Abstract

This dissertation explores how financial markets are shaped by monetary policy and financial regulation. In the first chapter, I study how banks adjust their balance sheet to the prospect of stricter supervision (co-authored with Camelia Minoiu). We find that banks raise their capital ratios in anticipation of the new regime, but they do so mostly by shedding assets rather than by raising equity. The findings imply that stress tests have a macroprudential dimension that regulators may want to take into account. Chapter two sheds light on the transmission of monetary policy through financial institutions’ propensity to buy risky assets. I evaluate US life insurers’ bond acquisitions during the low interest period after the Great Recession (2009–2015). Life insurers bought corporate bonds with lower credit ratings as interest rates fell. I find no correlation with solvency, which implies that risk-shifting theories cannot account for the observed pattern. Instead, risk-taking is concentrated in public insurers, suggesting that earnings pressure from low interest rates may account for the observed increase in risk-taking. The final chapter develops a theory of Banking Union. In the model, financially-integrated areas benefit from coordinating their bank recapitalization measures and from sharing fiscal capacity. These two elements—joint resolution and joint funding of bailouts—are central elements of the mechanism adopted by the Euro area. However, the theory applies more generally. As the global financial system becomes increasingly connected, cross-border coordination of financial policies becomes more relevant.
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Monetary policy and financial regulation are the government’s primary tools for influencing financial markets. This dissertation is organized in three chapters that shed light on the transmission of such policy interventions.

The first chapter evaluates how banks adjust their balance sheets in anticipation of stricter supervision (co-authored with Camelia Minoiu). We exploit a discontinuity in the assignment mechanism of the European Central Bank’s Comprehensive Assessment in order to identify the effects of increased regulatory scrutiny on bank balance sheets. We find that banks adjust to stricter supervision by reducing leverage, and most of the adjustment stems from shrinking assets rather than from raising equity. We estimate a seven percent reduction in leverage, two thirds of which are due to asset shrinkage. Securities are adjusted much more strongly than the loan book. On the liability side, banks mostly reduce their reliance on wholesale funding.

Using data on syndicated loan issuance, we find that very weak banks also reduce the supply of credit. The evidence highlights banks’ reluctance to adjust capital when the leverage target changes and suggests that macroprudential considerations matter for stress-testing in practice.

The second chapter investigates the effect of monetary policy on risk-taking in capital markets. During the low interest-period starting in 2009, life insurers tilted their corporate bond acquisitions towards issues with lower credit quality, longer maturities, and lower liquidity. Rajan (2005) suggests that risk-shifting explains insurers’ propensity to take on more risk when interest rates are low. However, neither insurers’ solvency nor their financial strength ratings explain changes in the riskiness of their bond acquisitions. Even firms with a negligible likelihood of defaulting on their creditors reduced the credit quality of their bond acquisitions. I propose the alternative hypothesis that insurers take on more risk due to earnings pressure in periods of low interest rates. This theory does not require insurers to be close to default and yet explains increased risk-taking when interest rates are low. Moreover, it implies that public firms are more strongly affected than private firms and mutual insurers. This prediction is borne out in the data. The results suggest that a
recruitment channel of monetary policy is active and even solvent insurers may transmit and amplify unconventional monetary policies.

The third chapter develops a theory of why financially-integrated areas need to coordinate their financial policies at a supranational level. I present a model of the feedback loop between sovereign and bank solvency in an international setting. I analyze the impact of shocks to sovereigns’ and banks’ balance sheets on output, investment, and welfare as well as the consequences of redistributing net worth between banks, governments, and across countries. The model implies that national bailouts can have positive or negative externalities on other countries, depending on the network structure and the accompanying fiscal policies. As a consequence, the size and funding structure of uncoordinated bailouts differ from the social optimum. Committing to a system of international transfers from sovereigns to banks can increase expected welfare by improving the distribution of net worth in adverse scenarios. Such a policy reduces market failures that are induced by the sovereign-bank interaction and their spillovers abroad.
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To my parents
Chapter 1

How do Banks React to Stricter Supervision?\textsuperscript{1}

1.1 Introduction

Now what has been a restriction and we recognised that from the start, is that these exercises, of course, led the banks to be very careful in what they were doing with credit and with possible expansions of their balance sheet. They wanted to be as prepared as possible to pass this exam. (Constâncio, 2014)

After the financial crisis of 2007/2008, bank supervision has become much tighter. But how do banks adjust their balance sheets when faced with increased regulatory scrutiny? For example, do they become safer by holding larger capital buffers? Does tougher regulation lead to a credit crunch, thereby harming the real economy? Or does regulation have little bite and banks’ behavior remains mostly unchanged?

To answer these questions, we need a large-scale change in supervisory intensity and a way of establishing a credible counterfactual scenario. The introduction of the Eurozone’s Single Supervisory Mechanism (SSM) and the associated Comprehensive Assessment provides us with both. First, the new regime centralized supervision for a sizable part of the

\textsuperscript{1}Co-authored with Camelia Minoiu
banking system at the ECB and was designed to be “intrusive, tough, and fair.”\textsuperscript{2} Second, only banks with assets above a sharp cutoff were affected. Therefore, we can compare banks’ behavior on either side of this cutoff to establish how banks would have behaved absent regulatory changes.

We find that banks reduced leverage in anticipation of the new regime. We provide a simple model of leverage adjustment in which banks may shrink assets if equity issuance is perceived as costly. By decomposing leverage adjustments in the data, we find that the majority of the leverage adjustment is indeed due to asset shrinkage, suggesting that banks are averse to raising equity in the short run.

The reactions that we find around the cutoff reflect the behavior of banks in the unrestricted sample, which includes observations far from the discontinuity. In the unrestricted sample, banks that were subject to the Comprehensive Assessment also reduced leverage. Moreover, asset shrinkage drives the reduction in leverage as before. This gives us confidence that we are documenting a behavior that applies more generally.

We also find some evidence for a credit crunch, but only for very weak banks. Given that balance sheet changes represent stocks—which might vary due to sales of legacy portfolios—we cannot immediately conclude from banks’ asset shrinkage that they contracted the supply of credit. We address this concern with disaggregated data on syndicated loan issuance. Controlling for loan demand, we find evidence for a reduction in credit supply only for banks with very low capital ratios.

Our results underline a special role for securities on bank balance sheets. We find that for a given balance sheet contraction, banks disproportionately adjust their securities portfolios. As a consequence, large securities portfolios insulate loan books from asset shrinkage. However, this buffering feature of securities is much weaker when sovereign credit spreads are high: We find that the pass-through of balance sheet contractions to securities is lower for countries with impaired sovereign debt.

\textsuperscript{2}Daniele Nouy, Chair of the Supervisory Board of the SSM, in an interview with the Times of Malta (October 5th, 2014).
Our findings inform the debate around macroprudential financial policy. Hanson et al. (2011) define macroprudential financial policy as “an effort to control the social costs associated with excessive balance-sheet shrinkage on the part of multiple financial institutions hit with a common shock”. The authors identify two externalities associated with asset shrinkage: fire sales and credit crunches. Poorly capitalized banks do not take those externalities into account when choosing between equity issuance and assets sales. Applying this logic to stress testing, regulators ought to focus on the level of capital in the financial system as a whole in addition to individual banks’ capital ratios when assessing the banking sector (Greenlaw et al., 2012). While we do not conduct a thorough welfare analysis, our results highlight banks’ reluctance to adjust equity at short notice. We speculate that the Comprehensive Assessment would have benefitted from additional measures to address banks’ tendency to shrink assets in anticipation of the assessment.

The results in this paper are consistent with theories of banking that emphasize frictions in raising external finance in the form of equity. Both debt overhang and adverse selection can account for the observed reluctance in raising additional equity. Irrespective of the exact channel that is at play, our findings underscore the importance of a slow phase-in of higher capital requirements.

The existing literature on bank stress-testing can be divided into three strands. First, there is a large theoretical body of work that deals with questions of optimal disclosure. Second, a number of studies have conducted event studies of asset prices around the announcement of stress test results. Third, and most closely related to our analysis, is the finding that undercapitalized banks appear to restrict lending when stress-tested (Mésonnier and Monks, 2015; Calem et al., 2016; Gropp et al., 2016). This paper adds to the literature by providing a clean identification strategy that allows us to isolate the effects of stricter supervision on bank balance sheets.

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3See Goldstein (2014) for a survey.

4See, for example, Petrella and Resti (2013); Candelon and Sy (2015); Sahin and Haan (2015) and the references therein.
The fact that banks deleverage when faced with a tougher regulatory environment is consistent with evidence from very small banks in the United States. Agarwal et al. (2014) note that forced rotations of state and federal regulators lead to variation in regulatory intensity. In their setting, stricter regulation also leads banks to report higher capital ratios. However, the authors do not decompose changes in leverage into changes in assets and equity. The finding that such changes are mostly due to asset shrinkage is a central result of our paper. Moreover, their sample only covers local banks with assets below $500 million in assets. By contrast, our sample covers the vast majority of Eurozone bank assets and includes systemic banks. Since both banks’ business models and their regulatory environment vary by bank size, it is important to investigate the effects of tighter supervision for large banks as well.

