Specifically, substituting (1.15) and (1.16) into the optimality conditions of the competitive allocation with taxes, i. e. (1.35), and (1.36), replicates the planner's optimality conditions (1.13) and (1.14), as well as $\tilde{\lambda}_0 = \omega^j u'\left(\tilde{c}_0^j\right)$ for each j. Moreover, rebating revenues through T^j for all j ensures that individual period-0 budget constraints are satisfied, and the same holds for the resource constraint in consequence. To summarize, the competitive allocation with taxes satisfies the identical set of conditions, so it turns out to be constrained-efficient.

By the same arguments, we derive the homogeneous tax formula 1.17 in part (ii). □

Proof of Theorem 1.2

Theorem 1.2 follows from Propositions 1.3 and 1.7. □

Chapter 2

Sovereign Spreads, Collateral Frameworks, and Periphery Premia in the Eurozone

by Florian Schuster

Abstract

This chapter studies the emergence of sovereign bond yield spreads in the Eurozone prior to the 2007–2009 financial crisis. We trace their surge back to the revision of the ECB's collateral framework in 2005, which involved a shift from an unconditional to a conditional treatment of sovereign bonds as eligible central bank collateral, requiring them henceforth to hold a minimum credit rating. Our main result is that the channel, by which the event induced sovereign spreads to rise, is unrelated to credit ratings themselves or current macroeconomic and fiscal fundamental data. Instead, it is related to business cycle dissimilarities among Eurozone members: higher yields have been demanded from countries whose business cycles deviate most from the average Eurozone cycle. Adopting the common terminology in the literature, we refer to that effect as the periphery premium. We further show that periphery countries are associated with deteriorating market expectations about future macro-financial trends, which is, notably, not reflected in credit ratings.

Key words: bond yield spreads, sovereign debt, Eurozone, collateral framework

JEL codes: C32, E44, E62, G12

2.1 Introduction

Eurozone governments have experienced diverging sovereign bond yield spreads in the past 20 years, inspiring a debate on whether government debt should be considered safe or risky (Cœuré, 2016). While it is established that sovereign risk during and after the 2007–2009 financial crisis has been driven by variations in macroeconomic fundamentals, the determinants of sovereign spreads prior to the crisis are still largely unexplored.

In this chapter, we trace the pre-crisis emergence of Eurozone government bond yield spreads back to the revision of the ECB's collateral framework in 2005. The reform involved a shift from an unconditional to a conditional treatment of sovereign bonds as eligible central bank collateral, requiring them henceforth to hold a minimum credit rating. We show that the event of making eligibility conditional induced a significant widening of spreads.

We further investigate the underlying channels of this effect. Theoretically, sovereign spreads ought to rise in countries featuring unfavorable current macroeconomic and fiscal positions or inferior credit ratings. However, we show that spreads were unresponsive to either one. Instead, we propose a new channel that links yield differentials to asymmetries in business cycles. Our results indicate that sovereign spreads surged in countries whose business cycles were least aligned with the Eurozone average. Since these countries are commonly grouped under the term *periphery*, as opposed to the more homogeneous *core*, we frame this channel the *periphery premium*. We provide descriptive evidence that the periphery status at the time was correlated with markets expecting a deterioration of future macro-financial trends. Notably, these negative expectations were not reflected in credit ratings.

The emergence of sovereign bond yield spreads in the pre-crisis era is peculiar because the Eurozone lacks historical precedence, and they had been absent until the mid-2000s. Against this background, we provide an empirical analysis of the phenomenon. Our hypothesis is that yield differentials surged in response to a major change in the ECB's collateral policies. It introduced in 2005 a single list of eligible central bank collateral, replacing the myriad of national collateral frameworks that had previously been used in monetary policy transactions. Notably, the reform entailed the introduction of conditionality into the handling of sovereign bonds as central bank collateral. Unlike before, government debt was no longer considered unconditionally eligible, but would thereafter need to be rated appropriately by credit rating agencies.[1]

We test the hypothesis that the ECB's shift towards conditional eligibility originated the rise of sovereign spreads. To that end, we apply a difference-in-differences model to a panel

[1] In practice, ratings issued by S&P Global Ratings, Moody's, and Fitch were accepted.

of eight euro countries. Our identification strategy is set up along two dimensions. First, a natural way to differentiate countries is to compare those with favorable vs. unfavorable macroeconomic and fiscal fundamentals, such as debt levels, budget balances, economic growth, or external positions. Credit ratings are furthermore an obvious criterion, as they consolidate the former variables in a single indicator. In addition, reflecting the minimum requirement imposed in the wake of the reform, they served as the instrument to measure compliance with the new collateral rules. However, there was little variation in credit ratings during the period of interest, as most Eurozone countries held triple- or double-A ratings prior to 2009. Moreover, former studies suggest that macroeconomic variables played a minor role in explaining spread movements before the financial crisis (Bernoth and Erdogan, 2012; Afonso et al., 2015a,b).

That is why our second, and baseline, identification divides the Euro Area into core and periphery. Core countries show business cycles that are highly correlated with each other, while those of periphery countries are idiosyncratic, differing substantially from the core and among each other. We derive business cycle correlations empirically from a structural vector autoregression analysis following Blanchard and Quah (1989) and Bayoumi and Eichengreen (1992b). Looking into business cycle dissimilarities is motivated by the literature on optimum currency areas, pioneered by Mundell (1961), which stresses the risk they pose by undermining the effectiveness of the single monetary policy stance in parts of the union.

Our results show that the event of making collateral eligibility conditional had a substantial effect on Eurozone sovereign spreads. We find a significant uptick of yield differentials in response to the announcement of the revised collateral framework over the following months. The effect proves stable even in a short time window of several days. Moreover, it is robust to a placebo test and various modifications of the sample period and explanatory variables.

Strikingly, our analysis reveals that the former effect was not channeled by adverse current macroeconomic conditions or credit ratings. Markets did not respond to the reform by demanding premia from countries with unfavorable data on debt, fiscal balances, growth, etc., nor did they sanction lower credit ratings. Our estimates show that, if at all, those variables explain parts of the later variation of spreads over time. This finding contrasts the established understanding of sovereign bond pricing, predicting that concerns of macro-financial fundamentals are the main determinants of yield spreads (Alesina et al., 1992; Hilscher and Nosbusch, 2010; Beirne and Fratzscher, 2013).

Instead, we find that the widening of sovereign spreads was largely driven by a periphery premium. When repricing government bonds after the revision of collateral policies, markets responded to asymmetries in business cycles. Our estimates suggest that, keeping all else fixed, spreads in periphery countries rose by up to 20 basis points, which amounts to an overall doubling of yield differences. To unveil the underlying mechanism of how business cycle mismatches influence sovereign spreads, we provide evidence that periphery countries were associated with negative market expectations about future macroeconomic trends and creditworthiness than core countries. A possible explanation for the existence of the periphery premium is hence that, although countries exhibited similar macro-financial fundamentals at the time, the idiosyncracy of their business cycles was expected to feed into future financial problems.

This chapter sheds light on the determinants of sovereign risk perceptions in the Eurozone in the pre-crisis era. Albeit difficult to extrapolate to current episodes, our results highlight the importance of collateral frameworks for sovereign bond pricing. It was the revision of the ECB's framework that triggered markets to account for business cycle asymmetries when pricing government bonds, alongside the more prominent channel related to macro-fiscal indicators. Given the peculiar nature of the Euro Area as a monetary union without historical example, we therefore stress the role of business cycle synchronicity, making a case for policies that support further synchronization. Ultimately, our analysis raises concerns regarding the suitability of credit ratings as policy tools. Their adoption by the ECB in specifying eligibility requirements suggests they reflect current and expected trends in macro-fiscal positions, which is, however, not supported by our evidence.

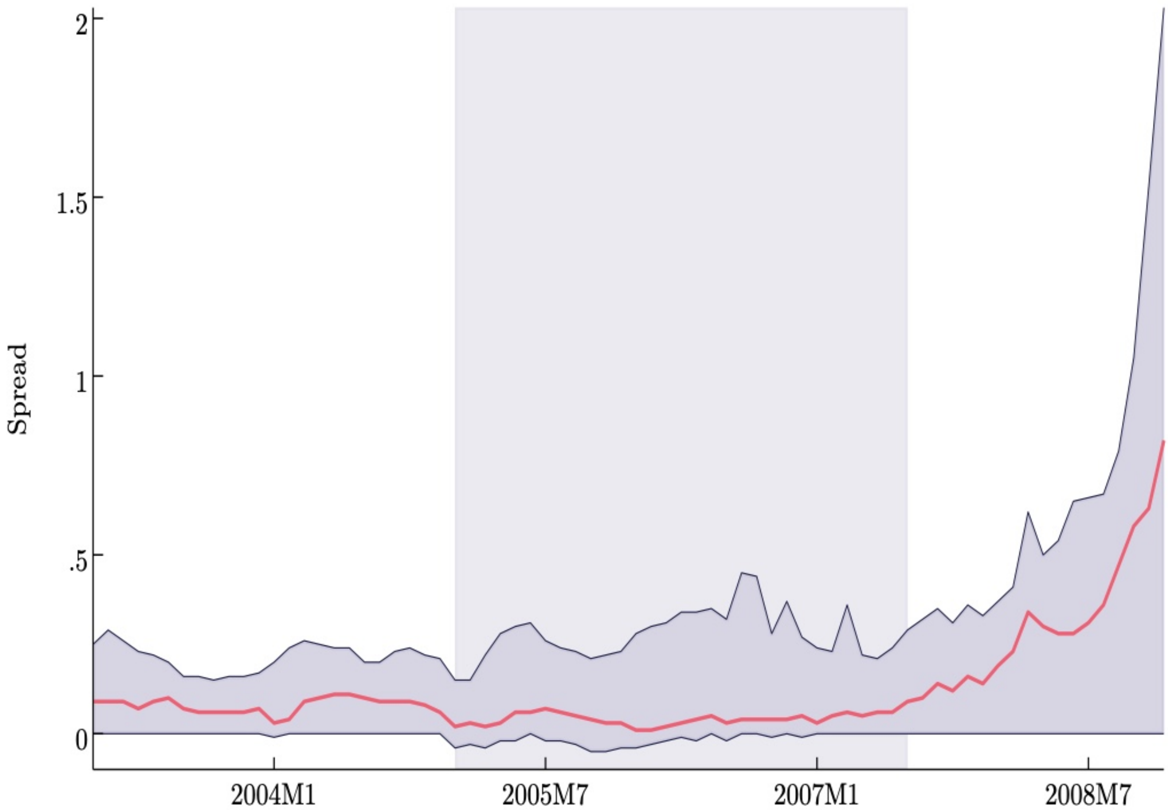
The remainder of the chapter is structured as follows. Section 2.2 reviews the literature on and trends of sovereign spreads in Europe. Section 2.3 sketches the revision of the ECB collateral framework. Section 2.4 introduces the empirical strategy and the data used for our analysis. We present our results in section 2.5 and make final remarks in section 2.6.

2.2 Survey on sovereign spreads in the Euro Area

There is a rich literature addressing the determinants of sovereign risk.[2] While it started with a focus on global lending to emerging markets (Eaton et al., 1986; Hilscher and Nosbusch, 2010), there has been a growing interest in the European case since the beginning of the European Economic and Monetary Union (EMU). The Euro Area, in particular, is special by construction. Government bonds of countries in a monetary union may not be free from default risk, while those of monetarily sovereign countries, borrowing in their

[2]Following the literature, we employ sovereign bond spreads as an approximative measure of risk premia associated with a government bond. Risk premia encompass default risk, liquidity risk, as well as exchange rate risk in the case of governments that issue debt in foreign currencies, and redenomination risk in the case of countries in a monetary union (Alesina et al., 1992; Manganelli and Wolswijk, 2009; Krishnamurthy et al., 2018; Kriwoluzky et al., 2019).

Figure 2.1: Sovereign spreads in the Euro Area
The pink line in this figure shows the evolution of median Euro Area sovereign spreads on ten year maturity government bond yields over the period 2003M1–2008M12 in percentage points. The blue lines refer to the fifth and 95th percentile, and the blue area marks the corresponding interval. The shaded area indicates the period from 2005M1 to the beginning of the financial crisis in 2007M8. Luxembourg has been excluded for reasons of data availability.



own currency, are indeed. They benefit from central banks intervening as a lender of last resort. In the case of the ECB, this function is called into question by the EU treaties and some recent court judgments[3], raising the question of whether Eurozone government debt should actually be considered safe or risky (Cœuré, 2016).

Figure 2.1 depicts the evolution of median sovereign spreads in the Euro Area from 2003 to late 2008, indicated by the pink line, as well as the range between the fifth and 95th percentile. During the first phase of the monetary union, government bonds were priced equally for all member states. Spreads – calculated relative to German bond yields – varied only slightly around zero. Although the median spread remained close to zero until the crisis, spreads started diverging increasingly as from 2005, the period marked by the grey-shaded area. Since the beginning of the crisis in August 2007, yield differences widened explosively and have fluctuated ever since.[4]

The empirical evidence on determinants of bond yield spreads in the Eurozone is am-

[3]See the judgments of the German Federal Constitutional Court in "Gauweiler, 2016" and "Weiss, 2020", as well as of the European Court of Justice in "Gauweiler 2015".

[4]See Figure 2.4 in the appendix for the later evolution of sovereign spreads.

biguous. The literature classifies potential determinants into macroeconomic and fiscal fundamentals – henceforth referred to as *macro-fiscal fundamentals*, capturing default or redenomination risk –, liquidity-related variables, investors' risk appetite, as well as political and regulatory factors. The role of macro-fiscal fundamentals is of particular interest because it establishes a disciplining channel between a government's financial and economic policy, and the corresponding market responses. Such a disciplining effect can equivalently emanate from credit ratings, which consolidate different macro-fiscal indicators and provide an overall assessment of a country's creditworthiness.

However, empirical studies of the disciplining channel come to conflicting conclusions. While some panel studies confirm that macro-fiscal variables are major drivers of spread movements as they represent an economy's basic economic strength (Alesina et al., 1992; Baek et al., 2005; Attinasi et al., 2009; Haugh et al., 2009; Schuknecht et al., 2011; Maltritz, 2012; Beirne and Fratzscher, 2013; De Grauwe and Ji, 2013; Constantini et al., 2014; De Grauwe et al., 2017), others highlight their minor quantitative importance (Afonso and Strauch, 2004; Beirne and Fratzscher, 2013; De Grauwe and Ji, 2013; De Grauwe et al., 2017; Kalan et al., 2018) and the fact that they have gained significance only since the financial crisis (Bernoth and Erdogan, 2012; Afonso et al., 2015a,b). We add to this literature by examining how macro-fiscal fundamentals have contributed to the initial surge of Euro Area yield spreads, and how they influenced their evolution thereafter.

The literature has further revealed that liquidity risk (Codogno et al., 2003; Attinasi et al., 2009) and international risk aversion (Baek et al., 2005; Haugh et al., 2009; Attinasi et al., 2009; Manganelli and Wolswijk, 2009; Schuknecht et al., 2011) are non-negligible drivers of sovereign spreads. We take account of these findings in our empirical model.

In conclusion, empirical results vary widely across studies. While they may well help to understand the unprecedented divergence of spreads across member states since the financial crisis, they are insufficient to explain why significant Euro Area sovereign spreads emerged in the first place. Our empirical analysis contributes to filling this gap. In this, it relates to the theoretical literature on multiple equilibria.

Multiple equilibria in government debt markets arise from self-fulfilling expectations, establishing a feedback loop between interest rates and debt stocks (Obstfeld, 1986; Calvo, 1988; Lorenzoni and Werning, 2019). Sovereign borrowing within a monetary union is arguably more likely to be subject to unfavorable market expectations as countries run a higher risk of liquidity and solvency crises (De Grauwe, 2011).[5]

Relating the determination of sovereign spreads in the Euro Area to multiple equilibria has been ignored by the empirical literature thus far. Recapturing Figure 2.1, it is evident

[5]Since the ECB may not buy up government debt without limits as a crunch occurs, euro countries face a non-zero risk of default, similar to emerging markets borrowing in foreign currencies (the so-called *original sin*; see Eichengreen et al. (2005)).

that European sovereign debt markets have seen phases of both low and high yield differences. We pursue the goal to identify the causes of this shift empirically. Specifically, we hypothesize that the emergence of spreads can be explained by a major revision of the ECB's collateral framework in 2005, being the focus of the following section.

2.3 The ECB's Single List

The key hypothesis of this chapter is that sovereign spreads in the Euro Area surged in response to the overhaul of collateral policies maintained by the ECB. This section gives a brief sketch of the change, and we derive research questions to be answered in the empirical part.

2.3.1 Reform and implications

Institutional factors such as central bank collateral frameworks are found to impact security markets (Haque et al., 1998; Capelle-Blancard et al., 2019). In the case of debt securities, the way central banks treat them as collateral in monetary policy operations may have sizable implications for yields and market liquidity, as has recently been discussed in Nguyen (2020) and Pelizzon et al. (2020).

Notably, the Eurosystem's collateral framework experienced a major reform during the run-up to the financial crisis. In short, the ECB switched from a qualitative, discretionary to a quantitative, market-based system. Although using private credit ratings to assess eligibility and determine haircuts has always been optional, it then became the central strategy of risk management. A minimum rating requirement, based on the ratings issued by S&P Global Ratings, Moody's, and Fitch, and differential haircuts were henceforth effectively applied to sovereign debt.

The reform we allude to was the creation of the so-called *Single List*. van't Klooster (2021) analyzes the roots of the reform.[6] The Single List was meant to replace the former two-tier collateral framework that allowed the ECB and national central banks discretion in deciding what securities to accept as eligible. The adoption of quantitative models helped to overcome this issue. It was decided to effectively delegate the eligibility decision to the market, by specifying haircuts and valuation margins on the basis of private agencies' credit ratings.

The new policy came to be particularly relevant for government debt. While the ECB had considered Eurozone government debt as unconditionally eligible prior to the Single List, it then came to subject sovereign bonds to conditional eligibility. Specifically,

[6] A chronology of the process that led to the creation of the Single List is provided in the appendix.

eligibility was made conditional on compliance with a minimum credit rating.

The ECB's move towards handling sovereign bonds with conditionality has proven to be an exacerbating factor of the financial crisis (Orphanides, 2017). Linking central bank eligibility to external risk assessment exerted sales pressure on low-rated sovereign bond holders because they could no longer be pledged as collateral. Governments thus had to pay an eligibility premium (Bindseil and Papadia, 2006; Bank for International Settlements, 2015; Corradin et al., 2017).

The shift attracted interest in the question of whether Euro Area debt does or does not bear default risk. The answer to that question potentially affects whether high or low spreads will arise in sovereign debt markets. Lengwiler and Orphanides (2023) adopt this stance, and model multiple equilibria as a consequence of central banks' differential treatment of government debt securities based on external assessments. Their conclusion is that such collateral policies might end up in sovereign debt crises and defaults that would have been absent if uniform haircuts had been applied.

Yet, an empirical analysis of the effects of this twist in collateral criteria on sovereign spreads is missing. Specifically, we investigate if the decision that established conditional eligibility as part of the Single List – referred to as the *SL event* in the following – originated the rise of sovereign bond yield spreads in the Eurozone prior to the crisis.

2.3.2 Link to sovereign spreads

The 2005 revision of collateral criteria has sent two distinct signals to markets. First, sovereign bond eligibility has henceforth been *conditional*, implying that certain governments' debt would eventually bear default risk. Second, eligibility was made conditional on *private credit ratings*, the variation of which should therefore explain the evolution of sovereign spreads.

However, if one neglects the case of Greece, there was very little variation in credit ratings across the Eurozone before the financial crisis. Euro countries all held high medium grades (AA) at least, while most of them maintained an AAA prime rating (see Figures 2.5 and 2.6 in the appendix). Thus, the surge of sovereign spreads should not be explained by the mere fact that the new collateral system was rating-based.

Instead, we hypothesize that the henceforth conditional pledgeability of sovereign bonds triggered the divergence of spreads in the Euro Area as from the mid-2000s. Conditional eligibility signals that the central bank would eventually allow government defaults – whatever the underlying economic criterion may be. Sovereign spreads would then arise if governments were highly reliant on the eligibility of their debt securities as central bank collateral. The fact that governments face default risk premia in the presence of conditional eligibility, which are independent of changes in macro-fiscal data, has been studied theoretically by Lengwiler and Orphanides (2023).

Against this background, our analysis answers the questions of (*i*) whether, and (*ii*) by which channels, there is a causal link between the ECB's shift towards conditional eligibility and the widening of sovereign spreads.

2.4 Empirical strategy and data

In this section, we present the strategy to explore the pre-crisis surge of government bond spreads in the Euro Area empirically. We set out the method employed in the empirical part and introduce the data the analysis builds upon.[7]

2.4.1 Method

To properly test the above hypotheses, we employ a difference-in-differences technique. We aim at estimating the effect of the decision of making sovereign bonds' eligibility as central bank collateral conditional. The essential identification challenge is to properly measure a country's exposure to this decision.

Ratings published by the established credit rating agencies are a natural measure of exposure, in light of the fact that the ECB imposed a minimum rating requirement. The lower the credit rating a country holds, the more likely it is that its bonds are considered ineligible, and the higher the country's exposure is. However, as explained above, private credit ratings barely varied prior to the financial crisis. Accordingly, when we perform the analysis with a rating-based measure, one does not find significant effects (see Table 2.10 and Figure 2.7 in the appendix). Thus, credit ratings turn out to be inappropriate as a measure of exposure. We use them as control variables in the main analysis instead.

As an alternative, a government's exposure further depends on the extent to which it relies on issuing pledgeable bonds. This reliance is the stronger, the more likely it is that the government faces high future financing needs. Satisfying large demands for financing on financial markets is facilitated if government bonds are traded in large and liquid markets. Market liquidity, in turn, tends to be higher provided that the bond in question is eligible as collateral at the central bank. That is because pledgeable bonds offer their holders a benefit beyond a pecuniary return. Conditional eligibility thus potentially tightens sovereign bond market liquidity, as it renders bonds in doubt of future pledgeability less attractive to hold. Governments with high demands for financing are thus exposed to potential liquidity, and eventually following solvency, problems. Against this background, our identification builds upon two distinct measures of exposure.

[7] A detailed overview of all variables and their sources is provided in the appendix.

Macro-fiscal channel. We refer to the *macro-fiscal channel* as the one that distinguishes countries by their respective macro-fiscal situation. Specifically, countries currently having higher debt levels, larger budget deficits, lower economic growth or low competitiveness can be argued to face greater future needs for financing, e. g. to refinance former debt or finance reform policies. Their exposure is higher because acquiring these funds would be facilitated by collateral eligibility, which is not unconditionally available in the revised framework. Hence, markets should be inclined to reprice government bonds after the event based on the risks associated with macro-fiscal fundamentals. As we have outlined in section 2.2, this channel is very prominent in the literature on sovereign risk, although of questionable relevance in the pre-crisis period (Bernoth and Erdogan, 2012; Afonso et al., 2015a,b).