The paper proceeds as follows: In section 1.2, we propose a simple theory of banks’ balance sheet adjustments. Section 1.3 provides details on the institutional background around the ECB’s Comprehensive Assessment and the new regulatory framework. In section 1.4, we discuss our data. We explain our identification strategy and the resulting estimates in section 1.5. The special role of securities in balance sheet adjustment is addressed in section 1.6. Loan-level regressions are presented in section 1.7. Finally, section 1.8 concludes.

1.2 Model

This section presents a dynamic, partial equilibrium model of bank deleveraging. The model features a deviation from the Modigliani-Miller benchmark: banks face adjustment costs in raising capital. The model elucidates under which conditions banks may react to stricter supervision by shrinking assets.

There are at least three reasons for banks to reduce leverage ahead of a tightening of supervision. First, in our setting the new regime featured recurring stress tests, which require banks to sustain minimum capital ratios under challenging macroeconomic scenarios. The required amount of capital to pass these tests may well exceed the amount that banks used to hold before. Second, the Comprehensive Assessment also included an Asset Quality Review, in which banks were forced to mark down assets that the new regulators deemed overvalued;
this process further reduces the available capital in banks’ books. Third, a major rationale for streamlining supervision at the ECB was that national regulators enforced similar rules in different ways. This applied, for example, to the eligibility of deferred tax assets as Tier 1 capital. Therefore, we model the tightening of supervision as a reduction in banks’ desired leverage.

Banks can reduce leverage by selling assets or by raising equity. Both margins of adjustment involve costs: Selling illiquid assets may be associated with fire sales and, in addition, might imply suboptimal scale. On the other hand, raising equity may also be difficult in the short-run, for example due to informational frictions (Myers and Majluf, 1984) or debt overhang (Myers, 1977). In our model, we solve for banks’ balance sheet choices as a function of these adjustment costs. We find that assets overshoot their long-run value if equity adjustment costs are relatively large. This is optimal from the banks’ point of view since over-adjusting assets (relative to the long-run) allows the bank to under-adjust equity (relative to the long-run); this behavior economizes on adjustment costs, even though it leads to suboptimal scale during the transition.

1.2.1 Setup

We model the ECB’s comprehensive assessment as an increase in the effective capital requirement. In the pre-period, weak regulatory oversight allowed banks to hold less capital relative to assets \( E \) than is nominally required (\( \bar{k} \)). We use \( \gamma \) as a measure of regulatory lenience such that the effective capital requirement is

\[
\frac{E}{A} \geq \bar{k} (1 - \gamma)
\]

We interpret the transfer of supervision to the ECB as a reduction in leniency \( \gamma \). It is clear from the above formulation that this maps to an increase in the effective capital requirement. To economize on notation, we work directly with the effective capital requirement \( \kappa \) in what follows, which simplifies the constraint to

\[
\frac{E}{A} \geq \kappa
\]
The comparative static of interest is an increase in the effective capital requirement.

**Cost of Capital**

The weighted average cost of capital is given by

\[
\text{WACC} \left( \frac{E}{A} \right) = \frac{E}{A} r_e + \left( 1 - \frac{E}{A} \right) r_d
\]  

(1.1)

where \( r_e \) and \( r_d \) are the required returns on equity and debt, respectively. We borrow from the literature on the cost of bank capital and introduce a deviation from Modigliani and Miller (1958)'s stylized environment. In the literature, at least four reasons have been proposed for why banks’ cost of capital falls with leverage:

1. Tax-advantages of debt financing (Modigliani and Miller, 1958, 1963; Miller, 1977)
2. Managerial incentives of (short-term) debt (Diamond and Rajan, 2001)
3. A money premium on (short-term, safe) debt (Gorton, 2010; Stein, 2012; Krishnamurthy and Vissing-Jorgensen, 2012)
4. Low risk anomaly (Baker and Wurgler, 2015)

In this paper, we follow Kashyap et al. (2010) and introduce a catch-all term \( \delta \) that reflects the additional cost of equity over and above what would be expected in a frictionless setup. We further assume that debt is risk-free and equity is priced according to the Capital Asset Pricing Model. Therefore, the required return on equity is given by \( r_e - r_f = \beta_E (r_m - r_f) \).

Note that the equity beta is given by \( \beta_E = \frac{A}{E} \beta_A \) where \( \beta_A \) is the firm’s asset beta. Substituting this into the WACC formula (1.1), banks’ cost of capital is given by

\[
\text{WACC} \left( \frac{E}{A} \right) = (r_f + \beta_A r_m) + \frac{E}{A} \delta \equiv \bar{r} + \frac{E}{A} \delta
\]  

(1.2)

The term \( \bar{r} = r_f + \beta_A r_m \) captures the cost of capital in a frictionless benchmark case. Equation (1.2) is a crucial ingredient for our model, since it creates an incentive to minimize the share of equity capital on banks’ balance sheets.
Adjustment Costs

Myers and Majluf (1984) propose a further cost of issuing equity that stems from asymmetric information between firms and investors. Their model endogenously generates a downward sloping demand curve for firms’ stocks due to adverse selection. In order to capture the fact that accumulating equity slowly—for example through retained earnings—is easier than issuing a large amount, we introduce a convex cost of issuance:

\[ c_E (E_t, E_{t-1}) = \frac{1}{2} c_c \times (E_t - E_{t-1})^2 \]  \hspace{1cm} (1.3)

Since bank assets tend to be illiquid, adjusting assets is not a frictionless process either. To account for adjustment costs in assets, we introduce a convex cost of asset sales:

\[ c_A (A_t, A_{t-1}) = \frac{1}{2} c_a \times (A_t - A_{t-1})^2 \]  \hspace{1cm} (1.4)

Both adjustment costs should be interpreted as reduced-form versions of frictions generated by asymmetric information.

Payoffs

Investing \( A \) units yields a stochastic gross return of \( f(A) + Ae \) where \( E[e] = 0 \) and \( Cov [e, r_m] = \beta_A Var [r_m] \). Hence, the expected return is \( f(A) \) and its beta is \( \beta_A \). We further assume a simple quadratic functional form for \( f(\cdot) \),

\[ f(A) = \varphi_0 A - \frac{1}{2} \varphi A^2 \]  \hspace{1cm} (1.5)

and let \( \varphi_0 > 1 + \bar{r} + \delta \). Expected flow profits are

\[ \pi (A_t, E_t; A_{t-1}, E_{t-1}) = f(A_t) - (1 + \bar{r}) A_t - E_t \delta - c_E (E_t, E_{t-1}) - c_A (A_t, A_{t-1}) \]  \hspace{1cm} (1.6)

subject to \( E_t \geq \kappa_t A_t \). The first term captures the expected gross return, the next two terms capture the cost of capital, and the last two terms capture the adjustment costs when raising additional equity and selling assets, respectively. Moreover, we assume that the bank was in
steady-state before the exercise, i.e. $E_0$ and $A_0$ solve

$$\max_{A_0, E_0} f'(A_0) - (1 + \bar{r}) A_0 - E_0 \delta \quad \text{subject to} \quad \frac{E_0}{A_0} \geq \kappa_0$$

which implies that

$$A_0 = \frac{1}{\varphi} \left( \varphi_0 - (1 + \bar{r} + \kappa_0 \delta) \right), \quad E_0 = \kappa_0 A_0 \quad (1.7)$$

Steady-state assets, $A_0$, depend on the capital requirement only if capital is “expensive” ($\delta > 0$) relative to a frictionless benchmark ($\delta = 0$). In steady-state, the bank equates expected marginal returns to the cost of capital. The existing literature on bank capital has concluded that the increase in banks’ cost of capital due to an increase in capital requirements are likely to be modest. Kashyap et al. (2010), for example, estimate that a ten percentage point increase in capital requirements would lead to an increase in the weighted average cost of capital of at most 45 basis points. In our framework, this would correspond to a cost $\delta$ of 4.5%.

The timing is as follows: The initial capital requirement, $\kappa_0$, is in force before period 0. Between period 0 and period 1, the regulator unexpectedly announces a new effective capital requirement of $\kappa$, which has to be met from period 1 onwards.

**Characterization of the Bank’s Optimal Policy**

We use standard techniques from dynamic optimization to describe the banks’ optimal policy. From period 2 onwards, the problem is stationary and the Bellman equation is given by

$$V(A_{t-1}, E_{t-1}) = \max_{A_t, E_t} \pi(A_t, E_t; A_{t-1}, E_{t-1}) + \lambda_t (E_t - \kappa A_t) + \beta V(A_t, E_t)$$

The necessary conditions for an interior maximum are

$$f'(A_t^*) - (1 + \bar{r}) - c_A'(A_t^*, A_{t-1}) - \kappa \lambda_t + \beta \frac{dV(A_t^*, E_t^*)}{dA_t} = 0 \quad (1.8)$$

$$-\delta - c_E'(E_t^*, E_{t-1}) + \lambda_t + \beta \frac{dV(A_t^*, E_t^*)}{dE_t} = 0 \quad (1.9)$$

$$\lambda_t (E_t^* - \kappa A_t^*) = 0 \quad (1.10)$$
Shrinking assets is associated with suboptimal scale and adjustment costs. However, it allows the bank to avoid raising equity (equation 1.8). The optimal choice of equity weighs the cost of issuing additional equity against the need to hit the capital requirement (equation 1.9). By the envelope theorem, we find that

\[
\frac{d}{dA_t} V(A_t, E_t) = c'_A (A^*_t, A_t), \quad \frac{d}{dE_t} V(A_t, E_t) = c'_E (E^*_t, E_t) \tag{1.11}
\]

The problem simplifies to a univariate optimization problem if the constraint binds at all times. For an increase in capital requirements, this will be the case as long as the bank actually needs to raise capital to achieve the long-run optimum. Therefore, we need to rule out extreme scenarios in which the optimal level of equity drops after a rise in the capital requirement, which happens when optimal bank size shrinks so much that additional capital is not required.

**Lemma 1.** (Sufficient condition for binding multipliers) The Lagrange Multipliers \(\lambda_t\) will be binding as long as the gross return function is sufficiently concave, i.e. \(q \geq q^* \Rightarrow \lambda_t > 0 \forall t\) where \(q^*\) is derived in the appendix.

**Proof.** (see appendix)

we assume that this condition is satisfied throughout the paper. Using lemma 1, the problem is straightforward to solve since \(E_t = \kappa A_t\) for all \(t\). Combining equations 1.3, 1.4, 1.5, 1.8, 1.9, and 1.11 leads to the following result:

**Lemma 2.** (Path of Assets) The optimal path of assets for \(t \geq 2\) is given by

\[
A_t = \bar{A} + (A_1 - \bar{A}) r^{t-1}
\]

where \(\bar{A} = \frac{1}{\varphi} (\varphi_0 - (1 + \bar{r} + \kappa \delta))\) is the long-run value of \(A_t\) and \(r\) determines the speed of convergence. The value of \(r\) is derived in the appendix.

**Proof.** (see appendix)

**Corollary 3.** (Long-run Assets) In the long-run, bank assets shrink if and only if equity capital is costly, i.e. \(\bar{A} < A_0 \iff \delta > 0\).
Proof. $A_0 - \bar{A} = (\kappa - \kappa_0) \delta > 0 \iff \delta > 0$ using the fact that $\kappa > \kappa_0$. \hfill \Box

To find $A_1$, note that the above value function $V(\cdot, \cdot)$ is valid from $t = 2$ onwards. Therefore, at $t = 1$ the problem is to solve

$$V_1(A_0, E_0) = \max_{A_1, E_1} \pi(A_1, E_1; A_0, E_0) + \beta V(A_1, E_1) \text{ s.t. } E_1 = \kappa A_1$$

Applying a similar logic as before yields lemma 4:

**Lemma 4.** *(Asset choice upon impact)* Assets in period 1 are given by

$$A_1 = w_0 \left( \frac{\psi_0}{\psi} A_0 \right) + (1 - w_0) \bar{A} \quad (1.12)$$

where $\psi_0 = \frac{1}{\bar{\psi}} (c_a + \kappa_0 \kappa c_e)$ and $\psi = \frac{1}{\bar{\psi}} (c_a + \kappa^2 c_e)$ are measures of adjustment costs and the weight on the initial period is given by $w_0 = \frac{\psi}{1 + \bar{\psi} + (1 - \bar{r}) \bar{\psi}}$.

It might be natural to interpret expression 1.12 as a weighted average of initial assets $A_0$ and long-run assets $\bar{A}$, where the weights are determined by the adjustment costs. Note, however, that it is not the case that $A_1$ is necessarily between $A_0$ and $\bar{A}$. In fact, under many parameterizations, assets overshoot their long-run value (i.e. $A_1 < \bar{A} < A_0$), which motivates proposition 5.

**Proposition 5.** *(Overshooting)* After an increase in capital requirements, assets adjust more in the short-run than in the long-run if raising equity is costly relative to shrinking assets. Formally, the condition

$$\frac{c_a + \kappa_0 \kappa c_e}{c_a + \kappa^2 c_e} < \frac{\varphi_0 - (1 + \bar{r} + \kappa \delta)}{\varphi_0 - (1 + \bar{r} + \kappa_0 \delta)} \quad (1.13)$$

implies that $A_1 < \bar{A}$.

**Proof.** Consider an increase from $\kappa_0$ to $\kappa > \kappa_0$. It follows that $\bar{A} < A_0$ and $A_0 - A_1 > A_0 - \bar{A} \iff A_1 - \bar{A} > 0$. From 1.12, $A_1 - \bar{A} \propto \frac{\psi_0}{\psi} A_0 - \bar{A}$. Plugging in for $\psi_0$, $\psi$, $A_0$, and $\bar{A}$ yields 1.13. \hfill \Box

The overshooting result might seem surprising at first. The intuition is conveyed most easily in a stylized case without adjustment costs in assets ($c_a = 0$) and no change in the
Condition 1.13 then simplifies to $\kappa_0 / \kappa < 1$, which is satisfied for any increase in capital requirements. Proposition 5 suggests that assets will fall below their initial value and gradually return. Consider a flat path of assets instead. Then, equity needs to jump when the higher capital requirement is introduced. But increasing equity is associated with convex adjustment costs. Therefore, reducing assets by one unit upon impact allows the bank to raise $\kappa$ units less equity in the same period. This avoids a first-order adjustment cost and is associated with a second order cost due to suboptimal scale. As a result, the bank will contract assets upon impact in order to smooth out the equity adjustment.

In figure 1.1, we plot the paths of assets, equity, the capital ratio, and the Lagrange multiplier for an increase in the effective capital requirement at $t = 1$ for low and high equity adjustment costs. The harder it is to increase equity (e.g. by retaining earnings or issuing new stock), the more assets have to shrank to meet the increase in capital requirements.

The model guides our empirical analysis in what follows: Did the transfer of supervision to the ECB have any bite at all? Do banks perceive equity adjustments as costly and shrink...
their balance sheets to reduce leverage in the transition? Or do they simply meet reduce
leverage by substituting debt with equity, leaving assets unaffected? Before testing these
hypothesis in the data, we discuss the institutional background around the introduction of
the Single Supervisory Mechanism and the Comprehensive Assessment.

1.3 Institutional Background

In this section, we describe why and how European leaders decided to form a so-called
Banking Union. One aspect of the Banking Union were sweeping changes to banking
regulation. Those changes generate variation in the tightness of supervision across banks
and time, which we analyze in the empirical section of this paper.

At the height of the European sovereign debt crisis, policymakers decided to form a
Banking Union in order to break the link between distressed sovereigns and distressed banks
(Rompuy, 2012). On December 14th, 2012, the European Council agreed on a three-pronged
approach. First, the largest Eurozone banks would be subject to the Single Supervisory
Mechanism (SSM), which implied a transfer of regulatory oversight from national regulators
to the ECB. Second, the Council decided to establish the European Stability Mechanism (ESM)
as a joint source of financing for bank bailouts. Third, the Council passed new legislation on
the resolution of failed banks: the Bank Recovery and Resolution Directive (BRR) and the
Single Resolution Mechanism (SRM). The apparent failure of existing bankruptcy procedures
for large financial institutions with cross-border activities motivated this change (Véron and

A crucial stepping stone on the way toward the Single Supervisory Mechanism was the
Comprehensive Assessment. The Comprehensive Assessment was carried out before the
ECB assumed its new supervisory role and comprised the a review of asset quality and a
stress test. The process covered bank assets worth €22tn, corresponding to around 80% of
the Eurozone banking system.

Figure 1.2 presents a timeline of events. The SSM was agreed on in December 2012 and
snapshots of bank balance sheets were taken on December 31, 2013. Therefore, banks had
about one year to adjust their balance sheets in preparation for the assessment. It is this adjustment period that we evaluate.

1.3.1 Assignment of Banks to the Comprehensive Assessment

In this section, we discuss the algorithm by which banks were assigned to the Comprehensive Assessment. One of the criteria was an asset cutoff. The sharp cutoff allows us to establish a plausible counterfactual for how banks would have behaved had they not been assigned to the new supervisory regime.