Core-periphery channel. That is why, as our baseline identification, we measure a government's exposure to the event by employing the core-periphery distinction of Euro Area members proposed by Bayoumi and Eichengreen (1992a,b). They distinguish European countries according to the synchronicity of their business cycles, following the literature on optimum currency areas started by the seminal contribution by Mundell (1961). Synchronized cycles among members of a monetary union would imply that symmetric policy responses could effectively counteract economic shocks – the crucial premise if monetary policy applies a single instrument to multiple countries. If synchronicity is poor in contrast, monetary policy responses would optimally be asymmetric, which is ruled out by construction.[8]

In Bayoumi and Eichengreen (1992b) and the following literature, business cycle synchronicity is measured in terms of cross-country correlations of supply and demand shocks. These shocks are retrieved from the data using a structural vector autoregression (SVAR) approach, which builds upon the seminal work by Blanchard and Quah (1989).[9] We update their estimates by applying the SVAR technique to output data from 1960 till the early 2000s. The procedure and results are reported in the appendix. Correlation coefficients are typically computed relative to Germany, which acts as the anchor country.

In accordance with Bayoumi and Eichengreen (1992b), we find that Germany and its

[8]To explain whether, and why, countries feature matching or differing business cycles, the literature typically refers to measures of international trade links, industrial specialization, financial integration, and the similarity of labor market regulation (Frankel and Rose, 1998; Böwer and Guillemineau, 2006; Kalemli-Ozcan et al., 2013).

[9]Bayoumi and Eichengreen (1992b) follow Blanchard and Quah (1989) in attributing output fluctuations to either demand or supply shocks, where the former are temporary and the latter are permanent in nature. After identifying structural shocks, cross-country correlations are computed. This method is most prominent to approximate correlations of cyclical output movements across the monetary union, where risk sharing via exchange rate or interest rate adjustments is impeded (Bayoumi and Eichengreen, 1992a,b; Frankel and Rose, 1997; Funke, 1997; Fidrmuc and Korhonen, 2003, 2004).

neighbor countries exhibit a high degree of symmetry, so they are grouped as the Euro Area *core*. Other countries' business cycles – the so-called *periphery* – show a weaker correlation both with the core and among each other.

Exploiting this feature, the identifying assumption underlying the core-periphery channel is the following: Periphery countries face asymmetric business cycles in comparison to Germany and core countries, so monetary policy of the conventional *one-size-fits-all* style will be less effective, and governments will require more borrowing in order to stabilize output fluctuations. Hence, periphery countries have a higher exposure to the SL event as conditional eligibility of sovereign bonds might well hamper them satisfying these liquidity needs on the market.

We include both a binary and a continuous core-periphery variable in the estimation. In the binary case, countries are grouped as core and periphery following Bayoumi and Eichengreen (1992b). We further use the coefficients for the correlation of economic disturbances between Germany and other member states produced by our SVAR analysis as a continuous treatment measure. When employing these coefficients, we solely concentrate on supply shocks.[10]

Regression models. Formalizing the former, our baseline model to test whether there is a causal link between the implementation of conditional eligibility and sovereign spreads consists of the following two difference-in-differences regressions, where equation (2.1) corresponds to the binary periphery indicator, and equation (2.2) to the continuous correlation measure:

$$\begin{aligned} Spread_{ct} = \alpha_c + \alpha_t + \beta \times Periphery_c \times SL_t^{2005M7} \\ + \gamma^0 \times X_{ct} + \gamma^1 \times X_{ct} \times SL_t^{2005M7} + \epsilon_{ct} \end{aligned} \tag{2.1}$$

$$\begin{aligned} Spread_{ct} = \alpha_c + \alpha_t + \beta \times Correlation_c \times SL_t^{2005M7} \\ + \gamma^0 \times X_{ct} + \gamma^1 \times X_{ct} \times SL_t^{2005M7} + \epsilon_{ct}. \end{aligned} \tag{2.2}$$

The outcome variable $Spread_{ct}$ is the sovereign spread of country c in month t vis-à-vis Germany. The variables α_c and α_t are country and time fixed effects. The treatment variable is the interaction of the exposure measure $Periphery_c$ or $Correlation_c$, respectively, with the time dummy SL_t^{2005M7} equal to one as of the Single List was announced in July 2005. Macro-fiscal fundamentals are added through the matrix X_{ct}, containing

[10] Supply shocks reveal more information about business cycle similarities than demand shocks because the latter are arguably endogeneous to membership in the monetary union. Coordinated economic policies as well as common monetary policy are important drivers of demand, but meaningless regarding the underlying properties of the business cycle (Fidrmuc and Korhonen, 2004).

current levels of the debt-to-GDP ratio ($Debt_{ct}$), its square ($Debt^2_{ct}$), the budget balance ($Budget_{ct}$), the primary budget balance ($PBudget_{ct}$), the growth rate ($Growth_{ct}$), the current account balance (CA_{ct}), and the real effective exchange rate ($REER_{ct}$), which we further interact all with the time indicator to take time-varying effects into account, as well as our liquidity measure ($Liquidity_{ct}$) and an indicator AAA_{ct} equal to one if a country was rated AAA.

To analyze the channels through which the SL event affected sovereign spreads, the model is slightly modified. The regression equations read:

$$Spread_{ct} = \alpha_c + \alpha_t + \beta^P \times Periphery_c \times SL_t^{2005M7} + \beta^{MF} \times MF_c \times SL_t^{2005M7} + \gamma^0 \times X_{ct}^{-MF} + \gamma^1 \times X_{ct}^{-MF} \times SL_t^{2005M7} + \epsilon_{ct} \tag{2.3}$$

$$Spread_{ct} = \alpha_c + \alpha_t + \beta^P \times Correlation_c \times SL_t^{2005M7} + \beta^{MF} \times MF_c \times SL_t^{2005M7} + \gamma^0 \times X_{ct}^{-MF} + \gamma^1 \times X_{ct}^{-MF} \times SL_t^{2005M7} + \epsilon_{ct}. \tag{2.4}$$

The basic structure of equations (2.3) and (2.4) is as before. We include country and time fixed effects, and the treatment variable is composed of an interaction of the (binary or continuous) periphery variable and the Single List time indicator. The only difference is the further interaction term we add, comprising the same time dummy and the pre-treatment value of one specific macro-fiscal fundamental, i. e. MF_c, in each regression. In equations (2.1) and (2.2), we let macro-fiscal fundamentals be time-variant, allowing us to trace how they drove spreads after the event. Yet, to identify whether they are the channel by which the SL event is causally linked to spreads, we now keep them fixed at the time of the event. We perform a regression for each macro-fiscal fundamental separately. The remaining macro-fiscal fundamental variables are collected in the matrix X_{ct}^{-MF}.

Discussion. A potential threat to our identifying assumption is that countries in the sample might grow up from the periphery status over time, and become part of the core. In particular, the synchronicity of business cycles could be endogenous to union membership, corresponding to the central promise of European integration: that the euro will bring countries economically closer together. The empirical evidence, however, suggests that business cycle dissimilarities have widened during our sample period. While synchronization was observed in the 1990s, divergence remained substantial until and during the Great Recession (De Grauwe and Mongelli, 2005; De Haan et al., 2008). Hence, we may plausibly assume that countries, which formed part of the core or the periphery, respectively, before the Eurozone was built, have persisted as such since then.

Another challenge is to ensure that our set of explanatory variables is indeed exogeneous to sovereign spreads. We argue that this is likely to be the case. First, as one can learn from section 2.3, the process that led to the conditional treatment of sovereign bonds as ECB collateral was neither foreseeable nor driven by sovereign spreads – as they were simply equal or close to zero. Second, there is not much concern with respect to macro-fiscal fundamentals or liquidity, either. Albeit high spreads should exert influence on debt levels, growth, etc. in the future, this should not occur in the same period.

Similarly, some of our explanatory variables, in particular macro-fiscal fundamentals, may themselves be potential outcomes of the collateral reform, which would raise concerns of multicollinearity. To address this issue, we run alternative versions of our baseline regressions with explanatory variables fixed at their pre-treatment levels and omitting country fixed effects. The results presented in the following sections remain unchanged.

2.4.2 Data and variables

For the identification of structural demand and supply shocks, which are required to construct the treatment variable, we use data on real GDP and the GDP deflator from the World Bank's World Development Indicators and the OECD Annual National Accounts since 1960. Moreover, as the outcome variable, we use *sovereign spreads*, computed as the difference between the yields of government bonds with a ten-year maturity of the sample countries and Germany. Our approach is common in the literature presented in section 2.2. Monthly yield data is provided by Eurostat.

Aside from that, we include a variety of controls. Information on *sovereign credit ratings* is available from S&P Global Ratings, Moody's and Fitch. Controls further encompass macro-fiscal fundamentals, which we choose in line with the literature.

Three fiscal variables are covered by the estimation. First, the *debt-to-GDP ratio*, extracted from Eurostat, acts as a measure of a country's debt level. The relationship is supposably non-linear, so we add the squared debt-to-GDP ratio to the regression, reflecting the fact that investors' sensitivity to potential default should increase the more debt a government accumulates. Second, the relative stock of debt is accompanied by the *budget balance* (as a percentage of GDP), which is in turn a flow variable. Both budget balances and GDP data are retrieved from the IMF's International Financial Statistics. Third, we add the less frequently used *primary budget balance*, calculated as the budget balance bar interest payments relative to GDP, and taken from the IMF's Government Finance Statistics. The measure is directly controlled by a government and not affected by changing interest rates, so it conveys more profound information on the actual fiscal stance than the budget balance itself.

Three further variables capture the broader macroeconomic environment. First, we include *economic growth* as an indicator of how well the government is able to raise tax revenue. Data comes from the OECD's Quarterly National Accounts. Second, we take a country's external balance into account, approximated by the *current account balance* relative to GDP. Data stems from the OECD's Main Economic Indicators. Current account surpluses and deficits affect sovereign default risk because they represent an economy's net foreign wealth or indebtedness, respectively. Third, international trade considerations are measured by the *real effective exchange rate*. We use the index of real effective exchange rates provided by the IMF's International Financial Statistics. It is informative on a country's competitiveness in the sense that an appreciation (depreciation) could induce future current account deficits (surpluses) and consequent debt problems.

Apart from macro-fiscal fundamentals, we further control for *liquidity* in our model, since higher liquidity should come along with lower spreads. As we elaborated in section 2.2, there is a wide range of potential variables, reaching from turnover volumes and bid-ask spreads to market size. Bearing in mind what the literature has revealed about significance and endogeneity of these measures, we follow Attinasi et al. (2009) in approximating liquidity risk by market size. Specifically, we use gross government debt issuance as a share of total Euro Area issuances. Information on debt issuances is offered by the ECB's Statistical Data Warehouse.

Lastly, international risk aversion proves to be a determinant of sovereign spreads. A natural figure for risk aversion would be the spread between top-rated US corporate bond yields and US treasury yields. However, since the measure varies only over time, it is implicitly integrated through time fixed effects.

We use data at the monthly level. Since macro-fiscal fundamentals are mostly published once a quarter, linear interpolation is required. Admittedly, this comes at the cost of reducing standard errors, but it allows for more variation in the dependent variable. Moreover, the interpolation is applied to highly persistent stock variables only, keeping the threat to valid statistical inference moderate (Dell'Ariccia et al., 2006; Hauner et al., 2010; Beirne and Fratzscher, 2013). In addition, for flow variables, such as the budget balance, that are only available quarterly, we assume these variables to be constant over the three months of a quarter.

The final sample consists of eight Euro Area founding member countries. We include as core countries Austria, Belgium, France, and the Netherlands, while Ireland, Italy, Portugal, and Spain serve as periphery countries. Germany is excluded for its role as reference country, and Greece faces endogeneity issues in our robustness checks, as we will see in the next section. We further omit the two smallest core Eurozone countries Finland and Luxembourg so as to keep the two groups of equal size.

Table 2.1: Summary statistics by group
This table compares periphery and core countries with regard to spreads and a range of macro-fiscal fundamentals over the period 2005M1–2005M6, when the Single List was announced. The lower part reports the month-on-month changes of spreads and some macro-fiscal fundamentals.

	Periphery		Core		
	Mean	SD	Mean	SD	t-stat
Spread	0.057	0.026	0.043	0.027	−0.943
Debt	62.392	0.431	72.663	1.155	20.409
Budget	−2.834	0.810	−4.009	3.456	−0.811
PBudget	2.114	0.064	1.003	0.029	−38648
Growth	2.782	0.155	2.103	0.246	−5.725
CA	−4.755	0.204	3.145	0.086	87.437
REER	102.233	0.860	103.987	0.954	3.344
$\Delta Spread_{t,t+1}^{2005M1-2005M6}$	0.000	0.031	0.001	0.029	0.048
$\Delta Debt_{t,t+1}^{2005M1-2005M6}$	0.246	0.078	0.688	0.443	2.407
$\Delta Budget_{t,t+1}^{2005M1-2005M6}$	−0.114	1.165	−0.021	4.029	0.055
$\Delta PBudget_{t,t+1}^{2005M1-2005M6}$	0.047	0.178	0.046	0.141	−0.003
$\Delta Growth_{t,t+1}^{2005M1-2005M6}$	0.093	0.078	−0.148	0.149	−3.507
$\Delta CA_{t,t+1}^{2005M1-2005M6}$	−0.101	0.211	−0.049	0.075	0.573
$\Delta REER_{t,t+1}^{2005M1-2005M6}$	−0.529	0.542	−0.517	0.586	0.038

2.5 Results

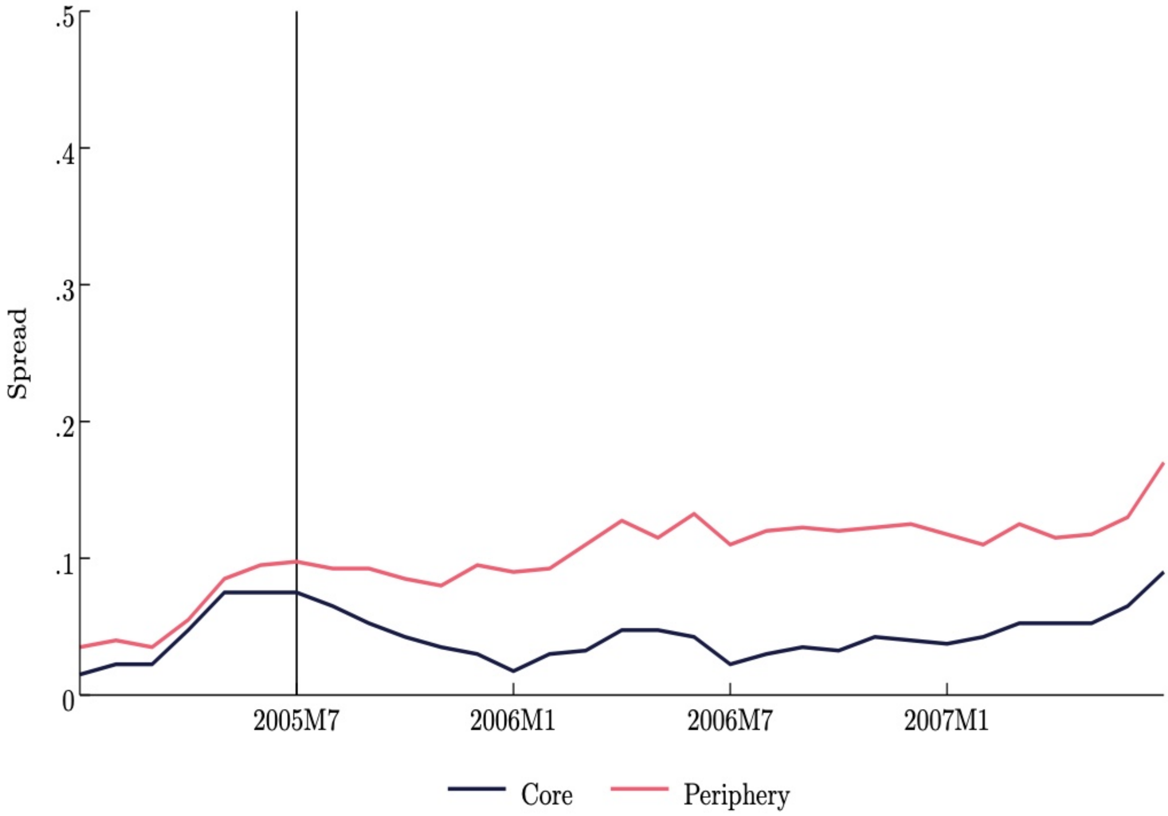
The empirical analysis is performed in two steps. First, we document that the introduction of conditionality into the ECB collateral framework contributed significantly to the rise of sovereign spreads. Second, we identify the underlying channels. We have already pointed out that the credit rating channel is inactive, which is why we subsequently compare the core-periphery – our baseline identification – and the macro-fiscal channel. A series of robustness checks is provided at the end of the section.

Before the results are presented, we show evidence that core and periphery Euro Area countries are suitable comparison groups. Table 2.1 reports summary statistics of the key variables in our model before the Single List was created for periphery and core countries separately.

The figures in the upper part of Table 2.1 reveal that the two groups both experienced spreads close to zero, but clearly differed in terms of macro-fiscal fundamentals. Notably, macro-fiscal variables tended to be more beneficial in peripheral Eurozone members. They had, on average, lower debt levels, smaller budget deficits, larger primary surpluses, higher growth rates, and lower real effective exchange rates.

The fact that the periphery exhibits more favorable average macro-fiscal fundamentals reassures our approach of distinguishing countries by business cycle synchronicity. It would be cast into doubt if the periphery status, in contrast, correlated with worse macro-fiscal data. Since this is not the case, we may plausibly argue that, if the SL event raised sovereign spreads in the periphery, the effect should not be driven by macro-fiscal data.

Figure 2.2: Sovereign spreads in the core and periphery Euro Area
This figure shows the evolution of average sovereign spreads on ten-year maturity government bond yields in core and periphery Euro Area countries, respectively, relative to Germany over the period 2005M1–2007M7 in percentage points. The vertical line at 2005M7 indicates the announcement time of the SL event.



Moreover, albeit differing in levels, key variables in the periphery and the core evolved similarly prior to the event. In the lower panel of Table 2.1, we report trends in spreads and macro-fiscal fundamentals until June 2005.[11] The co-movement of these variables is evident, most importantly in the case of sovereign spreads. Figure 2.2, depicting average spreads in the two groups before the financial crisis, supports this pattern. All in all, these findings assure the appropriateness of our approach.

2.5.1 Implementation of conditional eligibility

First, we establish that the ECB's decision to make collateral eligibility conditional contributed to the emergence of sovereign bond yield spreads. The main coefficient of interest is β in equations (2.1) and (2.2).

Table 2.2 shows the results, where columns (1) and (2) refer to the binary treatment variable, and columns (3) and (4) refer to the continuous treatment variable. It turns out that periphery countries experienced higher spreads in response to the event. The effect

[11] t-statistics smaller than two in absolute terms indicate that different trends can be ruled out with a probability of at least 95%.

Table 2.2: Sovereign spreads and conditional eligibility
This table reports estimates of the effect of the SL event on sovereign spreads in periphery countries relative to core countries over the period 2005M1–2006M12. The corresponding regression equations are (2.1) and (2.2). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. The treatment variable is the interaction of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and either a binary periphery dummy or a continuous shock correlation variable. Further controls are added, independently in columns (1) and (3), and interacted with the time dummy in columns (2) and (4). Columns (1) and (2) report coefficients for the binary treatment variable, while columns (3) and (4) report coefficients for the continuous treatment variable. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread			
	(1)	(2)	(3)	(4)
$SL^{2005M7} \times Periphery$	0.0304*	0.1994***		
	(0.0157)	(0.0489)		
$SL^{2005M7} \times Correlation$			−0.0913**	−0.5388***
			(0.0435)	(0.1518)
Debt	0.0042	−0.0080	0.0038	−0.0097
	(0.0049)	(0.0084)	(0.0049)	(0.0089)
$Debt^2$	0.0000	0.0001**	0.0000	0.0001**
	(0.0000)	(0.0001)	(0.0000)	(0.0001)
Budget	0.0019***	0.0033***	0.0019***	0.0032***
	(0.0007)	(0.0005)	(0.0006)	(0.0005)
PBudget	−0.0056	−0.0158	−0.0058	−0.0444**
	(0.0047)	(0.0189)	(0.0047)	(0.0203)
Growth	0.0061	0.0099	0.0057	0.0089
	(0.0089)	(0.0135)	(0.0089)	(0.0140)
CA	−0.0058*	−0.0125***	−0.0055*	−0.0103**
	(0.0034)	(0.0044)	(0.0033)	(0.0046)
REER	−0.0110	0.0303**	−0.0097	0.0269**
	(0.0067)	(0.0120)	(0.0062)	(0.0125)
Liquidity	0.0007	0.0007	0.0007	0.0007
	(0.0008)	(0.0006)	(0.0008)	(0.0006)
$SL^{2005M7} \times AAA$		−0.0955		0.0328
		(0.0742)		(0.0672)
$SL^{2005M7} \times Debt$		0.0192**		0.0209**
		(0.0083)		(0.0091)
$SL^{2005M7} \times Debt^2$		−0.0001**		−0.0001**
		(0.0001)		(0.0001)
$SL^{2005M7} \times Budget$		−0.0042***		−0.0040***
		(0.0009)		(0.0009)
$SL^{2005M7} \times PBudget$		0.0017		0.0305
		(0.0178)		(0.0187)
$SL^{2005M7} \times Growth$		−0.0520***		−0.0498***
		(0.0151)		(0.0153)
$SL^{2005M7} \times CA$		0.0188***		0.0161***
		(0.0048)		(0.0050)
$SL^{2005M7} \times REER$		−0.0169		−0.0142
		(0.0118)		(0.0124)
Time FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Adj. R^2	0.915	0.953	0.915	0.953
Observations	144	144	144	144

is statistically significant, irrespective of whether the binary or the continuous treatment variable is used. It is furthermore economically important. Keeping all else fixed, spreads in the periphery increased by up to 20 basis points relative to the core.[12]

The coefficients of the interacted control variables furthermore indicate that, in the aftermath, countries with favorable macro-fiscal fundamentals benefited from lower spreads. The latter dampens the widening of yield differences in the periphery, whose macro-fiscal position turned out better than in the core, as outlined above. Nonetheless, that does not offset the overall sizable response of spreads. Given that they amounted on average to five basis points before and ten basis points after the event, our estimates in their entirety imply a doubling of sovereign spreads in periphery countries as a consequence of establishing conditional eligibility.