The criteria for inclusion in the Comprehensive Assessment reflect a trade-off between coverage and the cost of conducting the assessment (European Central Bank, 2014). The following two criteria were sufficient for inclusion and are relevant for our empirical strategy:

1. bank assets exceed €30bn (asset cutoff),

2. the bank is among the three largest credit institutions of its home country (rank condition).

In figure 1.3, we visualize the assignment based on size and country ranks. The vertical dashed line corresponds to the asset cutoff. Banks to the right of this line are assigned to the Comprehensive Assessment by virtue of having assets above $30bn. The horizontal

---

5 A third criterion was whether the ratio of bank assets to GDP exceeds 20%, provided bank assets also exceed €5bn. The assets-to-GDP cutoff was binding only for a few smaller banks in Cyprus and Luxembourg. By definition, these do not exceed the €30bn cutoff and are excluded for the purpose of the regression discontinuity design.

6 The ECB applied a 10% margin of error. Hence, the effective cutoff was €27bn, which we use for our empirical analysis.
dashed line corresponds to the rank condition. Banks below this line are assigned to the Comprehensive Assessment by virtue of being one of the three largest banks in their home country.

We construct our counterfactual by comparing banks to the left and to the right of the €30bn asset cutoff within the same country. In order to implement this comparison, we need to restrict the sample to countries that had banks on either side of the cutoff. This is true as long as there is at least one bank with more than €30bn in assets in this country, which applies to Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain.

1.3.2 Case Studies

Before proceeding to the empirical analysis, we present two case studies of banks that adjusted their balance sheets ahead of the Comprehensive Assessment, one from a regional
lender and one from a large universal bank. The examples suggest that both large and small banks significantly changed their behavior in anticipation of the test. The anecdotal evidence complements our more formal estimates in the following sections.

UniCredit, Italy’s biggest bank by assets, recorded an annual loss of €14bn in 2013. To put this number into perspective, UniCredit’s annual revenues were €24bn and its assets amounted to €846bn in the same year. The loss was mostly due to impairment of goodwill and additional loan loss provisions. The financial press interpreted management’s decision to increase loan loss provisions as a preemptive move ahead of the stress test.

Regional banks also adjusted their balance sheets in anticipation of the Comprehensive Assessment. ApoBank is a German bank that focuses on clients in the healthcare industry such as doctors and pharmacists. Its assets amounted to €35bn in 2013. Given that the bank’s size exceeded the €30bn cutoff, it was included in the Comprehensive Assessment. In the year before the stress test, the bank reduced its assets by 8.4%, which was driven by reductions in the bank’s securities portfolio. Even more strikingly, the bank trimmed its risk-weighted assets to €10.9bn, down from €17.1bn a year before. In its 2013 annual report, the bank’s management emphasizes that it was well-prepared for the stress test:

The results of the Asset Quality Review and the stress test of the ECB are scheduled to be announced in the second half of 2014. Due to the developments in our risk profile and our current capital base described above, we do not expect to have to make any extensive additional risk provisions or take any major capitalisation measures. (apoBank, Annual Financial Report 2013)

In other words, the bank deems itself well-prepared for the new regulatory regime because it has sold securities and thereby increased its capital ratios. Anecdotal evidence therefore supports the hypothesis that both large and small banks changed their behavior ahead of the ECB’s Comprehensive Assessment.

7 Unicredit, 2013 Consolidated Reports and Accounts (downloaded 11/9/2015)
1.4 Data and Descriptive Statistics

In this subsection, we describe our data. We concentrate on banks’ behavior in the year just before the Comprehensive Assessment and show that stress-tested banks are systematically different from non-tested banks, which motivates our empirical strategy in the following section.

1.4.1 Sample Construction

In this subsection, we discuss the sources and the construction of our data. We collect annual Eurozone bank balance sheets and add supervisory data from the ECB. Supervisory data includes both the assignment as well as the results of the Comprehensive Assessment, which allows us to link bank behavior to supervision.

We source a panel of bank balance sheets for the period 2012–2015 from SNL Financial.\footnote{Latvia and Lithuania joined the Eurozone during the sample period, but followed tight pegs before. We convert Latvian banks’ balance sheets to Euros at the conversion rate of 0.7028 Lats per Euro (2011-2013). Lithuanian banks’ balance sheets are converted at 3.4528 Litas per Euro (2011-2014).} We add 10-year government bond yields from the ECB’s long-term interest rate statistics.\footnote{Estonia does not have any comparable bonds outstanding, so we omit the country when analyzing the relationship between balance sheet adjustments and yields.} Since the bank data is annual, we take the average yield in a given year. We identify the banks that were subject to the Comprehensive Assessment based on the results published by the ECB after the stress test European Central Bank (2014). We also add data on banks’ capital ratios under the baseline and the adverse scenario. We lose one institution, LCH.Clearnet, since it is not part of the SNL database. We consolidate the balance sheets of Wüstenrot Bausparkasse (ID 4257337) and Wüstenrot Bank AG Pfandbriefbank (ID 4143295) since the company was assigned to the Comprehensive Assessment based on holding company assets (European Central Bank, 2013), while SNL reports both subsidiaries separately.

A number of institutions are classified as banks by SNL but not treated as banks by the ECB. In particular, bad banks that are fully owned by governments were not part of the Comprehensive Assessment but are considered “banks” in the database. We therefore filter
out all institutions in the dataset that were not assigned to the Comprehensive Assessment even though their assets exceeded €30bn. The set of deleted entities includes, for example, Portigon AG, Heta Asset Resolution AG, and BancoPosta.

We identify a sample of control observations in SNL’s database of Eurozone financial institutions. First, we remove all banks that are subsidiaries of assessed banks as well as holding companies of assessed banks. For several banks, we manually add information on their corporate structure in order to avoid such double-counting. Then, we apply an economic filter to the data since SNL reports data for banks as well as non-bank financial institutions. We delete banks that are not classified as “bank” or “savings bank/thrift/mutual”. We also delete very small banks with assets below €500m and banks whose fiscal year ends in months other than December. Finally, we require institutions to have a loans-to-assets ratio of at least 20% and a deposits-to-assets ratio of at least 20%. For consistency, we apply the same filter to the set of banks that were part of the Comprehensive Assessment. In order to avoid that our results are distorted by outliers, we winsorize all outcome variables at the 2.5% level. Manual checks suggest that many of these are reporting errors for smaller banks, for example due to changes in the level of consolidation.

Our preferred measure of banks’ leverage is the ratio of total assets to tangible common equity. We prefer the leverage ratio as a measure of capital to regulatory capital for two reasons: First, there is little ambiguity in the accounting treatment of this measure. Tier 1 capital as well as total regulatory capital may include hybrid equity instruments, goodwill, and deferred tax assets, which have limited loss-absorbing ability and their treatment varies by country. Asset risk weights are zero for sovereign debt, which turned risky for several European sovereigns in the time period under consideration and risk weights may be subject to manipulation (Mariathasan and Merrouche, 2014; Behn et al., 2014). The total assets figure does not suffer from these shortcomings. Second, it is frequently argued that (unweighted) leverage provides a more useful basis for assessing bank solvency than regulatory capital ratios (e.g. Acharya et al., 2014; Steffen, 2014). Therefore, we focus on leverage defined as total assets over tangible common equity in subsequent analyses.
1.4.2 Descriptive Statistics

In this subsection, we present descriptive statistics for banks that were subject to the Comprehensive Assessment and for banks that were not. In addition to being larger, stress-tested banks tend to be more levered and more reliant on wholesale financing. These differences in bank characteristics imply that we cannot simply attribute all differences in behavior to the change in the supervisory regime—we need an identification strategy.

Summary statistics are reported in table A.1 in the appendix. Our final dataset contains close to a hundred banks that were part of the Comprehensive Assessment and around a thousand control banks. For most of the analysis, we are interested in banks’ balance sheet adjustments in 2013 and we use covariates as of December 31, 2012. We define bank size as the natural logarithm of total assets, where assets are denominated in millions of Euros. The average bank in our sample has a deposits-to-assets ratio of 66%, a loans-to-assets ratio of 60%, and a securities-to-assets ratio of 24%.

We cannot naively compare stress-tested banks to non-tested banks since the former group is significantly different on observable characteristics: In table 1.1, we compare the mean characteristics of the two groups. Banks that were part of the Comprehensive Assessment are significantly larger, rely more on wholesale financing, and are more leveraged.

In addition to observable differences between the two groups, we have to be wary of unobserved confounding factors that correlate with banks’ assignment to the new supervisory regime. For instance, the phase-in of Basel III could account for some of the adjustments we observe on stress-tested banks’ balance sheets, and Basel III likely affects stress-tested banks more than the control group due to their funding structure. The Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR), for example, penalize reliance on short-term wholesale funding. This might explain part of the reduction in banks’ reliance on market funds in our data.

Given that stress-tested banks have significantly different characteristics and might be influenced by unobserved time-varying factors, we need a more elaborate empirical strategy to isolate the effect of tighter supervision. In the following section, we present our regression
<table>
<thead>
<tr>
<th>(Share of Assets, in %)</th>
<th>Stressed</th>
<th>Not Stressed</th>
<th>Difference</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposits</td>
<td>49.98</td>
<td>67.25</td>
<td>-17.27</td>
<td>-9.61</td>
<td>0.00</td>
</tr>
<tr>
<td>Wholesale Funding</td>
<td>44.27</td>
<td>24.56</td>
<td>19.71</td>
<td>10.28</td>
<td>0.00</td>
</tr>
<tr>
<td>Tangible Common Equity</td>
<td>4.72</td>
<td>8.05</td>
<td>-3.34</td>
<td>-7.85</td>
<td>0.00</td>
</tr>
<tr>
<td>Loans</td>
<td>58.18</td>
<td>60.07</td>
<td>-1.89</td>
<td>-1.16</td>
<td>0.25</td>
</tr>
<tr>
<td>Securities</td>
<td>24.45</td>
<td>24.03</td>
<td>0.42</td>
<td>0.32</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Table 1.1: Stress-Tested Banks Differ Systematically from Other Banks

discontinuity design. Under weak conditions, these estimates have a causal interpretation as the average treatment effect on a bank at the discontinuity.

### 1.5 Regression Discontinuity Design

In this section, we present our main estimates. Banks whose assets exceed €30bn experienced a change in supervision whereas smaller banks did not. By comparing banks around this cutoff, we can identify the effect of tighter supervision on bank behavior.

#### 1.5.1 Identification

In this subsection, we discuss how we identify the effect of tighter regulation. We use a regression discontinuity design (RDD), which is a well-established method in the treatment effects literature\(^{12}\) that has also become popular in financial economics.\(^{13}\) The strategy allows us to overcome confounding selection effects by focusing on comparable banks around the assignment cutoff.

Intuitively, the treatment effect is found by comparing banks just to the left of an assignment cutoff to banks just to the right of this cutoff. In the absence of treatment, the two groups would have plausibly behaved in similar ways. In our case, we allow for the fact that large banks might have adjusted to Basel III in different ways compared to small banks, for instance. We only require there to be no discrete jump in such omitted trends at the cutoff.

\(^{12}\)Lee and Lemieux (2010) provide survey of regression discontinuity designs in economics.

\(^{13}\)For examples, see Keys et al. (2010, 2012); Bubb and Kaufman (2014); Howell (2015).
In the RDD subsample, the treatment indicator is defined as

\[
\text{Stress-Tested}_i = \begin{cases} 
1 & \text{if } A_i \geq 0 \\
0 & \text{if } A_i < 0
\end{cases}
\]

where \( A_i \) denotes the distance from the cutoff (often called the “running variable”). In our case, \( A_i \) is the difference between actual bank size (log assets) and the cutoff value. The object of interest is

\[
\tau \equiv \lim_{a \downarrow 0} E \left[ y_i | A_i = a \right] - \lim_{a \uparrow 0} E \left[ y_i | A_i = a \right] \quad (1.14)
\]

We expect treatment effects to be heterogeneous in our application: Stricter regulation could be more challenging for weak banks or banks with poor risk-management. In this scenario, \( \tau_i \) varies across banks and the estimand \( \tau \) in equation (1.14) can be interpreted as the average treatment effect (ATE) on the subpopulation of banks at the cutoff (Hahn et al., 2001).

We follow the guidelines in Imbens and Lemieux (2008) and Lee and Lemieux (2010) when implementing our non-parametric approach. Define \( m(a) \) as the conditional expectation of outcome \( Y_i \) for a bank with running variable \( a \) (normalized bank size),

\[
m(a) = E \left[ Y_i | A_i = a \right]
\]

The function \( m(\cdot) \) can be estimated with separate, locally linear regressions to the left (\( \hat{m}_- (a) \)) and to the right (\( \hat{m}_+ (a) \)) of the cutoff:

\[
\hat{m}_b (a) = \begin{cases} 
\hat{\alpha}_- (x) & \text{for } a < 0 \\
\hat{\alpha}_+ (x) & \text{for } a \geq 0
\end{cases}
\]

The local linear regression estimate at point \( a \) to the left of the cutoff is defined by

\[
(\hat{\alpha}_- (a), \hat{\beta}_- (a)) = \arg \min_{\alpha, \beta} \sum_{i=1}^{N} \mathbf{1} \{ A_i < 0 \} \times (Y_i - \alpha - \beta (A_i - a))^2 \times K \left( \frac{A_i - a}{h} \right)
\]

and similarly to the right of the cutoff. Here, \( K(\cdot) \) denotes the chosen kernel and \( h \) denotes
the chosen bandwidth. Finally, the estimated treatment effect is given by

\[ \hat{\tau} = \hat{\alpha}_+ (0) - \hat{\alpha}_- (0) \]  

(1.15)

which is the empirical analogue to expression (1.14). In order to implement this approach, we need to choose a kernel \( K(\cdot) \) and a bandwidth \( h \). For our benchmark result, we use a uniform kernel. This reduces to estimating

\[ y_i = \beta \times \text{Stressed}_i + (\gamma_1 \times \text{Cutoff}_i + \gamma_2 \times \text{Cutoff}_i \times \text{Stressed}_i) + \epsilon_i, \quad |\text{Cutoff}_i| < h \]

by OLS, where \( h \) denotes the chosen bandwidth and \( \text{Cutoff}_i \) denotes the bank \( i \)'s distance to the cutoff.

We add country fixed effects to this specification. Therefore, we estimate the treatment effect off the differential behavior of banks on either side of the cutoff within the same country. While such fixed effects are not strictly necessary for identification, they increase the precision of our estimates by absorbing macroeconomic effects that are common across all banks of a given country.

Specifically, for bank \( i \) headquartered in country \( j(i) \), we estimate

\[ y_i = \beta \times \text{Stressed}_i + (\gamma_1 \times \text{Cutoff}_i + \gamma_2 \times \text{Cutoff}_i \times \text{Stressed}_i) + \theta_{j(i)} + \epsilon_i, \quad |\text{Cutoff}_i| < h \]  

(1.16)

where \( \theta_{j(i)} \) denotes the country fixed effect. In table 1.2, we present benchmark estimates for a bandwidth of 3.0.\(^{14}\) We estimate a 6.8% reduction in leverage, which is driven by a 4.3% reduction in assets. On the asset side, securities are most affected (-12.4%). On the liability side, the changes in scale are matched by a disproportionate reduction in wholesale financing (-10.9%). We find small and noisy estimates for equity, loans, and deposits.

---

\(^{14}\)The automatic bandwidth selection algorithm of Imbens and Kalyanaraman (2012) selects bandwidths in a similar range (table A.2), although for a triangular kernel. We provide estimates for a wide range of bandwidths in the appendix.
Table 1.2: Benchmark Regression Discontinuity Design

### 1.5.2 Estimation on the Full Sample

In this subsection, we estimate the correlation between a stress-test indicator and bank behavior on the full sample. The estimates are very similar to the estimates in our regression discontinuity design in the preceding section. This suggests that the local effects from our RDD match the main patterns in the data even far from the discontinuity.

In theory, the regression discontinuity estimate in the preceding subsection only applies locally: It is the average treatment effect on a bank at the cutoff. Treatment effects may be different far away from the cutoff. For example, large banks may already have sophisticated risk-management in place, leading to smaller effects. Alternatively, large banks may be particularly weak due to their relationships with distressed sovereigns, so stress-testing them might lead to even more dramatic results. To gauge the external validity of our RDD results, we estimate the treatment effect using OLS on the whole sample, controlling for observable differences between treated and untreated banks.

In our baseline setup, we estimate the following specification across the entire sample of Eurozone banks:

\[ y_i = \beta_1 \times \text{Stressed}_i + x_i' \gamma + \theta_i + \epsilon_i \]
where $y_i$ is an outcome variable for bank $i$, Stressed$_i$ is an indicator for whether bank $i$ was stress-tested, $x_i$ is a vector of control variables, $\theta_j$ is a country fixed effect, and $e_i$ is an error term. The set of covariates comprises bank size, the wholesale ratio, the loan ratio, and the capital ratio. Bank size adjusts for the fact that many stress-tested banks are large relative to control banks. The wholesale ratio controls for differences in banks’ liability structure (wholesale funding vs. deposits). The loan ratio controls for differences in banks’ asset structure (loans vs. securities). Bank capitalization is measured as tangible common equity over assets and is known to correlate with banks’ lending behavior even absent a stress-test (e.g. Peek and Rosengren, 1997).