Notably, yield spreads are unresponsive to whether governments do or do not have a prime rating (AAA). We will be more precise on control variables in general, and macro-fiscal fundamentals in particular, below.

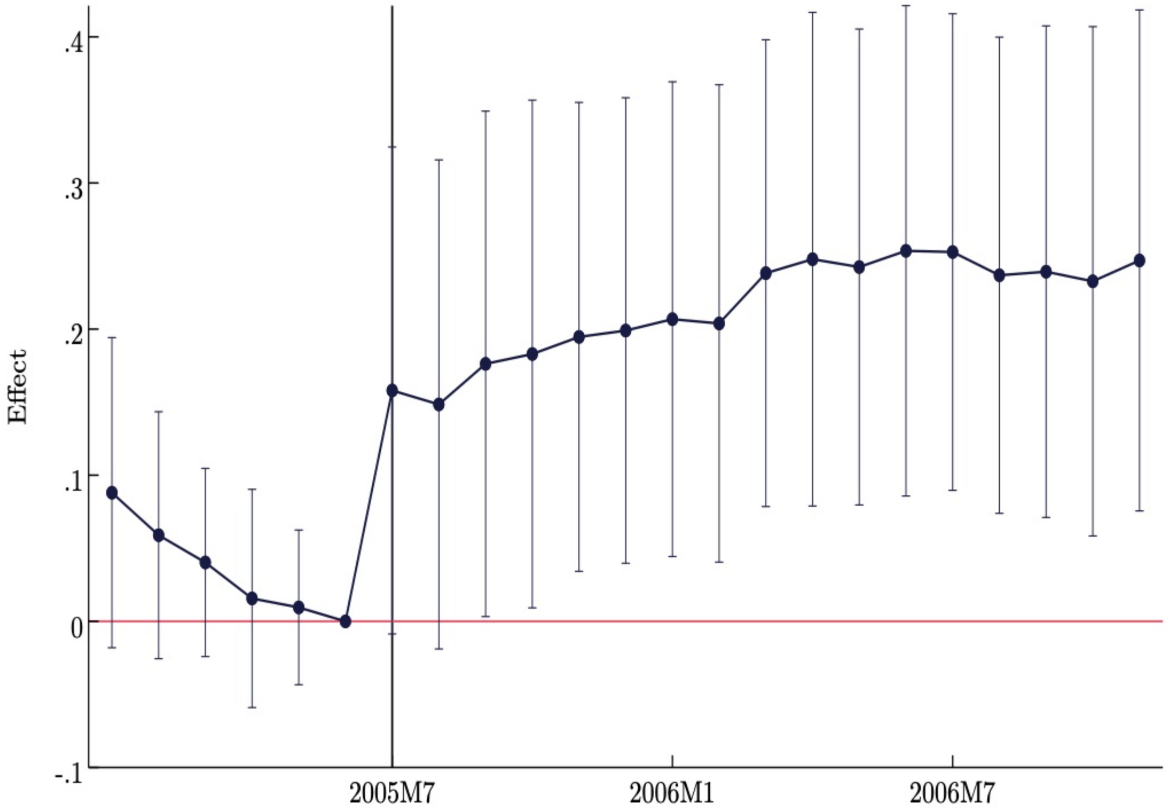
The coefficients presented thus far are average estimates over the entire sample period. In addition, we study the effect of implementing conditional eligibility more in detail by allowing for time-variant coefficients for each month separately. This is helpful to understand the dynamics of the effect, and to test the assumption of common trends prior to the event. To that end, we estimate the following two modifications of our baseline model:

$$\begin{aligned} \mathit{Spread}_{ct} &= \alpha_c + \alpha_t + \sum_{j=-J}^{J} \beta_j \times \mathit{Periphery}_c \times SL_{t+j}^{2005M7} \\ &\quad + \gamma^0 \times X_{ct} + \gamma^1 \times X_{ct} \times SL_t^{2005M7} + \epsilon_{ct} \qquad (2.5) \\ \mathit{Spread}_{ct} &= \alpha_c + \alpha_t + \sum_{j=-J}^{J} \beta_j \times \mathit{Correlation}_c \times SL_{t+j}^{2005M7} \\ &\quad + \gamma^0 \times X_{ct} + \gamma^1 \times X_{ct} \times SL_t^{2005M7} + \epsilon_{ct}. \qquad (2.6) \end{aligned}$$

Figure 2.3 shows the regression results for equation (2.5). Since the estimates for months before the SL event are all small and insignificant, we find support for the assumption that pre-treatment spreads of core and periphery countries evolved homogeneously. Moreover, after the event, there is a sharp upward trend of spreads in the peripheral Euro Area

[12] The coefficients turn out to be larger if controls are interacted with the time dummy. This is because, after the event, the total estimated effect of our set of controls has a decreasing effect on spreads, which, in columns (1) and (3), is all captured by the first coefficient. However, in columns (2) and (4), the latter isolates the treatment effect on periphery relative to core countries. Since the Single List time dummy is furthermore mechanically correlated with the interacted controls, standard errors increase as well if the latter are added to the model.

Figure 2.3: Coefficient estimates around the event
This figure shows regression coefficients and confidence intervals for the difference in sovereign spreads between periphery and core Euro Area countries in each month. The coefficient is normalized to zero in 2005M6, i. e. the month before the SL event. Vertical lines indicate 99% confidence intervals based on standard errors robust to heteroskedasticity and autocorrelation. The vertical line at 2005M7 indicates the announcement time of the SL event.



compared to the core. Coefficients become significant and keep rising until 2006M4, remaining at this level afterwards. They are sizeable, amounting to roughly 20 basis points, in line with the average effect.

In summary, our evidence establishes a causal link between the adoption of conditional collateral eligibility standards and the subsequent rise in sovereign bond yield spreads. We now turn to the channels by which the shift in collateral policies took effect.

2.5.2 Periphery premium

We proceed by estimating equations (2.3) and (2.4). This specification directly compares the core-periphery and the macro-fiscal channel, allowing us to identify which dominates in the transmission of the SL event to sovereign spreads.

β^P yields an estimate of the effect that we refer to as the *periphery premium*. It captures the variation in spreads in response to the event that can be explained by asymmetries in the business cycles of a country and the remaining Eurozone. It reflects the fact that being different from the core is economically disadvantageous under a common monetary

Table 2.3: Channels (binary)
This table reports estimates of the effects of the SL event on sovereign spreads in periphery countries relative to core countries, and in comparison of countries with different levels of macro-fiscal fundamentals, respectively, over the period 2005M1–2006M12. The corresponding regression equation is (2.3). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. Treatment variables are interactions of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and the binary periphery dummy as well as, by column, the level of one macro-fiscal fundamental in the month prior to the SL event. Further controls are added, both independently and interacted with the time dummy. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$SL^{2005M7} \times Periphery$	0.1994***	0.0341	0.2255	0.1745***	0.1825***	0.1703**	0.1759***
	(0.0489)	(0.0660)	(0.1512)	(0.0464)	(0.0507)	(0.0855)	(0.0560)
$SL^{2005M7} \times AAA^{2005M6}$	−0.0955						
	(0.0742)						
$SL^{2005M7} \times Debt^{2005M6}$		0.0008					
		(0.0009)					
$SL^{2005M7} \times Budget^{2005M6}$			−0.0037				
			(0.0175)				
$SL^{2005M7} \times PBudget^{2005M6}$				0.0024			
				(0.0170)			
$SL^{2005M7} \times Growth^{2005M6}$					−0.0145		
					(0.0335)		
$SL^{2005M7} \times CA^{2005M6}$						0.0157	
						(0.0100)	
$SL^{2005M7} \times REER^{2005M6}$							−0.0377
							(0.0246)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interacted Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.953	0.936	0.944	0.950	0.944	0.951	0.951
Observations	144	144	144	144	144	144	144

policy.

In contrast, β^{MF} represents the macro-fiscal channel. If it is significant, the estimate tells us that spreads emerged because investors responded to the SL event by demanding higher yields from countries with an unfavorable position in macro-fiscal fundamental MF_c at the time of treatment. We perform several estimations with MF_c being either the credit rating indicator AAA or one of the macro-fiscal fundamental variables. Our results are compiled in Table 2.3 and Table 2.4 for both the binary and the continuous exposure measure, respectively.

Both tables unveil a striking result. The periphery premium is highly significant under most specifications while macro-fiscal channels and credit ratings are of minor importance. If the binary exposure variable is used (see Table 2.3), the periphery premium is significant compared to all macro-fiscal channels but through debt and the budget balance, which are, in turn, insignificant as well. The premium amounts to approximately 17 to 20 basis points, resembling the estimates of the effect of implementing conditional eligibility reported in the previous section. Adjusting for the dampening effect of control variables,

Table 2.4: Channels (continuous)
This table reports estimates of the effects of the SL event on sovereign spreads in periphery countries relative to core countries, and in comparison of countries with different levels of macro-fiscal fundamentals, respectively, over the period 2005M1–2006M12. The corresponding regression equation is (2.4). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. Treatment variables are interactions of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and the continuous shock correlation variable as well as, by column, the level of one macro-fiscal fundamental in the month prior to the SL event. Further controls are added, both independently and interacted with the time dummy. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$SL^{2005M7} \times Correlation$	-0.5388^{***}	0.0719	-0.8340^{***}	-0.5381^{***}	-0.5083^{***}	-0.3825	-0.5426^{***}
	(0.1518)	(0.1656)	(0.2940)	(0.1358)	(0.1100)	(0.2621)	(0.2386)
$SL^{2005M7} \times AAA^{2005M6}$	-0.0328						
	(0.0672)						
$SL^{2005M7} \times Debt^{2005M6}$		-0.0004					
		(0.0005)					
$SL^{2005M7} \times Budget^{2005M6}$			0.0042				
			(0.0043)				
$SL^{2005M7} \times PBudget^{2005M6}$				0.0307			
				(0.0148)			
$SL^{2005M7} \times Growth^{2005M6}$					-0.0069		
					(0.0338)		
$SL^{2005M7} \times CA^{2005M6}$						0.0097	
						(0.0082)	
$SL^{2005M7} \times REER^{2005M6}$							-0.0335
							(0.0178)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interacted Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.953	0.933	0.944	0.950	0.945	0.951	0.951
Observations	144	144	144	144	144	144	144

these numbers imply a doubling of peripheral sovereign spreads from five to ten basis points.

Employing the continuous exposure measure, the results are similar. Periphery member states experienced significantly increasing yield spreads, while macro-fiscal fundamental data did not contribute to this increase. The periphery premium is insignificant only if combined with the macro-fiscal channels through debt and the current account balance, both being insignificant themselves.

Overall, the empirical evidence suggests that, similar to credit ratings, macro-fiscal variables did not channel the surge in sovereign spreads in response to the revised collateral framework. Instead, the dominant force is a periphery premium. It indicates that markets demanded an additional premium from countries with business cycles poorly aligned with the remaining Eurozone.

Zooming in on the periphery premium. Our analysis reveals that the ECB's shift from an unconditional to a conditional handling of sovereign bonds as central bank collat-

Table 2.5: Descriptive statistics on expected macro-fiscal data by group
This table compares periphery and core countries with regard to official forecasts of macro-fiscal variables and market expectations of credit default. The first four rows display 2005–2007 averages of official forecasts of macro-fiscal variables. The middle four rows display 2005–2007 changes in official forecasts of macro-fiscal variables. Official forecasts are by the European Commission. The latter two rows display average 10-year CDS spreads, both over the period 2006M1–2008M9 and 2006M1–2006M12. Means are taken within the periphery and the core group, respectively.

	Periphery	Core	Source
Official forecast of:			
$\overline{Debt}^{2005-2007}$	62.100	69.200	
$\overline{Budget}^{2005-2007}$	−2500	−1800	Own calculations based on
$\overline{Growth}^{2005-2007}$	2.400	1.800	European Commission (2005)
$\overline{CA}^{2005-2007}$	−5400	2.100	
$\Delta Debt^{2005-2007}$	0.300	−1550	
$\Delta Budget^{2005-2007}$	0.150	0.000	Own calculations based on
$\Delta Growth^{2005-2007}$	0.550	0.950	European Commission (2005)
$\Delta CA^{2005-2007}$	−0500	−0275	
$\overline{CDS}^{2006M1-2008M9}$	0.202	0.077	Own calculations based on
$\overline{CDS}^{2006M1-2006M12}$	0.065	0.021	Fontana and Scheicher (2010)

eral widened government bond yield spreads significantly. Strikingly, however, this effect did not unfold through the channel related to macro-fiscal fundamentals, as spreads kept being unresponsive to variations in both macro-fiscal data and credit ratings. In place of the macro-fiscal channel, we find a periphery premium, entailing higher yield spreads for countries with dissimilar business cycles.

The underlying mechanism, establishing a causal link between business cycle mismatches and government bond pricing, is yet unclear. How can those mismatches affect sovereign spreads other than through differential default risk perceptions associated with a country's macro-fiscal situation? An obvious hypothesis is that, while asynchronous business cycles are not reflected in *current* macroeconomic data, they may well raise negative expectations about the *future* macro-fiscal position.

Performing a proper regression analysis using data on expected values of macro-fiscal variables is elusive. On the one hand, data retrieved from official forecasts or market-implicit expectations is scarce or not readily available for the sample period.[13] On the other hand, the cross-section dimension of our analysis is the country level, limited to members of the Eurozone, which naturally entails a small number of observations.

Instead, we provide descriptive statistics on variables related to market expectations about future default risk, disaggregatedly for the Eurozone periphery and core, in Table

[13] Some studies, e. g. Attinasi et al. (2009) and Haugh et al. (2009), make use of expected data based on official forecasts of fiscal variables. However, given long time intervals between the publication dates of those forecasts, their procedure requires restrictive assumptions like linear interpolation or constancy of variables imposed on the data over long sample periods.

2.5.[14] We employ two distinct data sources, comprising official forecasts of macroeconomic indicators as well as market-based measures. The first part of Table 2.5 shows the means of selected macro-fiscal variables over the period 2005–2007 as forecasted by the European Commission in the fall of 2005. We further compute time trends in these projections as the difference between the 2007 and 2005 values. Given that official forecasts by public institutions, such as the European Commission, inform investors about future macroeconomic developments, they may well be assumed to shape market expectations. In the lower part of the table, we complement those forecast-based indicators by market-based measures of default risk. A common measure is the spread of interest rates in credit default swaps (CDS) for a given country and the risk-free rate. We show the mean CDS spread for both groups over the short term (2006M1–2006M12) and the medium term until the beginning of the financial crisis (2006M1–2008M9).

The figures in Table 2.5 suggest that our periphery indicator is associated with an expected deterioration of future macro-fiscal fundamentals. Although the Eurozone periphery partially featured more beneficial expected levels than the core, e. g. with respect to debt levels or real GDP growth – a finding in line with pre-treatment trends (see Table 2.1) – its macro-fiscal position was projected to evolve less favorably. For instance, debt-to-GDP ratios were forecasted to rise in the periphery, while declining in the core. Similarly, with respect to the budget and current account balances, core countries were expected to outperform the periphery. This pattern is equivalently reflected in CDS spread differentials. Both over the short and the medium term, periphery CDS spreads turned out to be roughly three times as high as those in the core, capturing a substantially larger probability of default perceived by the market.

In conclusion, our measure of business cycle dissimilarities is arguably linked to adverse beliefs about the future creditworthiness of the Eurozone periphery. Such misalignments may translate into ineffective monetary policy, raising concerns about a deterioration of macro-fiscal fundamentals in the future. Thus, while the periphery premium does not reflect an *actual* economic or fiscal arrear relative to the core, it may well indicate that markets *expected* such an arrear to lie ahead. This further raises the question of whether credit ratings are a suitable policy tool, given they ought to be reflective of such negative market expectations. However, in light of our evidence on the lack of variation and significance of ratings for sovereign spreads, this is not supported by the data.

[14] We neglect the notion of redenomination risk, stemming from the possibility of a country dropping out of the monetary union, for the lack of available empirical measures of this type of risk.

2.5.3 Time-varying effects of macro-fiscal fundamentals

Our baseline analysis of the effect of adopting conditional eligibility produces additional insights into the time-varying importance of macro-fiscal fundamentals for sovereign spreads before and after the event (see Table 2.2). Hence, while the macro-fiscal channel cannot explain the emergence of yield differentials in response to the collateral policy revision, those variables may well have played a role in its aftermath, as is suggested by columns (2) and (4) of Table 2.2.

This pattern is particularly pronounced in the case of debt and economic growth. Whereas spreads were unresponsive to current levels of these variables prior to the SL event, they have been responsive indeed afterwards. Our estimates imply that, in the post-treatment period, a one standard deviation increase in the debt-to-GDP ratio results in a 50 basis point increase in spreads. Correspondingly, an increase of the growth rate by one standard deviation reduces spreads by eight basis points. These figures are sizable, reflecting that markets started to punish excessive debt positions and low economic growth. With regard to the fiscal stance, we find that the primary budget balance is largely uninformative for explaining spread movements. Moreover, the budget balance has quantitatively negligible explanatory power.

Moreover, a country's external position appears to matter. While the effect of the current account balance flips sign by the event, the real effective exchange rate turns out to have a time-invariant effect on sovereign spreads. It is economically significant, amounting to an increase of spreads by approximately 21 basis points in response to a one standard deviation increase of the exchange rate. Arguably, the estimate mirrors the special role of international competitiveness in a monetary union. When giving up control over its currency, a country waives the capacity to devaluate or revaluate in order to stabilize the economy. It is hence plausible that markets generally perceive the lack of currency control as an important factor of sovereign risk. This aspect has already been stressed in Maltritz (2012).

To conclude, our results provide evidence for a structural break in the link between macro-fiscal fundamentals and sovereign spreads. While they could not explain variations in yield differences before the revision of the collateral framework, some of them turned into significant determinants in the aftermath. That suggests that the link has been constituted by the adoption of conditional eligibility in 2005.

2.5.4 Robustness

To complete our analysis, we conduct several robustness tests, showing that our results do not change if we modify the empirical setup.

First, we check how sensitively our estimates respond to a modification of the credit rating measure. In the previous analysis, the binary indicator *AAA* was included as a control variable, being equal to one if a government held a prime rating, and to zero otherwise. In Table 2.11 in the appendix, we repeat the regressions based on the equations (2.1) and (2.2), replacing the prime rating indicator by the continuous variable *Rating*. The latter exhibits slightly more variation than its binary counterpart, however, given no sample country was given a rating lower than the high medium grade (AA), to a limited extent. Accordingly, we find no major changes of the coefficients from Table 2.2, neither with respect to statistical nor economic significance. Importantly, the rating variable remains insignificant, reassuring the robustness of the effect of implementing conditional eligibility on periphery countries' sovereign spreads.

Second, we test to what extent our estimates depend on the choice of the sample period, which has been set to 2005M1–2006M12 thus far. To this end, we perform the regressions based on equations (2.1) to (2.4) for two longer time horizons, starting in 2004M7, and extending the period to 2007M7 and 2008M8, respectively. These dates correspond to the months before the first signs of financial crisis appeared (which was in August 2007, as commonly agreed), and before the crisis reached its peak with the failure of Lehman Brothers in September 2008. The results are reported in Tables 2.12 to 2.17 in the appendix. Apart from some differences in the coefficients of control variables, the estimates of the effect and its channels are similar to those reported in the main text.

Third, we validate the effect of the implementation of conditional eligibility through a placebo test. We test whether the effect truly reflects the decision to make collateral eligibility conditional. The effect we measure could alternatively emanate from previous changes in actual credit ratings, thus reflecting usual market responses to rating publications rather than an institutional change questioning the unconditional eligibility of sovereign bonds as central bank collateral. Specifically, we modify the estimation of equations (2.1) and (2.2) by adding a placebo treatment indicator for November 2004. This was the time when Greek government bond ratings were set from A+ to A by S&P Global Ratings, approaching the later minimum requirement of A–.[15] Including the placebo indicator further requires a slight extension of the regression period (2004M8–2006M12). The results are compiled in columns (1) and (2) of Table 2.6. They suggest that the treatment effect of making eligibility conditional is barely affected, shrinking to 10 basis points, but remaining significant, while sovereign spreads did not respond to the downgrade in November 2004. We may conclude that our estimates truly capture the effect of

[15] To circumvent endogeneity issues, Greece is excluded from the sample. Assuming that downgrades have a signaling effect conveying information on the Eurozone as a whole, which has been argued to be plausible during the financial crisis, the Greek downgrade near the later threshold of A– might have induced investors to demand differentiated premia from other countries as well.

Table 2.6: Robustness tests

Columns (1) and (2) of this table report estimates of the effect of the SL event on sovereign spreads in periphery countries relative to core countries in two months over the period 2004M8–2006M12. The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. Treatment variables are interactions of either of two time dummies, that equal one as of the announcement of the Single List in 2005M7, and the last time a euro country experienced a rating downgrade before the SL event in 2004M11, respectively, and either a binary periphery dummy or a continuous shock correlation variable. Further controls are added, both independently and interacted with the time dummies. Column (1) reports coefficients for the binary treatment variable, while column (2) reports coefficients for the continuous treatment variable. The regressions in columns (1) and (2) include time and country fixed effects. Columns (3) to (6) of this table report estimates of the effect of the SL event on sovereign spreads in periphery countries relative to core countries seven days and one month after the announcement date on 22 July 2005, respectively. The corresponding regression equations are (2.7) and (2.8). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. The treatment variable is the interaction of a time dummy, that equals one as of 22 July 2005, and either a binary periphery dummy or a continuous shock correlation variable. Further controls are added. Columns (3) and (5) report coefficients for the binary treatment variable, while columns (4) and (6) report coefficients for the continuous treatment variable. The regressions in columns (3) to (6) include time fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread					
	2004M8–2006M12		7 days		30 days	
	(1)	(2)	(3)	(4)	(5)	(6)
$SL^{2005M7} \times Periphery$	0.1045**					
	(0.0508)					
$SL^{2005M7} \times Correlation$		−0.2912*				
		(0.1529)				
$SL^{2004M11} \times Periphery$	0.0078					
	(0.0095)					
$SL^{2004M11} \times Correlation$		−0.0311				
		(0.0281)				
$SL^{22jul2005} \times Periphery$			0.0117		−0.0033	
			(0.0132)		(0.0039)	
$SL^{22jul2005} \times Correlation$				0.0041		−0.0146*
				(0.0200)		(0.0078)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Interacted Controls	Yes	Yes	No	No	No	No
Adj. R^2	0.946	0.946	0.805	0.803	0.958	0.958
Observations	174	174	88	88	272	272

establishing conditional eligibility, but not of actual rating downgrades before.