We continue to find a strong effect on leverage (table 1.3). The point estimate suggests a 6.7% reduction in leverage for stress-tested banks, which is economically large and statistically significant at the 1% level. Looking at the components of leverage, we find that asset shrinkage accounts for most of the effect (-4.5%). Both effects are statistically significant at the 1% level. The point estimates for equity and deposit growth are small and imprecisely estimated. However, we do find a large reduction in wholesale funding (-8.0%), which is significant at the 1% level. On the asset side, we find that banks adjusted their holdings of securities disproportionately (-10.3%). In sum, the regression evidence paints a similar picture to the regression discontinuity design. Banks reacted to the prospect of tighter regulation by reducing leverage through asset sales. Asset sales primarily involved reducing securities holdings, and the proceeds were largely used to repay wholesale debt.

### 1.5.3 Robustness and Falsification Tests

In this subsection, we assess the robustness of our regression discontinuity design and present falsification tests. We find that the estimates are not particularly sensitive to the chosen bandwidth and kernel, and the design passes a range of validity and falsification tests. This gives us confidence that our estimates are not spurious and do indeed constitute a reaction to the changes in the supervisory regime.
<table>
<thead>
<tr>
<th>Dependent Variable: Annual Change in %</th>
<th>Leverage</th>
<th>(1)</th>
<th>Assets</th>
<th>(2)</th>
<th>Wholesale</th>
<th>(3)</th>
<th>Deposits</th>
<th>(4)</th>
<th>Loans</th>
<th>(5)</th>
<th>Securities</th>
<th>(6)</th>
<th>Stressed</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stressed</td>
<td>-7.4***</td>
<td>-4.53***</td>
<td>0.24</td>
<td>0.04</td>
<td>0.35***</td>
<td>0.07***</td>
<td>0.79***</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>-1.23***</td>
<td>-10.31***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bank Size</td>
<td>0.24</td>
<td>0.56***</td>
<td>(0.35)</td>
<td>(0.38)</td>
<td>(0.53)</td>
<td>(0.05)</td>
<td>(0.12)</td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wholesale/Assets</td>
<td>-0.04</td>
<td>-0.07***</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.05)</td>
<td>(0.05)</td>
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<td>(0.02)</td>
<td>(0.02)</td>
<td></td>
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</tr>
<tr>
<td>Equity/Assets</td>
<td>0.01</td>
<td>0.15</td>
<td>(0.18)</td>
<td>(0.11)</td>
<td>(0.15)</td>
<td>(0.15)</td>
<td>(0.04)</td>
<td>(0.04)</td>
<td>(0.04)</td>
<td>(0.04)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loans/Assets</td>
<td>0.01</td>
<td>0.05**</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.05)</td>
<td>(0.05)</td>
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<tr>
<td>Country FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>1,280</td>
<td>1,280</td>
<td>1,280</td>
<td>1,280</td>
<td>1,280</td>
<td>1,280</td>
<td>1,280</td>
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<td>1,280</td>
<td>1,280</td>
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</tr>
<tr>
<td>Adjusted R²</td>
<td>0.38</td>
<td>0.26</td>
<td>0.41</td>
<td>0.15</td>
<td>0.34</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Table 1.3: Stress Tested Banks Reduced Leverage by Shrinking Assets
Bandwidth Choice

When choosing a bandwidth for locally linear regressions, researchers face a bias-variance tradeoff: On the one hand, choosing a small bandwidth reduces the estimator’s bias; on the other hand, a smaller bandwidth increases the estimator’s variance due to a smaller effective sample size. Imbens and Kalyanaraman (2012) derive a data-driven procedure to choose a bandwidth given this tradeoff. They derive the bandwidth that is optimal under an asymptotic mean squared error criterion at the cutoff.

In table A.2, we implement the Imbens-Kalyanaraman approach analogous to our benchmark specification (1.16). We also report estimates for twice and half the bandwidth as is recommended. The results are very similar to our benchmark estimates in table 1.2: In anticipation of tighter regulation, there was a strong reduction in bank leverage (−7.4%), driven by a reduction in assets (−5.0%) and repayment in wholesale funding (−13.0%). We also confirm the now familiar pattern for the changes in asset composition: banks were more likely to reduce their holdings of securities (−13.5%) than the size of their loan books.

We also report estimates for our benchmark specification for a wide range of bandwidths in the appendix. As we reduce the bandwidth, the sample size drops from over 1,200 observations to around 80 observations, with a corresponding loss of precision. Importantly, the point estimates for our main results are similar irrespective of the bandwidth we choose. The results indicate a strong reduction in leverage for those banks that were assigned to the Comprehensive Assessment. The balance sheet adjustments are tilted towards sales of securities and repayment of wholesale debt, rather than increases in equity.

Covariates are Balanced at the Discontinuity

The crucial assumption of the regression discontinuity design is the continuity of the conditional expectation function through the cutoff. The assumption implies that in the absence of treatment there should be no discontinuities at the cutoff value, neither for outcomes nor for other variables. This implication can be evaluated by running a placebo RDD on baseline covariates that were fixed at the time of treatment. In our setting, we use balance sheet ratios
at the beginning of the year.

We jointly estimate the system

\[
\begin{align*}
\mathbf{y}_i^{(1)} &= \beta^{(1)} \times \text{Stressed}_i + (\gamma_1^{(1)} \times \text{Cutoff}_i + \gamma_2^{(1)} \times \text{Cutoff}_i \times \text{Stressed}_i) + \theta^{(1)}_{ij(i)} + \epsilon_i^{(1)} \\
&\quad \vdots \\
\mathbf{y}_i^{(k)} &= \beta^{(k)} \times \text{Stressed}_i + (\gamma_1^{(k)} \times \text{Cutoff}_i + \gamma_2^{(k)} \times \text{Cutoff}_i \times \text{Stressed}_i) + \theta^{(k)}_{ij(i)} + \epsilon_i^{(k)}
\end{align*}
\]  

(1.17)

where \( \mathbf{y}_i = (y_i^{(1)}, \ldots, y_i^{(k)}) \) is a \( k \)-dimensional covariate vector for bank \( i \) in country \( j(i) \).

We test whether the vector \( \beta = (\beta^{(1)}, \ldots, \beta^{(k)}) \) is zero using a \( \chi^2 \) test statistic (Imbens and Lemieux, 2008). The approach takes into account that we are testing multiple hypotheses and that the error terms \( \epsilon_i = (\epsilon_i^{(1)}, \ldots, \epsilon_i^{(k)}) \) may be correlated. Moreover, we allow for heteroskedastic error terms as in the baseline specification. In practice, we use the following balance sheet ratios: the deposit ratio, the wholesale ratio, the (tangible common) equity ratio, the loan ratio, and the securities ratio.

Table 1.4 shows that banks are indeed similar around the cutoff. While we find significant differences between stress-tested and untested banks when we estimate the system on the whole sample \( (h = \infty) \), these differences vanish as soon as we restrict the sample to banks of roughly similar size. The \( p \)-value associated with the null hypothesis that banks have the same balance sheets on either side of the cutoff \( (\beta = 0) \) exceeds 20\% for all bandwidths below 3.00.
Placebo Test within Untreated Banks

If our identification strategy is valid, then we should not find any discontinuous effects at random points of the size distribution and only at the asset cutoff that was actually used to assign treatment. We exploit this logic to conduct a placebo test within the set of banks that were not assigned to the Comprehensive Assessment. To avoid any bleeding, we restrict the RDD sample to banks that were not treated. We arbitrarily define banks with assets above the median in this subsample as placebo-stressed and repeat our locally linear regression analysis from table 1.2. The results are presented in table 1.5. We estimate quantitatively small effects of our placebo stress test. All estimates are statistically indistinguishable from zero for all outcome variables.

Ex-Post Failure Correlates with Ex-Ante Shrinkage within the Treatment Sample

If it is indeed correct that banks shrank their balance sheets in anticipation of the stress tests, then we should also find heterogeneity within the sample of stress-tested banks. In particular, we expect strong banks to react very little to the prospect of tighter supervision, whereas
weak banks are expected to adjust their balance sheets more. Since only a handful of banks actually failed, we calculate a continuous “buffer” measure for all banks. Banks could fail in two ways: by having a CET1 ratio below 8% in the baseline scenario or by having a CET1 ratio below 5.5% in the adverse scenario. We calculate bank \(i’s\) buffer by

\[
\text{buffer}_i = \min \left\{ \text{CET1 Ratio}_{i,\text{baseline}} - 8\%, \text{CET1 Ratio}_{i,\text{adverse}} - 5.5\% \right\}
\]

Banks that passed the Comprehensive Assessment comfortably exhibit a high value for buffer\(_i\), banks that passed narrowly exhibit a value close to zero, and banks that failed exhibit a negative value. We regress asset shrinkage (assets, loans, securities) on banks’ buffer and the control variables from our benchmark specification. The specification is given by

\[
y_i = \beta_0 + \beta_1 \times \text{buffer}_i + x_i' \gamma + \epsilon_i
\]

We find that firms with a smaller buffer reduced assets, loans, and securities more than firms with higher buffers (table 1.6). A one percentage point decrease in firms’ ex-post buffer is associated with a 0.6 percentage point reduction in asset growth, a 2.6 percentage point reduction in securities growth, and a 0.8 percentage point reduction in loan growth. All estimates are significant at the 1% level. These results hold even though we are (over-)controlling for initial capitalization, which stacks the cards against finding an additional effect of the ex-post buffer measure.