Fourth, we evaluate our results by testing immediate responses of spreads around the SL event. We estimate the following two equations using daily data:

$$Spread_{ct} = \alpha_t + \beta \times Periphery_c \times SL_t^{22jul2005} + \gamma \times X_{ct} + \epsilon_{ct} \quad (2.7)$$

$$Spread_{ct} = \alpha_t + \beta \times Correlation_c \times SL_t^{22jul2005} + \gamma \times X_{ct} + \epsilon_{ct}. \quad (2.8)$$

There are two major differences to the previous models. Since variation of macro-fiscal fundamentals is limited at the daily level within a narrow time frame around the event, we first drop interacted controls. Second, we omit country fixed effects, given that our control variables capture country specifics quite well. The estimation is performed for a time window starting one week prior to the event and ending either one week or one month thereafter. Results are reported in columns (3) to (6) of Table 2.6. We do not find a significant response of sovereign spreads for periphery countries relative to core countries within seven days after the SL event. Hence, it appears there was no immediate market reaction to the new collateral rules. Yet, the earliest effect we document is within one month. Although being significant only if the continuous exposure measure is employed, the estimate suggests that periphery countries experienced a relative increase of spreads within one month after the event.

2.6 Conclusion

Sovereign bond yield spreads in the Eurozone are a peculiar phenomenon, given that neither monetary policy nor financial markets can obtain guidance by a historical example in how to deal with government debt. Consequently, it is all but unclear whether Euro Area sovereign bonds should be seen as safe or risky. The literature has provided strong evidence for the importance of macroeconomic fundamentals in sovereign bond pricing for the post-crisis period. However, the evolution of sovereign spreads prior to 2007 has not yet been sufficiently studied.

This chapter establishes a causal link between the emergence of government bond yield differentials before the financial crisis and the overhaul of ECB collateral policies in 2005. The latter constituted a major shift from unconditional towards conditional eligibility of sovereign bonds as central bank collateral by requiring them to satisfy a minimum rating requirement. Our results indicate that the move induced a significant widening of spreads.

In terms of the channels by which the event took effect, our results reject the established view, suggesting that spreads should rise in countries with unfavorable current macroeconomic and fiscal positions or credit ratings. Instead, we find that markets responded to asymmetries in business cycles. We show that sovereign spreads surged in countries whose business cycles were least aligned with the Eurozone average. Using the terminology of core and periphery countries, which is common in the business cycle literature, our analysis therefore provides evidence for a periphery premium. We further zoom in on the underlying mechanism linking business cycle mismatches to sovereign spreads by showing that periphery countries at the time were subject to worse market expectations about future macro-financial developments and creditworthiness than core countries.

Our results highlight the essential part that collateral frameworks play for the pricing of sovereign risk. Adjustments in those frameworks have the potential to provoke market responses through different channels, going beyond macro-fiscal indicators and making predictions elusive. This is of particular importance in the context of the Euro Area, which still lacks historical precedence in comparison to other major monetary unions.

Furthermore, we stress the role of business cycle dissimilarities for the evolution of Eurozone government bond yield spreads. We provide indicative evidence that business cycle mismatches are associated with less favorable market expectations about future macro-fiscal positions. From a policy perspective, it may hence be worthwhile to track and support the synchronization of business cycles within the monetary union. Moreover, that raises concerns regarding the suitability of credit ratings as policy tools, as they are supposed to reflect a deterioration of market expectations, which is rejected by our evidence. In an academic view, a more profound than ours characterization of the channels linking asymmetries in business cycles to expected macro-fiscal fundamentals and sovereign risk is a potential subject of future research.

2.A Appendix

2.A.1 Chronology of the creation of the Single List

Building on the chronology provided by van't Klooster (2021), we briefly recall how fiscal considerations contributed to the creation of the Single List. It started with the 1988 Delors Committee report on the need for fiscal constraints in the evolving European monetary system. It argued that, given high price volatility and its exposure to abrupt shocks to market expectations (Minsky, 1986; Aliber and Kindleberger, 2015), bond markets were not suitable as a disciplining instrument for national fiscal policies. Instead, constraints were to be implemented by means of fiscal rules, helping to attain the coordination required in a monetary union. These rules were first formulated 1992 in the Maastricht Treaty and further developed in the 1997 Stability and Growth Pact. Since then, member states are bound by quantitative criteria for debt and annual deficits as well as bans on monetary financing through the ECB or inter-state bail-outs.

Nonetheless, sovereign debt continued as an important financial instrument for monetary policy. Given its crucial role for the functioning of financial markets, it was used as collateral that private institutions pledged in exchange for central bank money. How it should be treated in this context was subject to a debate within the Eurosystem in the late 1990s. On one side, proponents advocated the adoption of private credit ratings, while, on the other side, a group of national central banks led by the German Bundesbank was skeptical about giving power to private institutions. They suggested to ensure sufficient creditworthiness of sovereign borrowers through a strict enforcement of the Stability and Growth Pact. In April 1997, the two sides agreed upon a compromise: there should be a minimum rating requirement for government bonds, but it remained effectively unused as it was kept secret.

The agreement was called into question after the Stability and Growth Pact was blurred by Germany and France in the early 2000s. The call for tighter fiscal constraints, including a greater role for disciplining through the market, was considerable (Buiter and Sibert, 2005; Fells, 2005). In July 2005, the ECB finally abandoned the position proposed by the Delors report, and published the decision to make sovereign bond haircuts conditional on credit agency ratings. The minimum rating requirement, set at a level of A– on a conventional scale, was specified in November.

2.A.2 Identification of supply and demand shocks

Our idenficiation of strucutral supply and demand shocks replicates the procedure by Bayoumi and Eichengreen (1992b). They apply the identification strategy proposed by Blanchard and Quah (1989), who assume that supply shocks have a permanent effect on output, while demand shocks affect output only temporarily.

Shocks are decomposed using the structural vector autoregression (SVAR) system

$$X_t = A(L)\epsilon_t = \sum_{i=0}^{\infty} L^i \begin{pmatrix} a_{11,i} & a_{12,i} \\ a_{21,i} & a_{22,i} \end{pmatrix} \begin{pmatrix} \epsilon_t^{demand} \\ \epsilon_t^{supply} \end{pmatrix},$$

where $X_t = (\Delta y_t, \Delta p_t)'$ is a vector of first differences of the logarithms of real GDP and the GDP deflator as a measure of the price level, $A(L)$ is a matrix lag polynomial of order L, and $\epsilon_t = \left(\epsilon_t^{demand}, \epsilon_t^{supply}\right)'$ is a vector of demand and supply shocks. The identifying assumption is that demand shocks have no long-run effects on real GDP growth, formally written as

$$\sum_{i=0}^{\infty} a_{11,i} = 0.$$

Imposing this long-run restriction, the SVAR is estimated for each sample country with two lags and annual output and inflation data covering the period 1960–2005. We obtain estimates of structural demand and supply shocks, which we use to compute correlation coefficients relative to Germany. The following table summarizes the results for two time frames. The period 1960–2005, i. e. prior to the Single List reform, is used for the empirical analysis in the main text. The shorter period 1960–1988 is covered in Bayoumi and Eichengreen (1992b) and reported for comparison.

Table 2.7: Correlation of demand and supply shocks
This table provides estimates of the correlation coefficients for demand and supply shocks relative to Germany.

	1960–1988		1960–2005	
Country	Demand shocks	Supply shocks	Demand shocks	Supply shocks
Austria	0.65	0.69	0.68	0.73
Belgium	0.67	0.72	0.68	0.71
France	0.64	0.71	0.65	0.72
Ireland	0.32	0.15	0.37	0.06
Italy	0.63	0.53	0.60	0.61
Netherlands	0.62	0.71	0.62	0.69
Portugal	0.49	0.61	0.52	0.67
Spain	0.45	0.48	0.49	0.52

2.A.3 Additional figures and tables

Table 2.8: Variables
This table provides an overview of the variables included in the regressions.

Variable name	Description	Frequency	Source
Spread	Spread between yields on government bonds with a ten-year maturity of Euro Area countries and Germany	Monthly	Eurostat
Periphery	Binary periphery indicator equal to 0 if a country forms part of the core Euro Area, and to 1 if a country forms part of the periphery Euro Area		Assignment to core and periphery following Bayoumi and Eichengreen (1992a,b)
Correlation	Correlation of supply shocks between Euro Area countries and Germany		(Bayoumi and Eichengreen, 1992b), Funke (1997) (only Austria)
SL^{YYYYMM}	Binary Single List time dummy equal to 0 for periods prior to YYYYMM, and to 1 for periods thereafter		
AAA	Binary sovereign credit rating indicator equal to 0 if a country is rated below AAA, and to 1 if a country is rated AAA		S&P Global Ratings, Moody's, Fitch
Rating	Numerical variable of sovereign credit ratings in the interval from 0 to 23 where each number corresponds to a rating on the S&P Global Ratings scale or Moody's and Fitch equivalents with 0 corresponding to default and 23 corresponding to an AAA rating		S&P Global Ratings, Moody's, Fitch
Debt	Stock of outstanding government debt divided by GDP	Quarterly	Eurostat
Budget	Budget balance divided by GDP	Quarterly	IMF International Financial Statistics
PBudget	Primary budget balance divided by GDP	Annual	IMF Government Finance Statistics
Growth	Annual growth rate of GDP	Quarterly	OECD Quarterly National Accounts
CA	Current account balance divided by GDP	Quarterly	OECD Main Economic Indicators
REER	Real effective exchange rate index based on consumer price index	Monthly	IMF International Financial Statistics
Liquidity	Gross government debt issuance divided by total Euro Area gross government debt issuance	Monthly	ECB Statistical Data Warehouse

Table 2.9: Summary statistics
This table provides summary statistics of spreads, a range of macro-fiscal fundamentals, and liquidity over the sample period 2005M1–2006M12 used for the analysis in the main text.

	Mean	SD	Min	Max	N
Spread	0.066	0.086	−0.250	0.340	192
Debt	66.737	25.716	23.600	110.900	192
Budget	−1.570	4.497	−17.978	8.804	192
PBudget	1.872	1.455	−0.567	4.710	168
Growth	2.800	1.476	0.365	6.806	192
CA	−1.312	5.603	−11.709	9.635	192
REER	102.214	1.682	98.467	106.575	192
Liquidity	10.958	10.536	0.000	35.517	168

Figure 2.4: Sovereign spreads in the Euro Area by country
This figure shows the evolution of sovereign spreads on ten year maturity government bond yields of the sample Euro Area countries over the period 1999M1–2019M12 in percentage points.

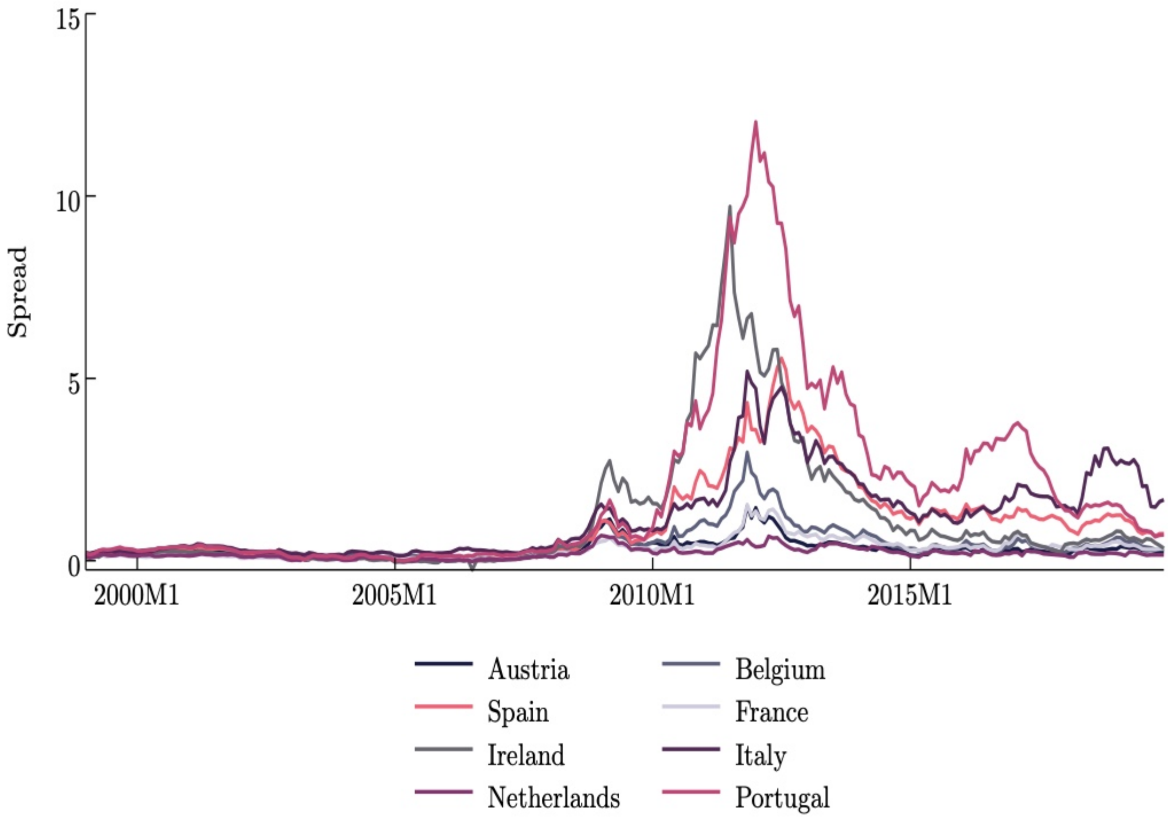


Figure 2.5: Sovereign credit ratings of sample Euro Area countries
This figure shows the evolution of sovereign credit ratings of the Euro Area countries included in the sample used for the analysis in the main text over the period 2003M1–2012M12. The figure includes ratings assigned by S&P Global Ratings, Moody's or Fitch only, and depicts the lowest rating assigned by one of these institutions at any point in time. The vertical line at 2005M7 indicates the announcement time of the SL event. The shaded area indicates the sample period 2005M1–2006M12 used for the analysis in the main text. The horizontal lines demarcate grade ranges.

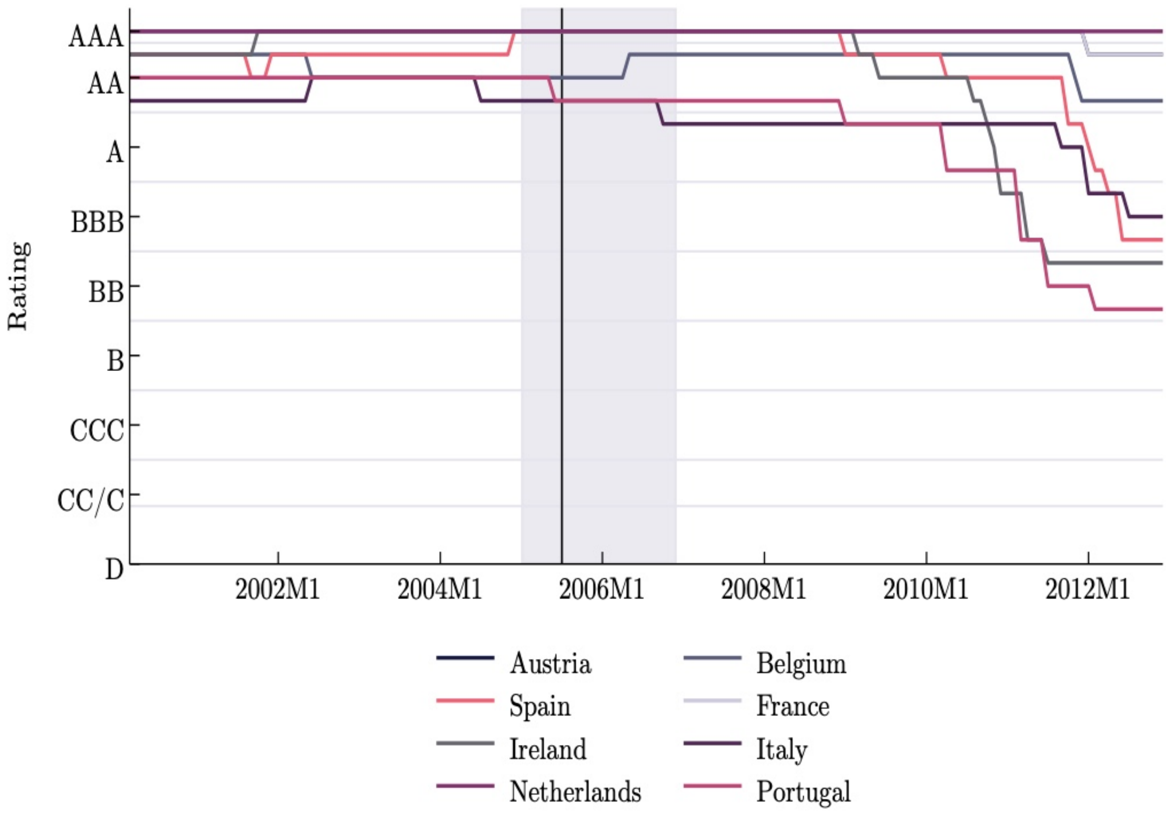


Figure 2.6: Sovereign credit ratings of Germany and Greece

This figure shows the evolution of sovereign credit ratings of Germany and Greece over the period 2003M1–2012M12. The figure includes ratings assigned by S&P Global Ratings, Moody's or Fitch only, and depicts the lowest rating assigned by one of these institutions at any point in time. The vertical line at 2005M7 indicates the announcement time of the SL event. The shaded area indicates the sample period 2005M1–2006M12 used for the analysis in the main text. The horizontal lines demarcate grade ranges.

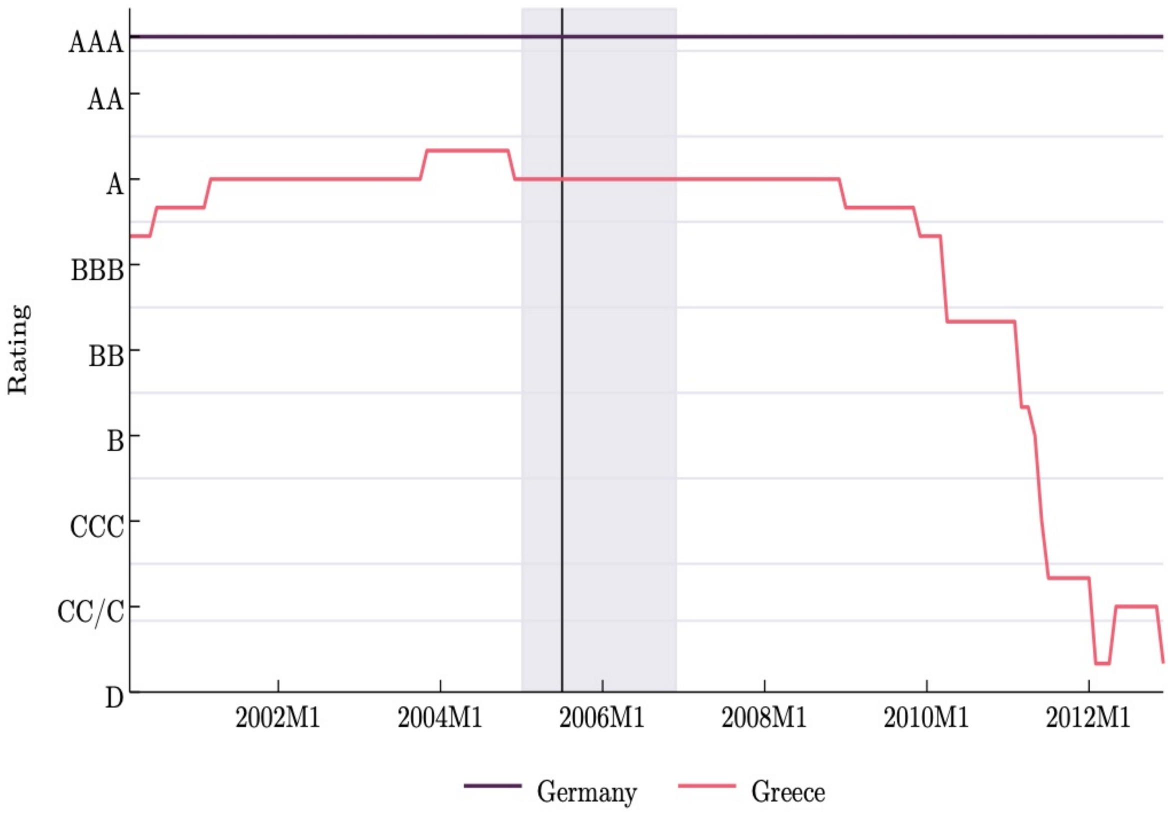


Table 2.10: Sovereign spreads and conditional eligibility (rating-based distinction)

This table reports estimates of the effect of the SL event on sovereign spreads in AAA-rated countries relative to below-AAA-rated countries over the period 2005M1–2006M12. The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. The treatment variable is the interaction of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and either a binary prime rating dummy or a continuous rating variable. Further controls are added, independently in columns (1) and (3), and interacted with the time dummy in columns (2) and (4). Columns (1) and (2) report coefficients for the binary treatment variable, while columns (3) and (4) report coefficients for the continuous treatment variable. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread			
	(1)	(2)	(3)	(4)
$SL^{2005M7} \times AAA$	−0.0528***	0.0593		
	(0.0125)	(0.0652)		
$SL^{2005M7} \times Rating$			−0.0179***	−0.0063
			(0.0041)	(0.0092)
Debt	−0.0012	0.0064	−0.0012	0.0009
	(0.0053)	(0.0078)	(0.0053)	(0.0065)
$Debt^2$	0.0001***	0.0000	0.0001**	0.0001
	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Budget	0.0017***	0.0037***	0.0017***	0.0035***
	(0.0006)	(0.0005)	(0.0006)	(0.0005)
PBudget	−0.0071	−0.0350*	−0.0028	−0.0463***
	(0.0050)	(0.0209)	(0.0050)	(0.0166)
Growth	0.0105	0.0458***	0.0053	0.0495***
	(0.0081)	(0.0134)	(0.0082)	(0.0133)
CA	−0.0003	−0.0006	0.0005	0.0030
	(0.0038)	(0.0047)	(0.0037)	(0.0042)
REER	0.0014	0.0330**	−0.0003	0.0269**
	(0.0048)	(0.0143)	(0.0047)	(0.0123)
Liquidity	0.0005	0.0006	0.0009	0.0007
	(0.0007)	(0.0006)	(0.0007)	(0.0006)
$SL^{2005M7} \times Debt$		0.0021		0.0082*
		(0.0069)		(0.0048)
$SL^{2005M7} \times Debt^2$		−0.0000		−0.0001*
		(0.0001)		(0.0000)
$SL^{2005M7} \times Budget$		−0.0043***		−0.0042***
		(0.0009)		(0.0009)
$SL^{2005M7} \times PBudget$		0.0218		0.0326**
		(0.0196)		(0.0163)
$SL^{2005M7} \times Growth$		−0.0833***		−0.0891***
		(0.0162)		(0.0154)
$SL^{2005M7} \times CA$		0.0046		0.0015
		(0.0044)		(0.0031)
$SL^{2005M7} \times REER$		−0.0223		−0.0155
		(0.0144)		(0.0123)
Time FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Adj. R^2	0.925	0.951	0.925	0.950
Observations	144	144	144	144

Figure 2.7: Coefficient estimates around the event (rating-based distinction)
This figure shows regression coefficients and confidence intervals for the difference in sovereign spreads between below-AAA-rated countries and AAA-rated countries in each month. The coefficient is normalized to zero in 2005M6, i. e. the month before the SL event. Vertical lines indicate 99% confidence intervals based on standard errors robust to heteroskedasticity and autocorrelation. The vertical line at 2005M7 indicates the announcement time of the SL event.

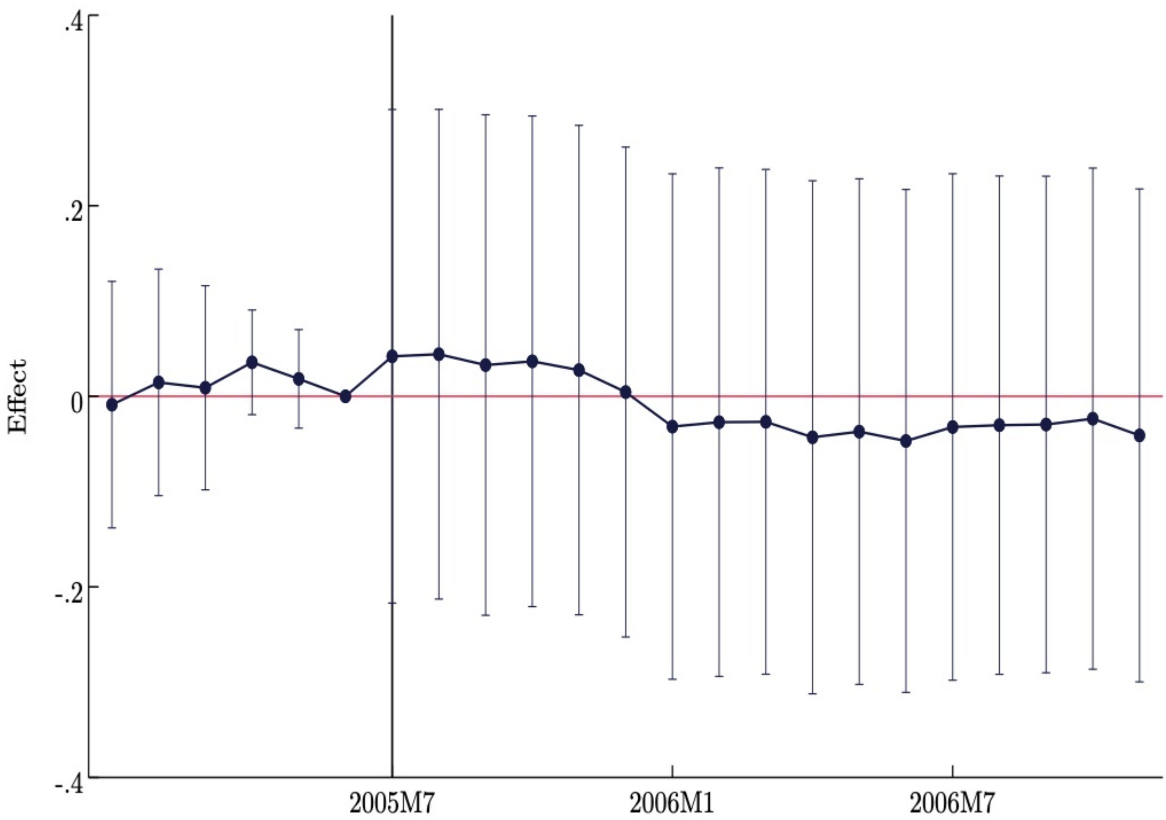


Table 2.11: Sovereign spreads and conditional eligibility (incl. continuous rating variable)

This table reports estimates of the effect of the SL event on sovereign spreads in periphery countries relative to core countries over the period 2005M1–2006M12. The corresponding regression equations are (2.1) and (2.2). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. The treatment variable is the interaction of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and either a binary periphery dummy or a continuous shock correlation variable. Further controls are added, independently in columns (1) and (3), and interacted with the time dummy in columns (2) and (4). Credit ratings are controlled for by a continuous rating variable instead of a binary variable distinguishing AAA-rated from below-AAA-rated countries. Columns (1) and (2) report coefficients for the binary treatment variable, while columns (3) and (4) report coefficients for the continuous treatment variable. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread			
	(1)	(2)	(3)	(4)
$SL^{2005M7} \times Periphery$	0.0304*	0.1671***		
	(0.0158)	(0.0400)		
$SL^{2005M7} \times Correlation$			−0.0915**	−0.5183***
			(0.0438)	(0.1401)
Rating	−0.0018	0.0391	−0.0017	−0.0143
	(0.0103)	(0.0387)	(0.0103)	(0.0391)
Debt	0.0042	−0.0089	0.0037	−0.0113
	(0.0050)	(0.0084)	(0.0049)	(0.0067)
$Debt^2$	0.0000	0.0001**	0.0000	0.0001**
	(0.0000)	(0.0001)	(0.0000)	(0.0001)
Budget	0.0019***	0.0032***	0.0019***	0.0031***
	(0.0007)	(0.0005)	(0.0007)	(0.0005)
PBudget	−0.0053	−0.0158	−0.0055	−0.0437**
	(0.0056)	(0.0193)	(0.0056)	(0.0177)
Growth	0.0059	0.0067	0.0055	0.0064
	(0.0090)	(0.0141)	(0.0090)	(0.0146)
CA	−0.0056	−0.0110**	−0.0053*	−0.0093*
	(0.0035)	(0.0047)	(0.0034)	(0.0049)
REER	−0.0111	0.0322***	−0.0098	0.0272**
	(0.0068)	(0.0117)	(0.0062)	(0.0117)
Liquidity	0.0007	0.0009	0.0007	0.0009
	(0.0008)	(0.0006)	(0.0008)	(0.0006)
$SL^{2005M7} \times Rating$		−0.0503		−0.0242
		(0.0384)		(0.0385)
$SL^{2005M7} \times Debt$		0.0199**		0.0226***
		(0.0079)		(0.0083)
$SL^{2005M7} \times Debt^2$		−0.0002**		−0.0002**
		(0.0001)		(0.0001)
$SL^{2005M7} \times Budget$		−0.0039***		−0.0038***
		(0.0009)		(0.0009)
$SL^{2005M7} \times PBudget$		0.0037		0.0315*
		(0.0183)		(0.0167)
$SL^{2005M7} \times Growth$		−0.0522***		−0.0507***
		(0.0155)		(0.0157)
$SL^{2005M7} \times CA$		0.0179***		0.0159***
		(0.0053)		(0.0054)
$SL^{2005M7} \times REER$		−0.0195*		−0.0146
		(0.0112)		(0.0113)
Time FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Adj. R^2	0.914	0.953	0.914	0.953
Observations	144	144	144	144

Table 2.12: Sovereign spreads and conditional eligibility (2004M7–2007M7)

This table reports estimates of the effect of the SL event on sovereign spreads in periphery countries relative to core countries over the period 2004M7–2007M7. The corresponding regression equations are (2.1) and (2.2). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. The treatment variable is the interaction of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and either a binary periphery dummy or a continuous shock correlation variable. Further controls are added, independently in columns (1) and (3), and interacted with the time dummy in columns (2) and (4). Columns (1) and (2) report coefficients for the binary treatment variable, while columns (3) and (4) report coefficients for the continuous treatment variable. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread			
	(1)	(2)	(3)	(4)
$SL^{2005M7} \times Periphery$	0.0352***	0.1039**		
	(0.0104)	(0.0405)		
$SL^{2005M7} \times Correlation$			−0.1948**	−0.8394***
			(0.0850)	(0.2829)
Debt	0.0057*	−0.0023	0.0080***	−0.0042
	(0.0030)	(0.0055)	(0.0031)	(0.0055)
$Debt^2$	0.0000	0.0001*	−0.0000	0.0001**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Budget	0.0010**	0.0033***	0.0011**	0.0033***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
PBudget	−0.0174***	−0.0244***	−0.0181***	−0.0234***
	(0.0025)	(0.0035)	(0.0026)	(0.0035)
Growth	0.0020	0.0162*	0.0030	0.0147
	(0.0046)	(0.0096)	(0.0049)	(0.0100)
CA	−0.0045**	−0.0078**	−0.0053**	−0.0083***
	(0.0021)	(0.0033)	(0.0022)	(0.0031)
REER	−0.0045	0.0125**	−0.0045	0.0104*
	(0.0035)	(0.0058)	(0.0042)	(0.0059)
Liquidity	0.0003	0.0001	0.0003	0.0002
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
$SL^{2005M7} \times AAA$		−0.1050**		−0.0376
		(0.0525)		(0.0435)
$SL^{2005M7} \times Debt$		0.0115**		0.0134**
		(0.0057)		(0.0055)
$SL^{2005M7} \times Debt^2$		−0.0001**		−0.0001**
		(0.0000)		(0.0000)
$SL^{2005M7} \times Budget$		−0.0037***		−0.0036***
		(0.0008)		(0.0008)
$SL^{2005M7} \times PBudget$		0.0073		0.0064
		(0.0047)		(0.0047)
$SL^{2005M7} \times Growth$		−0.0274**		−0.0250**
		(0.0109)		(0.0110)
$SL^{2005M7} \times CA$		0.0071**		0.0082***
		(0.0029)		(0.0029)
$SL^{2005M7} \times REER$		0.0018		0.0043
		(0.0063)		(0.0065)
Time FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Adj. R^2	0.912	0.935	0.909	0.935
Observations	222	222	222	222

Table 2.13: Channels (binary, 2004M7–2007M7)
This table reports estimates of the effects of the SL event on sovereign spreads in periphery countries relative to core countries, and in comparison of countries with different levels of macro-fiscal fundamentals, respectively, over the period 2004M7–2007M7. The corresponding regression equation is (2.5). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. Treatment variables are interactions of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and the binary periphery dummy as well as, by column, the level of one macro-fiscal fundamental in the month prior to the SL event. Further controls are added, both independently and interacted with the time dummy. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$SL^{2005M7} \times Periphery$	0.1039**	0.0511**	0.1083*	0.1116*	0.1099***	0.0729	0.0768*
	(0.0405)	(0.0245)	(0.0608)	(0.0612)	(0.0377)	(0.0503)	(0.0424)
$SL^{2005M7} \times AAA^{2005M6}$	−0.1050**						
	(0.0525)						
$SL^{2005M7} \times Debt^{2005M6}$		0.0001					
		(0.0006)					
$SL^{2005M7} \times Budget^{2005M6}$			0.0031				
			(0.0066)				
$SL^{2005M7} \times PBudget^{2005M6}$				−0.0344*			
				(0.0204)			
$SL^{2005M7} \times Growth^{2005M6}$					−0.0242		
					(0.0189)		
$SL^{2005M7} \times CA^{2005M6}$						0.0045	
						(0.0035)	
$SL^{2005M7} \times REER^{2005M6}$							−0.0100
							(0.0108)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interacted Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.935	0.922	0.925	0.909	0.933	0.933	0.932
Observations	222	222	222	222	222	222	222

Table 2.14: Channels (continuous, 2004M7–2007M7)

This table reports estimates of the effects of the SL event on sovereign spreads in periphery countries relative to core countries, and in comparison of countries with different levels of macro-fiscal fundamentals, respectively, over the period 2004M7–2007M7. The corresponding regression equation is (2.5). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. Treatment variables are interactions of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and the continuous shock correlation variable as well as, by column, the level of one macro-fiscal fundamental in the month prior to the SL event. Further controls are added, both independently and interacted with the time dummy. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$SL^{2005M7} \times Correlation$	-0.8394^{***}	-0.2682	-0.7266^{**}	-0.9302^{**}	-0.8739^{***}	-0.9172^{**}	-0.6060^{*}
	(0.2829)	(0.1720)	(0.3336)	(0.4219)	(0.2538)	(0.4538)	(0.3074)
$SL^{2005M7} \times AAA^{2005M6}$	-0.0376						
	(0.0435)						
$SL^{2005M7} \times Debt^{2005M6}$		0.0001					
		(0.0003)					
$SL^{2005M7} \times Budget^{2005M6}$			0.0005				
			(0.0022)				
$SL^{2005M7} \times PBudget^{2005M6}$				-0.0264			
				(0.0161)			
$SL^{2005M7} \times Growth^{2005M6}$					-0.0222		
					(0.0188)		
$SL^{2005M7} \times CA^{2005M6}$						0.0089^{**}	
						(0.0041)	
$SL^{2005M7} \times REER^{2005M6}$							-0.0085
							(0.0098)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interacted Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.935	0.922	0.926	0.911	0.934	0.934	0.932
Observations	222	222	222	222	222	222	222

Table 2.15: Sovereign spreads and conditional eligibility (2004M7–2008M8)

This table reports estimates of the effect of the SL event on sovereign spreads in periphery countries relative to core countries over the period 2004M7–2008M8. The corresponding regression equations are (2.1) and (2.2). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. The treatment variable is the interaction of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and either a binary periphery dummy or a continuous shock correlation variable. Further controls are added, independently in columns (1) and (3), and interacted with the time dummy in columns (2) and (4). Columns (1) and (2) report coefficients for the binary treatment variable, while columns (3) and (4) report coefficients for the continuous treatment variable. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread			
	(1)	(2)	(3)	(4)
$SL^{2005M7} \times Periphery$	0.0563***	0.2206***		
	(0.0123)	(0.0412)		
$SL^{2005M7} \times Correlation$			−0.2879***	−1.3692***
			(0.0984)	(0.3573)
Debt	0.0099***	−0.0199***	0.0120***	−0.0182**
	(0.0026)	(0.0059)	(0.0029)	(0.0071)
$Debt^2$	−0.0001***	0.0001***	−0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Budget	0.0001	0.0028***	0.0001	0.0027***
	(0.0005)	(0.0006)	(0.0006)	(0.0006)
PBudget	−0.0081***	−0.0184***	−0.0084***	−0.0169***
	(0.0019)	(0.0037)	(0.0020)	(0.0039)
Growth	−0.0031	0.0044	−0.0030	0.0108
	(0.0047)	(0.0097)	(0.0049)	(0.0103)
CA	0.0056**	−0.0023	0.0053**	−0.0004
	(0.0024)	(0.0035)	(0.0024)	(0.0037)
REER	0.0017	0.0026	0.0020	0.0018
	(0.0035)	(0.0051)	(0.0042)	(0.0058)
Liquidity	−0.0009	−0.0008	−0.0009	−0.0009
	(0.0008)	(0.0008)	(0.0008)	(0.0007)
$SL^{2005M7} \times AAA$		−0.1616***		−0.0162
		(0.0517)		(0.0504)
$SL^{2005M7} \times Debt$		0.0267***		0.0244***
		(0.0057)		(0.0070)
$SL^{2005M7} \times Debt^2$		−0.0002***		−0.0002***
		(0.0000)		(0.0000)
$SL^{2005M7} \times Budget$		−0.0031***		−0.0030***
		(0.0009)		(0.0009)
$SL^{2005M7} \times PBudget$		0.0157***		0.0147***
		(0.0041)		(0.0043)
$SL^{2005M7} \times Growth$		−0.0151		−0.0200*
		(0.0114)		(0.0120)
$SL^{2005M7} \times CA$		0.0102***		0.0091***
		(0.0029)		(0.0033)
$SL^{2005M7} \times REER$		0.0158**		0.0176***
		(0.0061)		(0.0067)
Time FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Adj. R^2	0.926	0.940	0.921	0.939
Observations	300	300	300	300

Table 2.16: Channels (binary, 2004M7–2008M8)

This table reports estimates of the effects of the SL event on sovereign spreads in periphery countries relative to core countries, and in comparison of countries with different levels of macro-fiscal fundamentals, respectively, over the period 2004M7–2008M8. The corresponding regression equation is (2.5). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. Treatment variables are interactions of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and the binary periphery dummy as well as, by column, the level of one macro-fiscal fundamental in the month prior to the SL event. Further controls are added, both independently and interacted with the time dummy. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$SL^{2005M7} \times Periphery$	0.2206***	0.0490**	0.0988	0.2423***	0.2265***	0.2738***	0.2417***
	(0.0412)	(0.0246)	(0.0668)	(0.0580)	(0.0363)	(0.0537)	(0.0454)
$SL^{2005M7} \times AAA^{2005M6}$	−0.1616***						
	(0.0517)						
$SL^{2005M7} \times Debt^{2005M6}$		0.0011					
		(0.0007)					
$SL^{2005M7} \times Budget^{2005M6}$			−0.0128*				
			(0.0075)				
$SL^{2005M7} \times PBudget^{2005M6}$				−0.0083			
				(0.0202)			
$SL^{2005M7} \times Growth^{2005M6}$					−0.0027		
					(0.0193)		
$SL^{2005M7} \times CA^{2005M6}$						0.0140***	
						(0.0038)	
$SL^{2005M7} \times REER^{2005M6}$							0.0069
							(0.0097)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interacted Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.940	0.938	0.939	0.937	0.940	0.936	0.937
Observations	300	300	300	300	300	300	300

Table 2.17: Channels (continuous, 2004M7–2008M8)

This table reports estimates of the effects of the SL event on sovereign spreads in periphery countries relative to core countries, and in comparison of countries with different levels of macro-fiscal fundamentals, respectively, over the period 2004M7–2008M8. The corresponding regression equation is (2.5). The outcome variable is the country-level sovereign spread of a ten-year maturity government bond relative to Germany. Treatment variables are interactions of a time dummy, that equals one as of the announcement of the Single List in 2005M7, and the continuous shock correlation variable as well as, by column, the level of one macro-fiscal fundamental in the month prior to the SL event. Further controls are added, both independently and interacted with the time dummy. All regressions include time and country fixed effects. Standard errors in parentheses are robust to heteroskedasticity and autocorrelation. Stars indicate the 10%, 5%, and 1% significance level, respectively.

	Spread						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$SL^{2005M7} \times Correlation$	-1.3692^{***}	-0.1762	-1.1327^{***}	-1.4824^{***}	-1.5641^{***}	-1.6563^{***}	-1.3071^{***}
	(0.3573)	(0.1774)	(0.3686)	(0.3953)	(0.3138)	(0.4564)	(0.4098)
$SL^{2005M7} \times AAA^{2005M6}$	-0.0162						
	(0.0504)						
$SL^{2005M7} \times Debt^{2005M6}$		0.0006^{**}					
		(0.0003)					
$SL^{2005M7} \times Budget^{2005M6}$			-0.0029				
			(0.0024)				
$SL^{2005M7} \times PBudget^{2005M6}$				0.0132			
				(0.0179)			
$SL^{2005M7} \times Growth^{2005M6}$					0.0004		
					(0.0218)		
$SL^{2005M7} \times CA^{2005M6}$						0.0110^{***}	
						(0.0040)	
$SL^{2005M7} \times REER^{2005M6}$							0.0022
							(0.0099)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interacted Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.939	0.937	0.937	0.936	0.938	0.934	0.935
Observations	300	300	300	300	300	300	300

Chapter 3

The Political Economy of Bracket Creep

by Felix Bierbrauer and Florian Schuster

Abstract

This chapter analyzes the political economy of bracket creep, the effect of inflation pushing tax payers into higher tax brackets. We model bracket creep as a tax reform, using perturbation methods and a Mirrleesian model of income taxation. Our main finding is a median voter result for bracket creep. Under plausible assumptions on the tax system, if the median tax payer is a beneficiary, bracket creep has majority support from the poorer half of the population. We then check whether political support is always aligned with welfare improvements. We find that this may or may not be the case, depending on the social welfare function used for evaluation. While political support comes along with positive welfare effects under a Rawlsian measure, this is not true if evaluated based on the total surplus. Ultimately, we examine how bracket creep interferes with the efficiency of existing tax systems. We show that, for a tax system that maximizes either social welfare or government revenue ex ante, bracket creep is efficiency-reducing in a welfare and a Pareto sense, respectively.

Key words: bracket creep, political economy, income taxation, inflation, social welfare, Pareto efficiency

JEL codes: D72, E31, H21, H24

3.1 Introduction

Bracket creep, the effect of inflation pushing tax payers into higher tax brackets, has long been a controversially debated subject in many countries. It is commonly associated with economic costs, by lowering productive activity, and questionable legitimacy, constituting a de-facto tax increase "through the back door". With that said, this chapter analyzes the political economy and efficiency properties of bracket creep.

There is a scarce literature providing empirical country studies of the economic effects of bracket creep. However, although being a recurrent topic in the political sphere, a stringent analysis of the political economy of bracket creep is missing. Is it always rejected or can there be a majority of tax payers in favor? If yes, under what conditions? Is political support for bracket creep in line with its efficiency implications? We develop a theoretical framework where bracket creep is analyzed as a tax reform. Accounting for the effects of inflation on both tax rates and the real value of taxes and transfers, we derive formal conditions to test these questions.

Our main finding is a median voter result for bracket creep. Under plausible assumptions on the tax system, if the median tax payer is a beneficiary, bracket creep has majority support from the poorer half of the population. We then check whether political support is always aligned with welfare improvements. We find that this may or may not be the case, depending on the social welfare function used for evaluation. While political support comes along with positive welfare effects under a Rawlsian measure, this is not true if evaluated based on the total surplus. Ultimately, we examine how bracket creep interferes with the efficiency of existing tax systems. We show that, for a tax system that maximizes either social welfare or government revenue ex ante, bracket creep is efficiency-reducing in a welfare and a Pareto sense, respectively.

The analysis builds upon a Mirrleesian model of income taxation, which we augment by defining the tax schedule over nominal rather than real income. Prices for labor and consumption are determined by the market. Bracket creep is then modeled as a tax reform. The defining element is that it involves an increase of marginal tax rates, albeit real income has not risen. In addition, inflation lowers the real value of income, tax payments, and government transfers. The interplay of these two effects shape the political economy and efficiency implications of bracket creep, which we study using perturbation methods and functional derivatives.

Our analysis is performed in three steps. First, we derive formal conditions for bracket creep being politically feasible in the sense of being supported by a majority of tax payers. To that end, we characterize the conditions under which the median tax payer is a beneficiary. Our first key result, stated in Theorem 3.1, is that, if that is the case, and the tax function is convex, any household with below-median income is a beneficiary as well.