### 1.6 Pass-Through and the Role of Securities

Our estimates in the preceding sections showed that banks disproportionately adjust the securities on their balance sheets, which motivates a closer look in this section. We find that large securities books insulate loan portfolios from asset shrinkage in normal times, but this relationship is weakened when sovereign spreads are high. The results suggest that sovereign distress affects how banks deleverage.

A salient feature of the banking crisis in Europe was the concurrent weakness of sovereigns in the Eurozone periphery (Greece, Ireland, Italy, Portugal, and Spain). Figure 1.4 exhibits
Table 1.6: Ex-Post Buffer Predicts Ex-Ante Asset Shrinkage

<table>
<thead>
<tr>
<th></th>
<th>Assets</th>
<th>Securities</th>
<th>Loans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Buffer (%)</td>
<td>0.60***</td>
<td>2.55***</td>
<td>0.84***</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.90)</td>
<td>(0.23)</td>
</tr>
<tr>
<td>Bank Size</td>
<td>−1.77**</td>
<td>−6.13***</td>
<td>−1.46**</td>
</tr>
<tr>
<td></td>
<td>(0.70)</td>
<td>(1.87)</td>
<td>(0.60)</td>
</tr>
<tr>
<td>Wholesale/Assets</td>
<td>−0.02</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.20)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Equity/Assets</td>
<td>−0.94**</td>
<td>−2.68***</td>
<td>−1.01**</td>
</tr>
<tr>
<td></td>
<td>(0.40)</td>
<td>(1.04)</td>
<td>(0.40)</td>
</tr>
<tr>
<td>Loans/Assets</td>
<td>0.10</td>
<td>0.45**</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.21)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Country FE</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Constant</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>97</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.14</td>
<td>0.20</td>
<td>0.13</td>
</tr>
</tbody>
</table>

yields on 10-year government bonds for selected Eurozone countries. When the Comprehensive Assessment was announced, spreads were still high and periphery sovereign debt was trading at substantial discounts, compared to pre-crisis levels.

High returns on securities can crowd out other activities by financial intermediaries, and this channel is particularly relevant for sovereign debt (Acharya and Steffen, 2015). Regulatory incentives and bank accounting rules further strengthen banks’ tendency to retain or even increase their exposure to impaired sovereign debt. First, Eurozone sovereign debt carries a risk-weight of zero under Basel II (under some conditions). Second, reduced market values on hold-to-maturity assets affect banks’ net income only when these securities are sold. As a consequence, both bank regulation and accounting rules strongly discourage sales of sovereign debt that trades below book value.

In this section, we investigate the pass-through from assets to securities for the banks in our data, pooling both treated and untreated banks. By definition, asset growth \((\Delta A / A)\) is a
weighted average of loan growth ($\Delta L / L$), securities growth ($\Delta S / S$), and the growth rate of other assets ($\Delta O / O$):

$$\frac{\Delta A}{A} = \frac{L}{A} \frac{\Delta L}{L} + \frac{S}{A} \frac{\Delta S}{S} + \frac{O}{A} \frac{\Delta O}{O} \approx w_l \frac{\Delta L}{L} + w_s \frac{\Delta S}{S} \quad (1.18)$$

where $w_l$ is the share of loans in assets and $w_s$ is the share of securities in assets. The influence of other assets tends to be small since their weight is low and they tend to be fairly stable. We start by estimating the pass-through from asset growth to securities growth by estimating a linear model:

$$\frac{\Delta S_i}{S_i} = \gamma_0 + \gamma \times \frac{\Delta A_i}{A_i} + \epsilon_i \quad (1.19)$$

If pass-through is completely neutral, then we would expect $\gamma_0 = 0$ and $\gamma_1 = 1$. Moreover, we hypothesize that bank and country characteristics determine how strongly banks adjust through securities. We group banks into four categories, depending on whether they are
headquartered in a country with sovereign yields above the median or below, and whether they grow or shrink assets. We denote the yield in bank $i$’s country of incorporation, $j(i)$, by $z_{j(i)}$ and the median yield by $\bar{z}$. We therefore estimate the model

$$
\frac{\Delta S_i}{S_i} = \begin{cases} 
\beta_1 \times \frac{\Delta A_i}{A_i} + \epsilon_i & \text{if } \Delta A_i \geq 0 \cap z_{j(i)} \geq \bar{z} \rightarrow \text{Expansion, High Yield} \\
\beta_2 \times \frac{\Delta A_i}{A_i} + \epsilon_i & \text{if } \Delta A_i < 0 \cap z_{j(i)} \geq \bar{z} \rightarrow \text{Contraction, High Yield} \\
\beta_3 \times \frac{\Delta A_i}{A_i} + \epsilon_i & \text{if } \Delta A_i \geq 0 \cap z_{j(i)} < \bar{z} \rightarrow \text{Expansion, Low Yield} \\
\beta_4 \times \frac{\Delta A_i}{A_i} + \epsilon_i & \text{if } \Delta A_i < 0 \cap z_{j(i)} < \bar{z} \rightarrow \text{Contraction, Low Yield}
\end{cases}
$$

Figure 1.5 illustrates the adjustment function. Intuitively, we allow for different coefficients depending on whether bank $i$ grows or shrinks its balance sheet, and whether bank $i$ is based in a high-yield country or a low-yield country. Using specifications 1.19 and 1.20, we test the following hypotheses:

- **Hypothesis 1 (High Pass-Through into Securities):** For a given amount of asset growth, securities are adjusted more, i.e. $\gamma > 1$.  

$\gamma > 1$.
• **Hypothesis 2 (Asymmetric Impact of Sovereign Yields):** High sovereign yields are attractive to banks that expand their balance sheets, but make banks reluctant to sell securities when they shrink their balance sheets, i.e. $\beta_1 > \beta_2$.

Table 1.7 presents the results of this exercise. First, we find a high pass-through of asset adjustments into securities (hypothesis 1). We estimate that a 1% adjustment in assets is matched by a 1.8% adjustment in securities ($\hat{\gamma} = 1.77$, column 1). Second, we find evidence for an asymmetric impact of sovereign yields. When banks operate in a high-yield environment, then asset expansions are passed through to securities even more strongly ($\hat{\beta}_1 = 2.47$, column 3). However, the opposite is true for asset contractions. We now find that a 1% contraction in assets is matched only by a 0.6% reduction in securities ($\hat{\beta}_2 = 0.63$, column 3). We do not find a similar asymmetry between balance sheet expansions and contractions for banks in low-yield countries and we cannot reject the null hypothesis that $\beta_3$ and $\beta_4$ are equal. The results are consistent with impaired sovereign debt being both an attractive asset to buy and an unattractive asset to sell. For completeness, we also report specifications that include a constant in columns (2) and (4), which does not affect our conclusions.

### 1.7 Loan-Level Analysis

By analyzing loan-level issuance data, we test whether the Comprehensive Assessment was associated with a reduction in the supply of credit. We focus on loans extended around the March 2013 stress test announcement date and find a reduction in credit supply only for very banks. While we cannot rule out a credit crunch in other segments of the market, this suggests that the effects of banks’ balance sheet clean-up on the real economy might have been limited.

We employ a granular dataset from the syndicated loan market, where large firms borrow from multiple banks. Syndicated loan flows exhibit strong co-movement with total loan flows (Gadanecz, 2004), despite the fact that the average syndicated loan is very large with an average size of $500$ million. Syndicated loans represent a significant share of originating
banks’ loan portfolios. For example, they account for 26 percent of total C&I loans on the balance sheets of U.S. banks supervised by federal regulators, and for 36 percent of C&I loans on the balance sheets of foreign banks in the U.S. (Ivashina and Scharfstein, 2010). Moreover, syndicated loans represent almost one third of cross-border loan claims of internationally-active banking systems (Cerutti et al., 2015).