The reason is that the burden associated with higher marginal tax rates and inflation increases along the income distribution, with richer households being harmed the most. Hence, if the median voter is a beneficiary, the poorer half of households forms a majority in favor of bracket creep.

Second, we ask whether majority support for bracket creep goes along with positive welfare implications, providing an answer in Theorem 3.2. We first derive sufficient and necessary conditions for bracket creep being welfare-improving, applicable to different social welfare functions. Using a Rawlsian welfare measure, bracket creep creates a welfare improvement provided that the poorest household is a beneficiary. Squared with our median voter result, implying that any supporting majority includes the poorest household, it follows that, whenever there is a majority in favor, there are positive welfare gains. If, in contrast, welfare implications are evaluated through the lens of the total surplus, bracket creep is never beneficial. Voting outcomes and welfare effects may thus be mismatched.

Third, our framework can be used to analyze how bracket creep interacts with the efficiency of taxation. The main results are presented in Theorems 3.3 and 3.4, where we consider two scenarios with the tax system featuring different efficiency properties. On the one hand, suppose it is *welfare*-maximizing. We find that the optimal level of tax rates is independent of current prices, and hence unchanged by inflation. Therefore, bracket creep, pushing actual tax rates beyond that level, is welfare-reducing. On the other hand, we consider the slightly relaxed case of a tax system that is at the Laffer bound, and thus *revenue*-maximizing. It turns out that bracket creep is Pareto-damaging, as poor households, who solely live on government transfers, are harmed by inflation reducing the real value of those.

This chapter makes a contribution in two ways. In an academic view, it adds to the literature on bracket creep and the interaction of inflation and income tax systems. We are the first to provide a theoretical framework to study the normative properties of bracket creep as a tax reform. In particular, we extend the scope of this literature by a political economy analysis. From a policy perspective, our results have some practical implications. They provide a foundation for normative attitudes towards bracket creep, and give advise on suitable policy responses. For instance, in the context of discussions of whether or not to adjust income tax systems to inflation, our results imply that policy makers should take the specifics of the income distribution and social preferences into account, as bracket creep can, but needs not, be politically disliked and efficiency-reducing.

The remainder of the chapter is structured as follows. Section 3.2 provides a brief review of the related literature. We present the model of bracket creep as a tax reform in section 3.3. The political economy and efficiency analysis is performed in section 3.4. Section 3.5 concludes.

3.2 Related Literature

This chapter contributes to the literature on bracket creep and the interaction of inflation and income tax systems. Theoretical studies of bracket creep are scarce. Exceptions are Altig and Carlstrom (1991a,b, 1993), building upon the general equilibrium framework with nominal income taxes by Auerbach and Kotlikoff (1987). They examine the macroeconomic and welfare impacts of bracket creep. We relate to their work by showing that inflation-induced changes of marginal tax rates and the resulting distortions of labor supply have the potential to reduce social welfare. However, we expand their scope in providing conditions under which welfare effects may be positive. The former has also been pointed out by Heer and Süssmuth (2013), who document inequality-reducing effects of bracket creep. As opposed to these studies, we explicitly disentangle effects related to the tax reform involved in bracket creep and changes in the real value of taxes and transfers. This allows for a clear characterization of the driving forces underlying the efficiency implications.

Empirical analyses traditionally look into redistributive effects (Immervoll, 2005; Zhu, 2015) or tax payers' behavioral responses (Saez, 2003) in order to evaluate the normative implications of bracket creep. We embed these two perspectives in one theoretical framework and derive sufficient statistics. Moreover, we add the notion of political feasibility to this literature, showing whether or not bracket creep is supported by a majority of tax payers.

The methods used in this chapter link to recent advances in the literature on the political economy and efficiency of income taxation. We adopt the strategy of Bierbrauer et al. (2021) in providing conditions for bracket creep being politically feasible. Their work builds upon earlier contributions on the political economy of taxation (Downs, 1957; Osborne and Slivinski, 1996; Besley and Coate, 1997), with a special focus on the validity of median voter theorems (Rothstein, 1990, 1991) and their application to taxation (Roberts, 1977; Gans and Smart, 1996; Brett and Weymark, 2016, 2017). We relate to those in the sense of applying a median voter argument to detect political support for bracket creep in a non-linear income tax system. Furthermore, our analysis draws on the insights in Bierbrauer et al. (2023), in particular in studying Pareto efficiency in the context of bracket creep. Thus, our work is broadly linked to the analysis of Pareto efficiency of taxation (Stiglitz, 1982; Brito et al., 1990; Werning, 2007; Lorenz and Sachs, 2016; Badel and Huggett, 2017).

The way we model bracket creep is an application of the methodology developed in the analysis of tax reforms. This literature has been pioneered by Feldstein (1976). Specifically, we employ perturbation methods and functional derivatives in the context of nonlinear tax systems, following Piketty (1997), Roberts (2000), Saez (2001), Golosov et al.

(2014), Bierbrauer et al. (2021), and Bierbrauer et al. (2023). We are the first to use a tax reform framework for studying the impact of inflation on marginal tax rates.

3.3 Model

We study the political feasibility as well as efficiency properties of bracket creep in a Mirrleesian model of income taxation. Households derive utility from consumption and face an effort cost from the supply of labor to firms. We start out by constructing a simple model economy featuring an income tax system and endogenously determined equilibrium prices for consumption and labor. We then introduce tax reforms and describe the impact of inflation on taxes through the lens of this framework.

3.3.1 Market equilibrium

The model economy consists of a household and a firm sector as well as a government, and features an income tax system. There is a single consumption good produced by firms using the labor input provided by households. The prices of the consumption good and labor are market-determined.

Households. There is a continuum of households of mass one. Households' preferences are assumed to be quasi-linear in consumption, given by the utility function

$$u(c, y, \omega) = c - k(y, \omega),$$

where y is labor supply (in efficiency units) and ω measures a household's productive ability, distributed across the set $\Omega = [\underline{\omega}, \bar{\omega}] \subset \mathbb{R}_+$ according to the cumulative distribution function $\Phi_\Omega(\cdot)$ with density $\phi_\Omega(\cdot)$. The function $k(y, \omega)$ measures the effort cost associated with labor, which we assume to be increasing and convex. Using this utility function, preferences satisfy the Spencer-Mirrlees single crossing condition, implying that more productive types have lower marginal effort costs and thus choose higher effort and income than lower types, independently of the tax system.

A household's disposable income used for consumption is given by

$$p_c c = p_c c_0 + p_y y - \tilde{T}(p_y y),$$

where p_c is the price of one unit of the consumption good, p_y is the wage earned per unit of efficient labor, c_0 is a lump-sum transfer, and $\tilde{T}(\cdot)$ is a tax schedule with nominal income as the tax base. $\tilde{T}(\cdot)$ is assumed to be continuous, increasing, and convex, covering both linear and progressive tax systems. Without loss of generality, we let $\tilde{T}(0) = 0$. Let $p = (p_c, p_y)$ summarize the price schedule of the economy. The utility-maximizing labor supply is denoted by $y^*(p, \omega)$. For ease of exposition, we assume that the poorest household generates no income, i. e. $y^*(p, \underline{\omega}) = 0$.

Firms. There is a representative firm producing output c_f using labor (in efficiency units) y_f with a constant-returns-to-scale technology, i. e. $c_f = \theta y_f$, where θ denotes the productivity per unit of efficient labor. The firm maximizes profits $p_c c_f - p_y y_f$. A solution to this problem exists provided that $\theta = \frac{p_y}{p_c}$. We assume in the following that the price schedule satisfies the former condition.

Government. The government collects income tax payments and rebates revenues to households in a lump-sum fashion. Its budget constraint thus equals

$$E_\Omega \left[\tilde{T}(y^*(p, \omega)) \right] = p_c c_0,$$

where the operator E_Ω indicates the population average.

Market clearing. In equilibrium, the two markets for goods and labor are cleared, i. e., on the goods market, $c_f = E_\Omega[c]$, and on the labor market, $y_f = E_\Omega[y^*(p, \omega)]$. In this simple setup, the price schedule p is determined by the market.

3.3.2 Bracket creep as a tax reform

Building upon the former, we introduce tax reforms and use this framework to model the impact of inflation on the tax system. The tools derived in this section will then be used to analyze the normative implications of bracket creep.

Tax reform representation. Let $p_0 = (p_{c,0}, p_{y,0})$ be the status-quo price schedule of the economy. Let further $\pi > 0$ denote the inflation rate, thus $p_1 = (p_{c,1}, p_{y,1})$ with $p_{c,1} = p_{c,0}(1 + \pi)$ and $p_{y,1} = p_{y,0}(1 + \pi)$ describes the post-inflation price schedule.[1]

We interpret inflation and its impact on the tax system as a tax reform. For this purpose, we define pre- and post-inflation tax functions $T_0(y) = \tilde{T}(p_{y,0} y)$ and $T_1(y) = \tilde{T}(p_{y,1} y)$, respectively, both having labor supply (in efficiency units) as the tax base. The change of the tax bill of a household with labor supply y is then given by $T_1(y) - T_0(y) = \tilde{T}(p_{y,1} y) - \tilde{T}(p_{y,0} y)$.

[1]Market clearing requires inflation to be the same for the consumption good and labor.

We follow the approach in the literature that uses perturbation methods and functional derivatives to analyze tax reforms (Piketty, 1997; Roberts, 2000; Saez, 2001; Golosov et al., 2014; Bierbrauer et al., 2021, 2023). Therefore, we interpret the change of tax payments as

$$T_1(y) - T_0(y) = \tilde{T}(p_{y,1}y) - \tilde{T}(p_{y,0}y) = \tau\tilde{h}(\pi, y),$$

where the function $\tilde{h}(\pi, y)$ gives the direction of the reform, and the scalar τ measures the reform intensity. In what follows, we let $\tau = \pi$; that is, we interpret the level of inflation as reform intensity.[2] The function $\tilde{h} : (\pi, y) \mapsto \tilde{h}(\pi, y)$ is implicitly defined by the change in tax payments, or equivalently,

$$\tilde{h}(\pi, y) = \frac{\tilde{T}(p_{y,1}y) - \tilde{T}(p_{y,0}y)}{\pi}. \tag{3.1}$$

Next, we characterize the effect of inflation on marginal tax rates. The change of marginal tax rates is given by

$$T_1'(y) - T_0'(y) = p_{y,1}\tilde{T}'(p_{y,1}y) - p_{y,0}\tilde{T}'(p_{y,0}y) = \pi\tilde{h}_y(\pi, y),$$

implicitly defining the derivative of the function $\tilde{h}(\pi, y)$ with respect to y as

$$\tilde{h}_y(\pi, y) = \frac{p_{y,1}\tilde{T}'(p_{y,1}y) - p_{y,0}\tilde{T}'(p_{y,0}y)}{\pi}. \tag{3.2}$$

In the following, we distinguish between *small* and *large* reforms. A small reform focuses on inflation increasing marginally from some initial level. We begin our analysis with small reforms, focusing on levels of inflation close to zero, and subsequently turn to large reforms, where inflation can be at any level.

Interpreting bracket creep as a small tax reform, the reform direction is given by the function $h : y \mapsto h(y)$, defined as

$$h(y) \equiv \lim_{\pi \to 0} \tilde{h}(\pi, y) = p_{y,0}y\tilde{T}'(p_{y,0}y). \tag{3.3}$$

It captures the effect of inflation on the change of tax payments for inflation being close to zero. Analogously, we write the change of marginal tax rates per unit of inflation as

$$h'(y) = \lim_{\pi \to 0} \tilde{h}_y(\pi, y) = p_{y,0}\tilde{T}'(p_{y,0}y) + p_{y,0}^2 y\tilde{T}''(p_{y,0}y). \tag{3.4}$$

[2] Formally, interpreting inflation as the perturbation intensity makes the direction $\tilde{h} : (\pi, y) \mapsto \tilde{h}(\pi, y)$ a function of the intensity. This speciality proves to be of no hindrance for our formal analysis, however, as we show in section 3.4.2. See footnote 9 for details.

Post-inflation budget constraint. According to the government budget constraint, the pre-inflation tax revenue, denoted as R_0, is used to finance basic consumption, i. e. $p_{c,0}c_0 = R_0$. Post-inflation tax revenue equals $R_1 = R_0 + R\left(\pi, \tilde{h}\right) = p_{c,0}c_0 + R\left(\pi, \tilde{h}\right)$, where $R\left(\pi, \tilde{h}\right)$ captures the inflation-induced change of tax revenue, and enters the households' budget constraint. After inflation, households choose y to maximize $u(c_1(y), y, \omega)$, where $c_1(y)$ solves

$$p_{c,1}c_1(y) = p_{c,0}c_0 + R\left(\pi, \tilde{h}\right) + p_{y,1}y - \tilde{T}(p_{y,1}y).$$

The budget constraint can alternatively be written as

$$c_1(y) = \frac{1}{1+\pi}c_0 + \frac{1}{p_{c,0}(1+\pi)}\left(R\left(\pi, \tilde{h}\right) - \tilde{T}(p_{y,0}y) - \pi\tilde{h}(\pi, y)\right) + \frac{p_{y,0}}{p_{c,0}}y. \tag{3.5}$$

Let $y^*\left(\pi, \tilde{h}, \omega\right)$ be type ω's post-inflation labor supply that maximizes utility subject to the budget constraint (3.5) for inflation rate π and reform direction $\tilde{h}$. We write $v\left(\pi, \tilde{h}, \omega\right)$ for the corresponding indirect utility, which will prove pivotal in the subsequent analysis, as it helps identify the beneficiaries of the tax reform involved in bracket creep.

3.4 Political economy and efficiency of bracket creep

We analyze the political economy and normative implications of bracket creep through the lens of the above framework. Specifically, we characterize to what extent bracket creep is supported by a majority of voters. We continue by examining whether political support is aligned with welfare implications, and explore the efficiency properties of bracket creep.

The analysis requires an identification of beneficiaries, which makes use of the inflation-induced change of a household's indirect utility. We commence by characterizing the change of indirect utility and its components. Equipped with these tools, we provide formal conditions for an analysis of how bracket creep impacts political feasibility, social welfare, and the efficiency of taxation.

For ease of comprehension, we first derive our main results for the *small*-reform representation of bracket creep, where inflation rises marginally above zero. A small reform is a natural starting point as it amounts to a linearized problem, simplifying the analysis and interpretation of results. We will then show that our results extend equivalently to the *large*-reform case.

3.4.1 Bracket creep as a small tax reform

Marginal change of indirect utility. The marginal change of type ω's indirect utility in response to inflation is obtained by an application of the envelope theorem. The derivative can be written as

$$v_\pi\left(\pi,\tilde{h},\omega\right) = \frac{1}{p_{c,0}(1+\pi)}\left(R_\pi\left(\pi,\tilde{h}\right) - \tilde{h}(\pi,y^*(\pi,\omega)) - \pi\tilde{h}_\pi(\pi,y^*(\omega))\right.$$
$$\left. + \frac{1}{(1+\pi)}\left(\tilde{T}(p_{y,0}y^*(\pi,\omega)) + \pi\tilde{h}(\pi,y^*(\pi,\omega)) - p_{c,0}c_0 - R\left(\pi,\tilde{h}\right)\right)\right), \quad (3.6)$$

where $u_c(\omega)$ is a shortcut for the marginal utility of consumption evaluated at $y^*(\pi,\omega) \equiv y^*\left(\pi,\tilde{h},\omega\right)$, and $R_\pi\left(\pi,\tilde{h}\right)$ is the Gateaux differential of tax revenue in direction $\tilde{h}$.[3]

The elements in the large bracket of expression (3.6) can be grouped as follows. The terms in the first line refer to net gains of type ω from the tax reform entailed by bracket creep. They are positive provided that, per unit of inflation, additional tax revenue $R_\pi\left(\pi,\tilde{h}\right)$ exceeds additional tax payments $\tilde{h}(\pi,y^*(\omega)) + \pi\tilde{h}_\pi(\pi,y^*(\omega))$. The terms in the second line represent net gains from the valuation effect of inflation, reflecting that it reduces the real value of both tax obligations $\tilde{T}(p_{y,0}y^*(\pi,\omega)) + \pi\tilde{h}(\pi,y^*(\pi,\omega))$ and the government transfer $p_{c,0}c_0 + R\left(\pi,\tilde{h}\right)$.

As we keep our focus on small reforms for now, the change of indirect utility for very low inflation is of particular interest. Evaluating equation (3.6) at $\pi \to 0$ yields

$$v_\pi(0,h,\omega) = \frac{1}{p_{c,0}}\left(R_\pi(0,h) - h(y_0(\omega)) + \tilde{T}(p_{y,0}y_0(\omega)) - p_{c,0}c_0\right) \quad (3.7)$$
$$= \frac{1}{p_{c,0}}\left(R_\pi(0,h) - p_{c,0}c_0 + p_{y,0}y_0(\omega)\left(\frac{\tilde{T}(p_{y,0}y_0(\omega))}{p_{y,0}y_0(\omega)} - \tilde{T}'(p_{y,0}y_0(\omega))\right)\right), \quad (3.8)$$

where $y_0(\omega) = y^*(0,h,\omega)$. Equation (3.7) is interpreted equivalently to (3.6). In equation (3.8), however, which is obtained upon substituting (3.3) for $h(y_0(\omega))$, gains and losses from bracket creep are grouped according to whether they originate from government transfers or tax obligations. The term $(1/p_{c,0})(R_\pi(0,h) - p_{c,0}c_0)$ refers to the balance of gains from marginal changes to government transfers, stemming from higher tax revenue and a revaluation of pre-inflation transfers. The latter part of equation (3.8), i. e.

$$\frac{1}{p_{c,0}}p_{y,0}y_0(\omega)\left(\frac{\tilde{T}(p_{y,0}y_0(\omega))}{p_{y,0}y_0(\omega)} - \tilde{T}'(p_{y,0}y_0(\omega))\right), \quad (3.9)$$

represents net gains originating from the marginal change of a household's tax obligations, comprising both changes in terms of their real value and marginal tax rates. Notably,

[3] For a detailed discussion of the Gateaux differential, see Bierbrauer et al. (2023).

the expression in the bracket is equivalent to the difference between the average and the marginal tax rate applied to nominal income.

Further characterizations. We now characterize the components of equations (3.7) and (3.8) in further detail. This characterization gives rise to the following three lemmas, which are useful in deriving our main results.

Lemma 3.1. *The function* $h \circ y_0 : \omega \mapsto h(y_0(\omega))$ *is non-decreasing in* ω*.*

Under an increasing and convex tax schedule, the reform direction for levels of inflation close to zero is a monotonic and non-decreasing function of a household's type. With the help of Lemma 3.1, we can model bracket creep as a monotonic tax reform. This implies that households with higher incomes incur a larger reform-induced increase of their tax bill than poorer ones, reflective of the convex nature of the tax schedule.

Lemma 3.2. *Net gains from the marginal change of tax obligations at the status quo, given by* (3.9)*, are non-positive for any* ω *and non-increasing in* ω*.*

Lemma 3.2 states that the effect of inflation on tax obligations at the status quo, given by expression (3.9), is never beneficial for any household. The reason is that, under a convex tax system, marginal tax rates always equal or exceed average tax rates. Therefore, the increase of the nominal tax bill, driven by a higher marginal rate, cannot be offset by a reduction of its real value, determined by the average rate. Moreover, Lemma 3.2 shows that the loss in indirect utility induced by bracket creep increases along the income distribution, with the richest household incurring the largest loss.

Lemma 3.3. *The inflation-induced change in tax revenue for levels of inflation close to zero is given by*

$$R_\pi(0, h) = E_\Omega \left[h(y_0(\omega)) + p_{y,0} y_{0\pi}(\omega) \tilde{T}'(p_{y,0} y_0(\omega)) h'(y_0(\omega)) \right], \tag{3.10}$$

where $y_{0\pi}(\omega)$ *denotes the derivative of* $y^*(\omega)$ *with respect to* π *evaluated at the status quo.*

Lemma 3.3 characterizes the Gateaux differential of tax revenue at the status quo in direction h. The change of revenue induced by inflation comprises as a mechanical effect the overall additional tax payments based on the status-quo income, i. e. $E_\Omega [h(y_0(\omega))]$, corrected for households' behavioral responses to the change of marginal tax rates, i. e. $E_\Omega \left[p_{y,0} y_{0\pi}(\omega) \tilde{T}'(p_{y,0} y_0(\omega)) h'(y_0(\omega)) \right]$. For intuition, note that households have less of an incentive to work as marginal tax rates increase in response to inflation rising slightly above zero. The term then captures the tax payments forgone attributed to this reduction of labor supply.

We proceed by applying Lemmas 3.1 to 3.3 in order to examine under what conditions bracket creep turns out to be beneficial in a political economy and efficiency sense.

Political feasibility. We refer to bracket creep as politically feasible if and only if it is supported by a majority of households. That depends on the median tax payer, who needs to be among the beneficiaries to form a majority for bracket creep. Therefore, we first provide a necessary and sufficient condition for the median voter benefiting for very low levels of inflation.

Lemma 3.4. *Let ω^m be the median voter's type. The median voter is a beneficiary of bracket creep for levels of inflation close to zero if and only if*

$$R_\pi(0,h) - p_{c,0}c_0 > -p_{y,0}y_0(\omega^m)\left(\frac{\tilde{T}(p_{y,0}y_0(\omega^m))}{p_{y,0}y_0(\omega^m)} - \tilde{T}'(p_{y,0}y_0(\omega^m))\right). \tag{3.11}$$

The interpretation of Lemma 3.4 is straightforward. The median voter is a beneficiary provided that the change in tax revenue is sufficiently large to outweigh this type's net losses from higher nominal tax obligations and a lower real value of taxes and transfers. Combined with our monotonicity results from Lemmas 3.1 and 3.2, this allows us to derive a median voter result for bracket creep.

Theorem 3.1. *The following statements are equivalent for levels of inflation close to zero:*

(i) Bracket creep is politically feasible.

(ii) The median voter benefits from bracket creep.

(iii) There is a majority of households with types $\omega \leq \omega^m$ supporting bracket creep.

Theorem 3.1 states that the majority support for bracket creep originates from the lower half of the income distribution. If the median voter is a beneficiary, all households with below-median incomes are too. Thus, the bottom half of the income distribution is in favor of letting bracket creep work.

This result is established by requiring the tax schedule to be increasing and convex, implying that the function $h(y)$ and net gains from the marginal change of tax obligations at the status quo are monotonic functions of ω. Intuitively, for tax revenue large enough, below-median incomes benefit from additional tax revenue exceeding their additional tax obligations. The rise in tax revenue is largely financed by higher marginal tax rates for higher incomes. Accordingly, bracket creep is least popular among richer households.

Social welfare. While majority support for bracket creep as an implicit tax reform may provide political legitimacy, it may not be favorable from a social welfare perspective. Specifically, depending on the welfare function used, higher tax rates in the upper half of the income distribution may cause welfare losses exceeding the benefits of the lower half, albeit the latter constitutes a political majority. That is why our analysis proceeds by characterizing the welfare implications of bracket creep. To that end, we limit our attention to cases where the status-quo tax system is an interior Pareto-optimum. The results are then squared with the conditions of political feasibility.

The following lemma states a necessary and sufficient condition for bracket creep being welfare-improving for inflation rates slightly above zero. To that end, we define social welfare as $w\left(\pi,\tilde{h}\right) = E_\Omega\left[g(w)v\left(\pi,\tilde{h},\omega\right)\right]$, where the function $g : \omega \mapsto g(\omega)$ assigns welfare weights to any type ω. We assume without loss of generality that $E_\Omega[g(w)] = 1$. Furthermore, we write $w_\pi(0,h)$ for the marginal inflation-induced change in welfare for levels of inflation near zero.

Lemma 3.5. *Suppose that the status-quo tax system T_0 is an interior Pareto-optimum. Bracket creep is welfare-improving for levels of inflation close to zero if and only if*

$$w_\pi(0,h) = \frac{1}{p_{c,0}} E_\Omega\left[g(w)\left(R_\pi(0,h) - p_{c,0}c_0 + p_{y,0}y_0(\omega)\left(\frac{\tilde{T}(p_{y,0}y_0(\omega))}{p_{y,0}y_0(\omega)} - \tilde{T}'(p_{y,0}y_0(\omega))\right)\right)\right] > 0. \tag{3.12}$$

Condition (3.12) can be evaluated using different welfare functions in order to characterize the welfare properties of bracket creep. First, consider the case of Rawlsian social welfare. The function $g(\omega)$ is then such that no weight is assigned to any household but the poorest, i. e. $g(\omega) = 0$ for all $\omega > \underline{\omega}$.

Proposition 3.1. *Suppose that the status-quo tax system T_0 is an interior Pareto-optimum. If the social welfare function is Rawlsian, bracket creep is welfare-improving for levels of inflation close to zero if and only if $R_\pi(0,h) > p_{c,0}c_0$.*

Under Rawlsian welfare, bracket creep is desirable from a welfare perspective if and only if the poorest household is a beneficiary. Assuming that this household has no labor income but receives solely government transfers, this is the case provided that additional tax revenue outweighs the loss in the real value of pre-reform transfers. Hence, for Rawlsian welfare and the change in tax revenue $R_\pi(0,h)$ being sufficiently high, the optimal policy response to inflation is to simply let bracket creep work.

Second, suppose social welfare is evaluated using a utilitarian welfare measure. Specifically, a utilitarian welfare function assigns equal weights to all households, i. e. $g(w) = 1$ for each ω. Further assuming quasi-linear preferences, the marginal change in social welfare then equals the change in the total surplus aggregated over households.

Proposition 3.2. *Suppose that the status-quo tax system T_0 is an interior Pareto-optimum. Bracket creep does not increase the total surplus for levels of inflation close to zero, i. e.*

$$w_\pi^U(0,h) = \frac{1}{p_{c,0}} E_\Omega \left[p_{y,0} y_{0\pi}(\omega) \tilde{T}'(p_{y,0} y_0(\omega)) h'(y_0(\omega)) \right] \leq 0.^4 \tag{3.13}$$

The proof of Proposition 3.2 hinges on the characterization of the Gateaux differential provided in Lemma 3.3. Since the government distributes tax revenue in a lump-sum way, the change in aggregate tax obligations at the status quo and the change in the transfer households receive cancel out. Similarly, the changes in the real values of pre-reform transfers and tax bills offset each other. The total surplus implication of near-zero inflation is then solely governed by the behavioral responses to higher marginal tax rates, as indicated by the right-hand side of equation (3.13). Under the above assumptions, this expression is unambiguously non-positive. Particularly, in the presence of a convex effort cost function, labor supply is reduced or kept constant in response to inflation, i. e. $y_{0\pi}(\omega) \leq 0$ for all ω. Bracket creep is therefore never beneficial if evaluated based on the total surplus.

Squaring Propositions 3.1 and 3.2 with our median voter result, it turns out that political support for bracket creep can be, but does not need to be, aligned with positive welfare effects. Proposition 3.1 implies that, in the Rawlsian case, this alignment holds true. If the median voter is a beneficiary, the poorest voter is as well, making bracket creep both welfare-improving and politically feasible. If welfare is evaluated based on the total surplus, however, matching voting outcomes and welfare implications requires a majority opposing bracket creep. Even if the poorer half of households is in favor of bracket creep, it is certainly detrimental to the total surplus. Thus, political preferences and welfare effects are only aligned provided that the median voter and all households with above-median income are losers. This contrasts the Rawlsian case, where a political majority in favor implies a welfare improvement. These findings are summarized in Theorem 3.2.

Theorem 3.2. *Suppose that the status-quo tax system T_0 is an interior Pareto-optimum, and inflation is close to zero.*

(i) Suppose that the social welfare function is Rawlsian. If bracket creep is politically feasible, it is also welfare-improving.

(ii) Suppose that social welfare is evaluated using the total surplus. Bracket does not increase the total surplus independently of whether or not it is politically feasible.

[4] The superscript U indicates the use of the utilitarian welfare function in the derivation of equation (3.13).

Another question related to the welfare implications of bracket creep is how it interferes with a welfare-maximizing status-quo tax system. Is the welfare maximum preserved even given the new price schedule, or is bracket creep then always harmful? Theorem 3.3 provides an answer to this question.[5]

Theorem 3.3. *Suppose that there is an income bracket* $[y_0'(\omega), y_0''(\omega)]$ *such that, at any income* $y_0(\omega)$ *in this bracket, the status-quo tax system* T_0 *is welfare-maximizing, i. e. it satisfies*

$$\tilde{T}'(p_{y,0}y_0(\omega)) = -\frac{1}{\theta}\frac{1-\Phi_\Omega(\omega)}{\phi_\Omega(\omega)}(1-G(\omega))k_{21}(y_0(\omega),\omega) \equiv \mathcal{B}^{WM}(\omega), \tag{3.14}$$

where $G(\omega) \equiv E_\Omega[g(s)|s \geq \omega]$ *is the average welfare weight of individuals at or above* ω*. Bracket creep is welfare-reducing relative to the status quo in this bracket for levels of inflation close to zero.*

Expression (3.14) is a version of Diamond's formula, which determines welfare-maximizing marginal tax rates as a function of the inverse hazard rate, the average welfare weight of those at or above the respective income level, and behavioral responses. The inverse hazard rate relates the mass of households that pay higher taxes without adjusting their behavior, $1-\Phi_\Omega(\omega)$, to the mass of those that do, $\phi_\Omega(\omega)$. A higher inverse hazard rate allows optimal marginal tax rates to be higher. Similarly, they are the higher, the less households in the upper tail of the income distribution matter for social welfare, captured by $1-G(\omega)$. Larger behavioral responses, quantified by $|k_{21}(y_0(\omega),\omega)|$, in contrast, lower welfare-maximizing tax rates.

Notably, formula (3.14) is a function only of real variables, implying that welfare-maximizing taxes are independent of the prevailing price schedule. For any rate of inflation, bracket creep pushes up marginal tax rates beyond that level. Therefore, bracket creep turns out to cause welfare losses relative to an optimal status quo.

Pareto efficiency. In the above analysis, we have assumed that the status-quo tax schedule is an interior Pareto-optimum. We now relax this assumption, turning to the case where the tax system is at the upper Pareto bound, and thus revenue-maximizing. Any marginal tax rate increase would thus lower the efficiency of the tax system, as it would increase households' tax burdens and reduce lump-sum transfers.

[5] Theorem 3.3 is a local statement for incomes in a given bracket. Notably, this specification includes the possibility of status-quo marginal tax rates being globally welfare-maximizing at any arbitrary level of income. However, since empirical studies of income tax systems have revealed that (in)efficiency of taxation may prevail only in specific areas of the income distribution (Bierbrauer et al., 2021), we take account of their finding by referring to a given bracket.

That raises the question of whether bracket creep mitigates or amplifies such efficiency losses. Our framework can be used to provide an answer, which is a priori unclear. To see why, note that bracket creep gives rise to a simultaneous increase of prices and marginal tax rates, contrasting it with explicit tax reforms where taxes are increased for given prices. The change in prices entails a change of the real value of taxes and transfers, the balance of which may dampen or exacerbate the costs associated with the tax increase.

We approach this question in a two-step procedure. First, we derive a Laffer bound for marginal tax rates. A status-quo tax schedule at this bound maximizes revenue, and a tax increase would involve a loss of efficiency. Second, we characterize how the Laffer bound changes if, in addition, valuation effects associated with inflation are taken into account. By this characterization, one may draw conclusions about the efficiency implications of bracket creep. If the Laffer bound is lowered, tax rates, which used to be revenue-maximizing ex ante, end up being inefficiently high ex post, constituting a Pareto damage. A higher Laffer bound, in contrast, implies that bracket creep does not need to be Pareto-damaging.

To start with, we consider an explicit tax reform that involves an increase of marginal tax rates for a given price schedule p_0. As we show in the appendix, the Laffer bound for marginal tax rates in this case has the well-known form

$$\tilde{T}'(p_{y,0}y_0(\omega)) > -\frac{1}{\theta}\frac{1-\Phi_\Omega(\omega)}{\phi_\Omega(\omega)}\frac{1}{\varepsilon(y_0(\omega))} \equiv \mathcal{B}^{TR}(\omega). \tag{3.15}$$

Marginal tax rates exceeding this threshold for each income level are sufficient for the tax increase to be Pareto-damaging. The Laffer bound $\mathcal{B}^{TR}(\omega)$ consists of two major elements. First, it relates marginal tax rates at income level $y_0(\omega)$ to the inverse hazard rate, comparing the mass of households that pay higher taxes and do not adjust their behavior, $1-\Phi_\Omega(\omega)$, to the mass of those that do, $\phi_\Omega(\omega)$. The higher this rate is, the higher marginal tax rates can be without causing a Pareto damage. Second, the extent of behavioral responses of households with income $y_0(\omega)$ is accounted for by the inverse of the function $\varepsilon : y_0(\omega) \mapsto \varepsilon(y_0(\omega))$, which is governed by a household's elasticity of taxable income. The more strongly earnings are reduced in response to taxation, the tighter is the threshold on marginal tax rates.

Next, we examine how the Laffer bound (3.15) is modified if bracket creep is considered, which gives rise to additional changes in real valuations that may affect efficiency. We assume that bracket creep involves an increase of marginal tax rates of the same magnitude at any income level as the one implemented by the explicit reform. The behavioral responses of any type ω are thus equivalently captured by $\varepsilon(y_0(\omega))$. It follows from equation (3.8) that bracket creep is Pareto-damaging for levels of inflation close to zero if, for any type ω,

$$R_\pi(0,h) < -p_{y,0}y_0(\omega)\left(\frac{\tilde{T}(p_{y,0}y_0(\omega))}{p_{y,0}y_0(\omega)} - \tilde{T}'(p_{y,0}y_0(\omega))\right) + p_{c,0}c_0.$$

The right-hand side captures net losses from an increase of tax rates and the valuation effects associated with inflation. Lemma 3.2 implies that it is positive, non-decreasing in ω, and thus minimized for the poorest type $\underline{\omega}$. Consequently, if the inequality is satisfied for $\underline{\omega}$, the same holds true for any $\omega \in \Omega$. Since we assume this type to receive income solely from government transfers, i. e. $y_0(\underline{\omega}) = 0$, it turns out that bracket creep is Pareto-damaging if

$$R_\pi(0,h) < p_{c,0}c_0,$$

where $p_{c,0}c_0$ represents the reduction of pre-inflation transfers in real terms. Starting from this condition, we derive a modified Laffer bound, characterized in Lemma 3.6.

Lemma 3.6. *Let $h'(y)$ be bounded from above by one. Bracket creep is Pareto-damaging for levels of inflation close to zero if, at any income $y_0(\omega)$,*

$$\tilde{T}'(p_{y,0}y_0(\omega)) > -\frac{1}{\theta}\frac{1-\Phi_\Omega(\omega)-p_{c,0}c_0}{\phi_\Omega(\omega)}\frac{1}{\varepsilon(y_0(\omega))} \equiv \mathcal{B}^{BC}(\omega). \tag{3.16}$$

In comparison to (3.15), equation (3.16) comprises one additional element. Specifically, the Laffer bound is lowered by the lowest type's net valuation losses, $p_{c,0}c_0$.[6] The fact that the poorest household's net valuation losses enter the Laffer bound allows for an assessment of whether bracket creep amplifies or mitigates the loss of efficiency associated with a tax increase starting from a revenue-maximizing status quo. It turns out that the Laffer bound is lower if valuation effects are considered, as we formally state in Proposition 3.3.

Proposition 3.3. *The Laffer bound on status-quo marginal tax rates is lower under bracket creep than in the case of an explicit tax increase for given prices, i. e., for any type ω,*

$$\mathcal{B}^{BC}(\omega) < \mathcal{B}^{TR}(\omega).$$

[6] Assuming $h'(y) \leq 1$ is necessary to obtain an analytical solution for the Laffer bound, which would otherwise be an increasing function of the status-quo marginal tax rate itself. Notwithstanding, the assumption is not needed to derive the main result of our analysis of Pareto efficiency stated in Proposition 3.3.

Proposition 3.3 now allows us to characterize the efficiency implications of bracket creep.

Theorem 3.4. *Suppose that there is an income bracket $[y_0'(\omega), y_0''(\omega)]$ such that, at any income $y_0(\omega)$ in this bracket, the status-quo tax system T_0 is revenue-maximizing, i. e. it satisfies $\tilde{T}'(p_{y,0}y_0(\omega)) = \mathcal{B}^{TR}(\omega)$. Bracket creep is Pareto-damaging in this bracket for levels of inflation close to zero.*

Theorem 3.4 states that bracket creep drives marginal tax rates beyond the Laffer bound.[7] Provided that status-quo marginal tax rates are revenue-maximizing ex ante, they end up being inefficiently high ex post, as bracket creep gives rise to a tax increase, and valuation effects lower the Laffer bound. To see why, note that a Pareto-damaging reform requires no more than the poorest household to be worse off. This type only receives income from government transfers, the real value of which is reduced by inflation. Taxes hence must not exceed the rate that maximizes revenue net of these valuation losses. Any tax rate above that level comes along with an inflation rate that reduces the real value of transfers by more than the tax increase raises additional revenue. The adverse effect of inflation is absent in the case of an explicit tax reform, where Pareto efficiency simply requires tax rates to stay below the revenue-maximizing level.

Therefore, relative to a reform for given prices, bracket creep proves to exacerbate the efficiency loss ensuing from a tax increase. This result rules out the possibility of bracket creep curbing the costs associated with income tax systems featuring such inefficiencies. For instance, if marginal tax rates anywhere in the income distribution are too high, there are no gains from valuation changes to offset that. Thus, our theory cannot rationalize a policy of letting bracket creep work in the presence of inefficiencies from status-quo tax rates beyond the Laffer bound.[8]

3.4.2 Bracket creep as a large tax reform

For simplicity, we have thus far analyzed political economy and normative properties of bracket creep as a small tax reform, looking at marginal increases of inflation slightly above zero. We now show that our results extend to an interpretation as a large reform; that is, for changes of inflation at any level.

[7] For the reasons given in footnote 5, Theorem 3.4 makes a local rather than a global statement.

[8] Besides the Laffer bound, there is a lower Pareto bound, with tax rates underneath being inefficiently low. Studying the impact of bracket creep on the efficiency of such a tax system is trivial. As bracket creep always involves a tax increase, it certainly has the potential to improve on the existing inefficiency. A sufficient condition for bracket creep being a Pareto improvement in that situation is that the tax increase raises sufficient additional revenue to compensate for the poorest household's valuation loss.

Change of indirect utility. Lemma 3.7 specifies an expression for the overall change of indirect utility of type ω for any given level of inflation π and reform direction $\tilde{h}$, denoted by $V\left(\pi, \tilde{h}, \omega\right)$.[9]

Lemma 3.7. *The change of indirect of utility of type ω for any given level of inflation π and reform direction $\tilde{h}$ is given by*

$$\begin{aligned} V\left(\pi, \tilde{h}, \omega\right) &= \int_0^{\pi} v_\pi\left(s, \tilde{h}, \omega\right) ds \\ &= \frac{1}{p_{c,0}(1+\pi)}\left(R\left(\pi, \tilde{h}\right) - \pi\tilde{h}(\pi, y^*(\pi,\omega)) + \pi\left(\tilde{T}(p_{y,0}y^*(\pi,\omega)) - p_{c,0}c_0\right)\right) \quad (3.17) \\ &= \frac{1}{p_{c,0}(1+\pi)}\left(R\left(\pi, \tilde{h}\right) - \pi p_{c,0}c_0 + (1+\pi)\tilde{T}(p_{y,0}y^*(\pi,\omega)) - \tilde{T}(p_{y,1}y^*(\pi,\omega))\right). \quad (3.18) \end{aligned}$$

Equation (3.17) groups terms into reform- and valuation-induced effects, and equation (3.18) into net gains from the change in government transfers or tax obligations, respectively. As for small reforms, we characterize the latter components in further detail, showing that Lemmas 3.1 and 3.2 have large-reform equivalents.

Lemma 3.8.

(i) The function $\tilde{h} \circ y^* : (\pi, y^*) \mapsto \tilde{h}(\pi, y^*(\pi,\omega))$ is non-decreasing in ω.

(ii) Net gains from the change of tax obligations, i. e.

$$\frac{1}{p_{c,0}(1+\pi)}\left((1+\pi)\tilde{T}(p_{y,0}y^*(\pi,\omega)) - \tilde{T}(p_{y,1}y^*(\pi,\omega))\right),$$

are non-positive for any ω and non-increasing in ω.

Political economy and efficiency analysis. Using Lemma 3.8, we identify conditions for how bracket creep impacts political support, social welfare, and status-quo efficiency properties at any level of inflation. Our results are compiled in the following proposition. Formally, we denote the change in social welfare induced by bracket creep by $W\left(\pi, \tilde{h}\right) \equiv E_\Omega\left[g(\omega)V\left(\pi, \tilde{h}, \omega\right)\right]$.

Proposition 3.4.

[9] Note that labor supply is a function of the level of inflation, i. e. $y^*\left(\pi, \tilde{h}, \omega\right)$, and, in going from small to large reforms, the direction of the perturbation $\tilde{h} : (\pi, y) \mapsto \tilde{h}(\pi, y)$ is different for each incremental change of π. This gives rise to the marginal effect $\partial\tilde{h}(\pi, y)/\partial\pi$ which feeds into the partial derivatives of labor supply and consumption. The former marginal effect drops out by the application of the envelope theorem. The latter is eliminated through integration by parts. Therefore, the overall change of indirect utility is derived from a straightforward extension of the above analysis of marginal changes.

(i) The median voter is a beneficiary of bracket creep if and only if

$$R\left(\pi, \tilde{h}\right) - \pi p_{c,0} c_0 > -\left((1+\pi)\tilde{T}(p_{y,0} y^*(\pi, \omega^m)) - \tilde{T}(p_{y,1} y^*(\pi, \omega^m))\right), \qquad (3.19)$$

and the following statements are equivalent:

(1) Bracket creep is politically feasible.

(2) The median voter benefits from bracket creep.

(3) There is a majority of households with types $\omega \leq \omega^m$ supporting bracket creep.

(ii) Suppose that the status-quo tax system T_0 is an interior Pareto-optimum. Bracket creep is welfare-improving if and only if

$$W\left(\pi, \tilde{h}\right) = \frac{1}{p_{c,0}(1+\pi)} E_\Omega \left[g(\omega)\left(R\left(\pi, \tilde{h}\right) - \pi p_{c,0} c_0 + (1+\pi)\tilde{T}(p_{y,0} y^*(\pi, \omega)) - \tilde{T}(p_{y,1} y^*(\pi, \omega))\right)\right] > 0. \qquad (3.20)$$

(1) If the social welfare function is Rawlsian, bracket creep is welfare-improving if and only if $R\left(\pi, \tilde{h}\right) > \pi p_{c,0} c_0$. It is furthermore welfare-improving if it is politically feasible.

(2) Bracket creep does not increase the total surplus, i. e.

$$W^U\left(\pi, \tilde{h}\right) = \frac{1}{p_{c,0}} E_\Omega \left[\tilde{T}(p_{y,0} y^*(\pi, \omega)) - \tilde{T}(p_{y,0} y_0(\omega))\right] \leq 0.\text{[10]} \qquad (3.21)$$

In particular, it does not increase the total surplus independently of whether or not it is politically feasible.

(3) Suppose that there is an income bracket $[y_0'(\omega), y_0''(\omega)]$ such that, at any income $y_0(\omega)$ in this bracket, the status-quo tax system T_0 is welfare-maximizing, i. e. it satisfies equation (3.14). Bracket creep is welfare-reducing relative to the status quo in this bracket.

(iii) (1) Bracket creep is Pareto-damaging if

$$R\left(\pi, \tilde{h}\right) < \pi p_{c,0} c_0. \qquad (3.22)$$

(2) Suppose that there is an income bracket $[y_0'(\omega), y_0''(\omega)]$ such that, at any income $y_0(\omega)$ in this bracket, the status-quo tax system T_0 is revenue-maximizing. Bracket creep is Pareto-damaging in this bracket.

[10]The superscript U indicates the use of the utilitarian welfare function in the derivation of equation (3.21).

These results are straightforward generalizations of those of the small-reform analysis. Proposition 3.4 provides conditions of whether or not bracket creep is favorable in a political economy and efficiency sense. Part (i) states that it is politically feasible if and only if supported by the lower half of the income distribution. According to part (ii), it is further welfare-improving under a Rawlsian welfare measure if the poorest household benefits, requiring that additional government transfers outweigh the valuation loss of pre-inflation transfers. With regard to the total surplus, however, bracket creep is never beneficial, driven by a reduction of labor supply ($y^*(\pi, \omega) < y_0(\omega)$ for all ω). Thus, political support and positive welfare implications may or may not be aligned, depending on the welfare measure used for evaluation. Ultimately, part (iii) states that bracket creep is Pareto-damaging provided that additional revenue is not enough to compensate the poorest household for the loss of government transfers in real terms. This is the case if the status-quo tax system is at the Laffer bound, and thus revenue-maximizing. Bracket creep then raises tax rates at the cost of shrinking revenue, rendering it insufficient to cover losses in the real value of transfer income.

3.5 Conclusion

This chapter presents an analysis of the political economy of bracket creep. We develop a theoretical framework, where bracket creep is modeled as a tax reform, to derive formal conditions for bracket creep being supported by majority of tax payers over a predetermined status-quo tax system. We further check whether political support for bracket creep is aligned with its efficiency properties. In deriving our results, we make use of perturbation methods and functional derivatives.

Our main finding is a median voter result for bracket creep. Under the assumption of a convex tax function, bracket creep is backed by a majority provided that the median voter is a beneficiary. In particular, the support stems from all households with below-median income. This finding is driven by the assumption of convexity of the tax schedule, implying that the burden associated with an increase of marginal tax rates is smaller for lower incomes.

We proceed by checking whether political support for bracket creep is always in line with beneficial effects on social welfare. We find that this is the case under a Rawlsian welfare function, where political support implies a welfare improvement. If welfare implications are evaluated based on the total surplus, bracket creep is never beneficial, even if favored by a majority. There may hence be a misalignment of voting outcomes and welfare effects.

Ultimately, we apply our framework to examine how bracket creep interacts with the efficiency of existing income tax systems. First, suppose it is welfare-maximizing. As the optimal level of tax rates is independent of current prices, bracket creep, pushing actual tax rates beyond that level, is welfare-reducing. Second, consider the slightly relaxed case where the tax system is at the Laffer bound, and thus revenue-maximizing. It turns out that bracket creep is Pareto-damaging, as the implicit tax increase shrinks revenue net of the losses in the real value of transfer income.

This chapter adds a political economy perspective to the literature on the interaction of inflation and income tax systems. While the analysis builds upon a static model of income taxation, it could be extended to a dynamic setting. Such a model would be suited to capture intertemporal adjustments of consumption and labor supply to inflationary pressure. Moreover, by embedding it in a broader macroeconomic framework, where prices and interest rates are formed endogenously, one would be able to account for channels of how inflation affects utility and voting over tax systems other than those modeled in this chapter.

Nonetheless, the formal conditions presented here can be used to perform empirical tests. Specifically, applying our theory to microdata on income tax systems would enable us to identify for each tax payer in the data whether he or she is a beneficiary of bracket creep. Based on that identification, it is possible to obtain empirical estimates of whether bracket creep is politically supported, as well as of its impact on efficiency. We leave this application to future research.

3.A Appendix

3.A.1 Proofs and derivations

Proof of Lemma 3.1

The assumptions on monotonicity and convexity of the tax schedule imply $\tilde{T}' > 0$ and $\tilde{T}'' \geq 0$. By equation (3.4), the function $h : y \rightarrow h(y)$ is then non-decreasing in y. Since y is in addition non-decreasing in ω according to the Spencer-Mirrlees single crossing condition, it follows that $h \circ y_0$ is non-decreasing in ω. □

Proof of Lemma 3.2

The assumptions on monotonicity and convexity of the tax schedule imply that the elasticity of tax payments with respect to income, defined as ρ, is larger than or equal to one for any level of income. It follows that

$$\rho \equiv \frac{d\tilde{T}(p_{y,0}y_0(\omega))}{\tilde{T}(p_{y,0}y_0(\omega))}\left(\frac{d(p_{y,0}y_0(\omega))}{p_{y,0}y_0(\omega)}\right)^{-1} \geq 1 \Leftrightarrow \tilde{T}'(p_{y,0}y_0(\omega)) \geq \frac{\tilde{T}(p_{y,0}y_0(\omega))}{p_{y,0}y_0(\omega)},$$

which proves that net gains from the marginal change of tax obligations are non-positive.

With quasi-linear in consumption preferences and a convex effort cost function, the derivative of net gains from the marginal change of tax obligations at the status quo with respect to ω equals

$$\theta y_0(\omega)\left(\frac{\tilde{T}(p_{y,0}y_0(\omega))}{p_{y,0}y_0(\omega)} - \tilde{T}'(p_{y,0}y_0(\omega))\right) - \theta p_{y,0}y_0(\omega)\tilde{T}''(p_{y,0}y_0(\omega))y_{0\omega}(\omega),$$

which is non-positive given our assumptions that the tax schedule is increasing and convex, implying $\tilde{T}'(p_{y,0}y_0(\omega)) \geq \tilde{T}(p_{y,0}y_0(\omega))/p_{y,0}y_0(\omega)$ and $\tilde{T}'' \geq 0$. Thus, net gains from the marginal change of tax obligations are non-increasing in ω. □

Proof of Lemma 3.3

Following Proposition 3 in Bierbrauer et al. (2023) and adopting their concept of the revenue function $\mathcal{R} : y \mapsto \mathcal{R}(y)$, the Gateaux differential evaluated at the status quo is given by

$$R_\pi(0,h) = \int_{\mathcal{Y}} h'(y)\mathcal{R}(y)dy = \int_{\omega_0(0)}^{\omega_0(\bar{y})} h'(y_0(\omega))\mathcal{R}(y_0(\omega))y_{0\omega}(\omega)d\omega, \qquad (3.23)$$

where $\mathcal{Y} = [0, \bar{y}]$ is the set of feasible incomes, $\omega_0(0)$ and $\omega_0(\bar{y})$ are the types associated with its boundaries, and $y_{0\omega}(\omega)$ is the derivative of $y^*\left(\pi, \tilde{h}, \omega\right)$ with respect to ω evaluated at the status quo. The second transformation follows from integration by substitution.

By the arguments in (Bierbrauer et al., 2021) and (Bierbrauer et al., 2023), the revenue function has the form

$$\mathcal{R}(y_0(\omega)) = p_{y,0}\tilde{T}'(p_{y,0}y_0(\omega))\frac{y_{0\pi}(\omega)}{y_{0\omega}(\omega)}\phi_\Omega(\omega) + 1 - \Phi_\Omega(\omega). \tag{3.24}$$

Furthermore, recall that $h'(y_0(\omega))$ is given by equation (3.4). We can therefore write the Gateaux differential as

$$\begin{aligned} R_\pi(0,h) = &\int_{\omega_0(0)}^{\omega_0(\bar{y})} p_{y,0}y_{0\pi}(\omega)\tilde{T}'(p_{y,0}y_0(\omega))h'(y_0(\omega))\phi_\Omega(\omega)d\omega \\ &+ \int_{\omega_0(0)}^{\omega_0(\bar{y})} (1-\Phi_\Omega(\omega))h'(y_0(\omega))y_{0\omega}(\omega)d\omega. \end{aligned}$$

The first integral is the population average $E_\Omega\left[p_{y,0}y_{0\pi}(\omega)\tilde{T}'(p_{y,0}y_0(\omega))h'(y_0(\omega))\right]$. The second integral can be solved by integration by parts, taking account of

$$h'(y_0(\omega))y_{0\omega}(\omega) = \frac{dh(y_0(\omega))}{d\omega}.$$

The integral is obtained as

$$\int_{\omega_0(0)}^{\omega_0(\bar{y})} (1-\Phi_\Omega(\omega))h'(y_0(\omega))y_{0\omega}(\omega)d\omega = E_\Omega\left[h(y_0(\omega))\right].$$

Combining the solutions to the two integrals yields expression (3.10). □

Proof of Lemma 3.4

Let ω^m be the median voter's type. The median voter benefits from bracket creep for low levels of inflation if and only if the change in this type's indirect utility, given by equation (3.8) evaluated at ω^m, is positive, or equivalently

$$R_\pi(0,h) - p_{c,0}c_0 > -p_{y,0}y_0(\omega^m)\left(\frac{\tilde{T}(p_{y,0}y_0(\omega^m))}{p_{y,0}y_0(\omega^m)} - \tilde{T}'(p_{y,0}y_0(\omega^m))\right),$$

which is condition (3.11) in the main text. □

Proof of Theorem 3.1

According to Lemma 3.2, the RHS of expression (3.11) is non-decreasing in ω. Hence, the inequality is satisfied for each $\omega \leq \omega^m$, which constitutes a majority supporting bracket creep, rendering bracket creep politically feasible. □

Proof of Lemma 3.5

Inserting indirect utility (3.8) into the definition of social welfare at the status quo, i. e. $w(0,h) = E_\Omega\left[g(w)v(0,h,\omega)\right]$, and taking the derivative with respect to π yield expression (3.12). If it is positive, welfare increases in response to a marginal increase of inflation. □

Proof of Propositions 3.1, 3.2, and Theorem 3.2

Suppose that the status-quo tax system T_0 is an interior Pareto-optimum. With $y_0(\underline{\omega}) = 0$, we have $\tilde{T}(p_{y,0}y_0(\underline{\omega})) = h(y_0(\underline{\omega})) = 0$. If social welfare is Rawlsian, we have $g(\omega) = 0$ for all $\omega > \underline{\omega}$, and $E_\Omega[g(w)] = 1$ implies $g(\underline{\omega}) = (\phi_\Omega(\underline{\omega}))^{-1}$. Plugging these values into equation (3.12) and rearranging yield the condition $R_\pi(0,h) > p_{c,0}c_0$. This condition is furthermore implied by inequality (3.4), which is the requirement for the median voter being a beneficiary of bracket creep. This proves part (*i*) of Theorem 3.2.

Now, suppose social welfare is utilitarian, we have $g(\omega) = 1$ for all ω. Plugging this into equation (3.12) and using the expression of the Gateaux differential (3.23) yield

$$w_\pi^U(0,h) = \frac{1}{p_{c,0}} E_\Omega\left[p_{y,0}y_{0\pi}(\omega)\tilde{T}'(p_{y,0}y_0(\omega))h'(y_0(\omega))\right].$$

The assumptions on monotonicity and convexity of the tax schedule imply $\tilde{T}' > 0$ and $\tilde{T}'' \geq 0$, and therefore $h'(y_0(\omega)) > 0$ for all ω. Moreover, as we show in the proof of Lemma 3.6, $y_{0\pi}(\omega) \leq 0$. Therefore, we may conclude that $w_\pi^U(0,h) \leq 0$ if utilitarian welfare is used. Together with inequality (3.4), which is the requirement for the median voter being a beneficiary of bracket creep, that implies part (*ii*) of Theorem 3.2. □

Proof of Theorem 3.3

We start out by deriving the welfare-maximizing tax formula (3.14) using a mechanism design approach as in Bierbrauer et al. (2021). We focus on direct mechanisms, which have been shown to be incentive-compatible if and only if they satisfy

$$u(\omega) = \underline{u} - \int_{\underline{\omega}}^{\omega} k_2(y(s),s)ds,$$

where $\underline{u} \equiv u(\underline{\omega})$ is the poorest household's utility, and the function $y : \omega \mapsto y(\omega)$ is non-decreasing. Furthermore, the resource constraint requires $E_\Omega\left[c(\omega)\right] \leq E_\Omega\left[y(\omega)\right]$. Inserting $c(\omega) = u(\omega) + k(y(\omega),\omega) = \underline{u} - \int_{\underline{\omega}}^{\omega} k_2(y(s),s)ds + k(y(\omega),\omega)$ as well as integration by parts yields

$$E_\Omega\left[c(\omega)\right] = \underline{u} + E_\Omega\left[k(y(\omega),\omega) - \frac{1-\Phi_\Omega(\omega)}{\phi_\Omega(\omega)}k_2(y(\omega),\omega)\right].$$

By inserting this expression into the resource constraint, one obtains

$$\underline{u} \leq E_\Omega \left[\theta y(\omega) - k(y(\omega), \omega) + \frac{1 - \Phi_\Omega(\omega)}{\phi_\Omega(\omega)} k_2(y(\omega), \omega) \right].$$

Next, we consider a social welfare function of the type $w = E_\Omega [g(\omega)u(\omega)]$ with welfare weights $g : \omega \mapsto g(\omega)$ as defined in the main text. Again replacing the utility function and integrating by parts, we can write social welfare equivalently as

$$w = \underline{u} - E_\Omega \left[\frac{1 - \Phi_\Omega(\omega)}{\phi_\Omega(\omega)} G(\omega) k_2(y(\omega), \omega) \right],$$

where $G(\omega) \equiv E_\Omega [g(s)|s \geq \omega]$ is the average welfare weight of individuals at or above ω. Since the resource constraint is binding for any optimal allocation, the former can be written as

$$w = E_\Omega \left[\theta y(\omega) - k(y(\omega), \omega) + \frac{1 - \Phi_\Omega(\omega)}{\phi_\Omega(\omega)} (1 - G(\omega)) k_2(y(\omega), \omega) \right].$$

The mechanism design problem is to choose a function $y : \omega \mapsto y(\omega)$ that maximizes the former expression and is non-decreasing. However, we solve a relaxed problem by dropping the monotonicity requirement. Any solution that maximizes social welfare and proves to be monotonic is obviously also a solution to the full problem. Specifically, we apply pointwise maximization. The first-order condition reads

$$-(1 - k_1(y(\omega), \omega)) = \frac{1 - \Phi_\Omega(\omega)}{\phi_\Omega(\omega)} (1 - G(\omega)) k_{21}(y(\omega), \omega) + \theta - 1.$$

The first-order condition characterizes a welfare-maximizing choice of y, which, in turn, determines the welfare-maximizing allocation. If this allocation is decentralized by means of an income tax schedule, each type ω solves

$$\max_y c_0 + \theta y - \frac{\tilde{T}(p_y y)}{p_c} - k(y(\omega), \omega).$$

The corresponding first-order condition is obtained as

$$k_1(y(\omega), \omega) = \theta \left(1 - \tilde{T}'(p_y y) \right).$$

Combining the former and the first-order condition of the pointwise maximization of social welfare and rearranging yields the optimal tax formula (3.14), i. e., for any type ω,

$$\tilde{T}'(p_{y,0}y_0(\omega)) = -\frac{1}{\theta}\frac{1-\Phi_\Omega(\omega)}{\phi_\Omega(\omega)}(1-G(\omega))k_{21}(y_0(\omega),\omega).$$

Since the right-hand side of this expression is independent of nominal variables, we may conclude that an increase of marginal tax rates at any income level $y_0(\omega)$ in an arbitrary income bracket $[y_0'(\omega), y_0''(\omega)]$ involved in bracket creep constitutes a welfare loss if the status quo is welfare-maximizing. □

Proof of Lemma 3.6

We derive the Laffer bound on status-quo tax rates for given prices p_0. Consider a tax reform with intensity $\hat{\tau}$ and direction $\hat{h}(y)$, which we assume to be a strictly increasing function. A tax increase is then Pareto-damaging if $R_{\hat{\tau}}(0,\hat{h}) < \hat{h}(y_0(\underline{\omega}))$. Further assuming that the poorest household has no labor income, i. e. $y_0(\underline{\omega}) = 0$, this condition simplifies to $R_{\hat{\tau}}(0,\hat{h}) < 0$. Upon replacing $R_{\hat{\tau}}(0,\hat{h})$ by (3.23), a sufficient condition is that $\mathcal{R}(y) < 0$ at any income level y. Substituting $\mathcal{R}(y)$ as in (3.24) and rearranging yields the Laffer bound (3.15).

To derive the Laffer bound that takes valuation effects into account, we apply the same procedure to the sufficient condition for bracket creep being Pareto-damaging, i. e.

$$R_\pi(0,h) < -p_{y,0}y_0(\omega)\left(\frac{\tilde{T}(p_{y,0}y_0(\omega))}{p_{y,0}y_0(\omega)} - \tilde{T}'(p_{y,0}y_0(\omega))\right) + p_{c,0}c_0.$$

The only additional assumption needed is that $\tilde{h}(\pi,y)$ is such that $\tilde{h}_y(\pi,y) \leq 1$ for any π, implying $h'(y) \leq 1$. Following the steps above, one obtains condition (3.16).

The Laffer bound comprises the function $\varepsilon : y_0(\omega) \mapsto \varepsilon(y_0(\omega))$, which is a shortcut for

$$\varepsilon(y_0(\omega)) \equiv p_{c,0}\frac{y_{0\pi}(\omega)}{y_{0\omega}(\omega)}.$$

Using the convex effort cost function, we can derive expressions for $y_{0\pi}(\omega)$ and $y_{0\omega}(\omega)$ from type ω's utility maximization problem. The first-order condition equals

$$\frac{1}{p_{c,1}}\left(p_{y,1} - p_{y,0}\tilde{T}'(p_{y,0}y) - \pi\tilde{h}_y(\pi,y)\right) = k_1(y,\omega).$$

An application of the implicit function theorem with respect to π, rearranging and evaluating at $\pi \to 0$ deliver the following expression for $y_{0\pi}(\omega)$:

$$y_{0\pi}(\omega) = -\frac{1}{p_{c,0}} \frac{p_{y,0}^2 y_0(\omega)\tilde{T}''(p_{y,0}y_0(\omega))}{\theta p_{y,0}\tilde{T}''(p_{y,0}y_0(\omega)) + k_{11}(y_0(\omega),\omega)} \leq 0.$$

An equivalent procedure with respect to ω yields

$$y_{0\omega}(\omega) = -\frac{k_{12}(y_0(\omega),\omega)}{\theta p_{y,0}\tilde{T}''(p_{y,0}y_0(\omega)) + k_{11}(y_0(\omega),\omega)}.$$

The ratio of the former two expressions is obtained as

$$\frac{y_{0\pi}(\omega)}{y_{0\omega}(\omega)} = \frac{1}{p_{c,0}} \frac{p_{y,0}^2 y_0(\omega)\tilde{T}''(p_{y,0}y_0(\omega))}{k_{12}(y_0(\omega),\omega)}.$$

□

Proof of Proposition 3.3 and Theorem 3.4

Proposition 3.3 follows from a comparison of the bounds (3.15) and (3.16). Theorem 3.4 is an immediate implication from Proposition 3.3.

Proof of Lemma 3.7

Equation (3.17) follows mechanically from integration by parts over the elements on the RHS of equation (3.6). Notably, this procedure eliminates the marginal effect of inflation on the reform direction $\tilde{h}_\pi(\pi, y)$. □

Proof of Lemma 3.8

Part (*i*): The function $\tilde{h} : (\pi, y) \mapsto \tilde{h}(\pi, y))$ is given by equation (3.1). Taking the derivative with respect to ω, one obtains the expression

$$\frac{d\tilde{h}}{d\omega}(\pi, y) = \frac{1}{\pi} p_{y,0} y_\omega \left((1+\pi)\tilde{T}'((1+\pi)p_{y,0}y) - \tilde{T}'(p_{y,0}y) \right),$$

where y_ω is the partial derivative of y with respect to ω, and which is unambiguously non-negative since $1 + \pi > 1$ and $\tilde{T}$ is increasing and convex.

Part (*ii*): Net gains from the change of tax obligations are non-positive if and only if $\tilde{T}((1+\pi)p_{y,0}y) \geq (1+\pi)\tilde{T}(p_{y,0}y)$. Using that $\tilde{T}(0) = 0$, $\tilde{T}$ continuous, increasing, and convex, as well as $1 + \pi > 1$, we have

$$\tilde{T}((1+\pi)p_{y,0}y = \int_0^y (1+\pi)p_{y,0}\tilde{T}'((1+\pi)p_{y,0}s)ds \geq \int_0^y (1+\pi)p_{y,0}\tilde{T}'(p_{y,0}s)ds = (1+\pi)\tilde{T}(p_{y,0}y),$$

which proves the non-positivity of net gains from the change of tax obligations.

Furthermore, the derivative of net gains from the change of tax obligations with respect to ω reads

$$\frac{p_{y,0}}{p_{c,0}} y_\omega (\tilde{T}'(p_{y,0}y) - \tilde{T}'((1+\pi)p_{y,0}y)),$$

which is unambiguously non-positive since $1 + \pi > 1$ and $\tilde{T}$ is increasing and convex. $\square$

Proof of Proposition 3.4

The proof of Proposition 3.4 is a straightforward replication of the steps in the above proofs, applied to the the change of indirect utility given in equation (3.18). $\square$

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List of Applied Software

Matlab R2022A was applied for the numerical application of the model in chapter 1.

Excel 2016 was applied for data organization and cleaning in chapter 2.

StataMP 17 was applied for the empirical analysis in chapter 2.

Texmaker 5.1.4 was applied for the compilation of this dissertation.

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Curriculum Vitae

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Current positions

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Economist

Previous positions

University of Cologne
October 2020 – March 2024
Teaching assistant in undergraduate macroeconomics

International Monetary Fund, Washington, DC
June 2023 – September 2023
Intern at Fiscal Affairs Department

German Economic Institute (IW), Cologne
March 2018 – July 2021
Research assistant for financial and real estate markets

Deutsche Bundesbank (German Federal Bank), Frankfurt am Main
February 2020 – May 2020

Intern at Financial Stability Department

G.I.B. Ltd., Siegen

August 2010 – September 2013

Student worker for software translation

Airbus Operations Ltd., Hamburg

July 2012 – August 2012

Intern for spares management

Education

University of Cologne

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PhD studies in economics, supervised by Prof. Dr. Felix Bierbrauer and Prof. Dr. Andreas Schabert

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October 2017 – September 2019

Master of Science in economics (grade: 1.2)

Autonomous University of Madrid

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Visiting student

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October 2013 – September 2017

Bachelor of Arts in mathematics and social sciences (grade: 1.1)

Awards and Scholarships

Friedrich Ebert Foundation

January 2014 – September 2019

Scholarship

Faculty of Economics, Management, and Social Sciences of the University of Cologne

December 2018

Dean's Award for outstanding academic achievements in graduate studies

Prime minister of North Rhine Westphalia

June 2013

Honors for outstanding schooling achievements

Non-peer-reviewed publications

Debt Surge Episodes – Conditions, Consequences, and Policy Implications, with Marwa Alnasaa, Lahcen Bounader, Il Jung, and Jeta Menkulasi, IMF Working Paper, forthcoming.

Suggestions for SGP Reform, with Jasper van Dijk, Philippa Sigl-Glöckner, and Vinzenz Ziesemer, Dezernat Zukunft, 2022.

A Proposal for Reforming the Stability and Growth Pact, with Philippa Sigl-Glöckner, Maximilian Krahé, and Florian Kern, Dezernat Zukunft, 2021.

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Affidavit

according to Article 9 (5) of the Doctoral Regulation of 1 August 2022

I hereby affirm that I have written this dissertation independently and without the use of other aids and literature than those indicated. No other person, apart from any co-authors listed in the thesis, were involved in the substantive preparation of this thesis. All passages that have been taken verbatim or in spirit from published and unpublished works of others are marked as such. I affirm that this dissertation has not yet been submitted to any other faculty or university for examination; that it has not yet been published — apart from the partial publications and incorporated articles and manuscripts indicated — and that I will not publish the dissertation before completion of the doctorate without the approval of the doctoral examination board. I am aware of the provisions of these regulations. Furthermore, I hereby declare that I have read the guidelines of the University of Cologne for ensuring good scientific practice and that I have observed them in carrying out the work underlying the dissertation and in writing the dissertation, and I hereby undertake to observe and implement the guidelines stated therein in all scientific activities. I affirm that the submitted electronic version corresponds completely to the submitted printed version. I affirm that to the best of my knowledge I have been truthful and have not concealed anything.

Cologne, April 2024