We employ a difference-in-differences strategy and control for loan demand in order to estimate the effect of tighter supervision on loan origination. We compare the lending behavior of large foreign banks in the Eurozone’s syndicated loan market to the lending behavior of large domestic banks. We use large foreign banks because we do not have enough control observations headquartered within the Eurozone.\footnote{The syndicated loan market is dominated by larger banks. The banks within the Eurozone but outside the SSM tend to be small and are usually not active in syndicated loans.} Therefore, the identification

\begin{table}
\centering
\begin{tabular}{lccccc}
\hline
& \multicolumn{4}{c}{Securities Growth in \%} \\
\hline
\hline
$\gamma$: $\frac{\Delta A_i}{A_i}$ & (1) & (2) & (3) & (4) \\
\hline
& 1.77$^{***}$ & 1.65$^{***}$ & (0.14) & (0.14) \\
$\beta_1$: $\frac{\Delta A_i}{A_i} \times (\Delta A_i \geq 0 \cap z_{ij(i)} \geq \bar{z})$ & 2.47$^{***}$ & 2.32$^{***}$ & (0.23) & (0.25) \\
& (0.23) & (0.25) \\
$\beta_2$: $\frac{\Delta A_i}{A_i} \times (\Delta A_i < 0 \cap z_{ij(i)} \geq \bar{z})$ & 0.63$^{***}$ & 0.86$^{***}$ & (0.21) & (0.23) \\
& (0.21) & (0.23) \\
$\beta_3$: $\frac{\Delta A_i}{A_i} \times (\Delta A_i \geq 0 \cap z_{ij(i)} < \bar{z})$ & 1.27$^{***}$ & 1.02$^{***}$ & (0.24) & (0.31) \\
& (0.24) & (0.31) \\
$\beta_4$: $\frac{\Delta A_i}{A_i} \times (\Delta A_i < 0 \cap z_{ij(i)} < \bar{z})$ & 1.15$^{***}$ & 1.50$^{***}$ & (0.24) & (0.28) \\
& (0.24) & (0.28) \\
\hline
pr($\hat{\beta}_1 = \hat{\beta}_2$) & – & – & 0.00 & 0.04 \\
pr($\hat{\beta}_3 = \hat{\beta}_4$) & – & – & 0.72 & 0.32 \\
Constant & No & Yes & No & Yes \\
Observations & 1,278 & 1,278 & 1,278 & 1,278 \\
Adjusted $R^2$ & 0.27 & 0.23 & 0.31 & 0.27 \\
\hline
\end{tabular}
\caption{Asymmetric Pass-Through from Assets to Securities}
\end{table}
of a loan supply response hinges on the assumption that banks outside the Eurozone did not experience any events around March 2013 that led them to adjust Eurozone lending differentially compared to their Eurozone counterparts.

We construct our samples of stress-tested and non-tested banks by focusing on the largest 200 lead banks during 2010-2014 by loan volume. We match 82 stress-tested banks to the top 200 list. The control group comprises 66 lenders in the syndicated loan market, also from the top 200, that we are able to match to financial statement information in SNL Financial. Consistent with the approach of the ECB Comprehensive Assessment, lending data is aggregated at the highest level of consolidation and matched to consolidated balance sheets. During the 2010-2014 period we observe 66,826 loans, of which 95 percent were syndicated. The matched banks together accounted for 60 percent of the total deal volume in the market over the period that we analyze.

We compare the change in lending by treated and untreated banks to the same borrower following the methodology of Khwaja and Mian (2008). Therefore, we aggregate loan volumes at the bank-borrower level and analyze the change in lending before and after March 2013, when the list of banks that would be subject to the Comprehensive Assessment was announced. We provide estimates for windows of 6 months, 9 months, and 12 months around this date.16 Our empirical model is given by:

\[ \Delta y_{ij} = \beta_j + \beta_1 \text{Stressed}_i + \beta_2 \text{Stressed}_i \times \text{Capital}_i + \gamma'z_i + \epsilon_{ij} \]  

(1.21)

where \( \Delta y_{ij} \) is the log-change in syndicated bank credit extended by bank \( i \) to borrower \( j \) and \( \text{Stressed}_i \) is an indicator for Eurozone banks that were subject to the stress test. We control for potential credit demand shifts using borrower fixed effects (\( \beta_j \)), which allow us to exploit multiple bank relationships of individual borrowers to isolate loan supply. We estimate the statistical significance of the regression coefficients with standard errors that are clustered at the bank level.

We also consider variants of equation (1.21) in which we control for bank characteristics

---

16All loans signed during the course of March 2013 are dropped from the analysis.
(\(z_i\)), which include bank size, the equity ratio, the wholesale ratio, and the loan ratio. Moreover, we test for heterogeneity in banks’ responses based on their financial health by adding an interaction term of the stress-test indicator with the initial capital ratio.

The results are reported in table 1.8. There are three variants of each specification: First, we include only the treatment indicator (Stressed), then we add control variables, and further we add the interaction with the capital ratio. The results indicate that on average Eurozone stress-tested banks did not systematically reduce the supply of loans compared to non-tested banks outside the Eurozone. The coefficient on Stressed, only become statistically significant if we condition on banks’ level of capital. As seen in columns 3, 6, and 9, only stress-tested banks with very weak capital positions (that is, common equity ratios lower than about 3 percent, based on column 6) reduced the supply of loans compared to non-tested banks with similarly low capital ratios.

In sum, we find some evidence for a credit crunch, but only for weak banks. We cannot detect a widespread reduction in the supply of large corporate loans in anticipation of the 2014 Comprehensive Assessment and the associated changes in the supervisory regime. However, banks with ex-ante weak equity positions, did reduce the supply of loans. Our results should nonetheless be interpreted with caution because our data only captures lending to large firms and only through bank syndicates. We cannot rule out the possibility that a reduction in the supply of bank credit occurred in other segments of the credit market, especially those serving smaller firms.

1.8 Conclusion and Policy Implications

In this paper, we examined changes in Eurozone banks’ balances sheets in anticipation of a new regulatory regime—the move of banking supervision from national regulators to the ECB through its Single Supervisory Mechanism. Our goal was to determine how banks adjusted their balance sheets when they learned about the prospect of stricter supervision.

We exploited a stress-test eligibility rule based on bank size and compared balance sheet outcomes for banks just above and below the size cutoff to show that banks significantly
<table>
<thead>
<tr>
<th>Window (around March 2013)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stressed</td>
<td>0.047</td>
<td>-0.052</td>
<td>-0.327**</td>
<td>0.050</td>
<td>-0.006</td>
<td>-0.210**</td>
<td>0.014</td>
<td>0.014</td>
<td>-0.172**</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.063)</td>
<td>(0.126)</td>
<td>(0.045)</td>
<td>(0.047)</td>
<td>(0.095)</td>
<td>(0.030)</td>
<td>(0.035)</td>
<td>(0.071)</td>
</tr>
<tr>
<td>Stressed x Capital</td>
<td>0.093**</td>
<td>0.067*</td>
<td>0.061***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
<td>(0.034)</td>
<td>(0.022)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>0.009</td>
<td>0.001</td>
<td>0.009</td>
<td>0.003</td>
<td>0.003</td>
<td>-0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.017)</td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.006)</td>
<td>(0.006)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wholesale/Assets</td>
<td>0.003</td>
<td>0.000</td>
<td>0.004</td>
<td>0.002</td>
<td>0.001</td>
<td>-0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loans/Assets</td>
<td>0.001</td>
<td>-0.002</td>
<td>0.004</td>
<td>0.002</td>
<td>0.002</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>1,664</td>
<td>846</td>
<td>846</td>
<td>3,765</td>
<td>2,045</td>
<td>2,045</td>
<td>6,399</td>
<td>3,535</td>
<td>3,535</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.853</td>
<td>0.850</td>
<td>0.851</td>
<td>0.762</td>
<td>0.765</td>
<td>0.766</td>
<td>0.710</td>
<td>0.705</td>
<td>0.706</td>
</tr>
<tr>
<td>Borrower FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No. banks</td>
<td>84</td>
<td>61</td>
<td>61</td>
<td>98</td>
<td>72</td>
<td>72</td>
<td>111</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>No. stress-tested banks</td>
<td>30</td>
<td>28</td>
<td>28</td>
<td>38</td>
<td>34</td>
<td>34</td>
<td>47</td>
<td>41</td>
<td>41</td>
</tr>
</tbody>
</table>

Table 1.8: Loan-Level Results
reduced their leverage in anticipation of the ECB’s Comprehensive Assessment. This decline in leverage was achieved mostly through a reduction in assets rather than an increase in equity. On the asset side, banks reduced securities the most. On the liability side, banks primarily reduced their reliance on wholesale funding.

A benign interpretation of the evidence is that banks “cleaned up” their balance sheets before supervisory changes. This is a positive finding since banks reduced leverage and became less reliant on potentially unstable wholesale funding. It is also possible, however, that reductions in bank assets were associated with fire sales and a reduction in credit supply, with implications for the real economy.

To determine if the supervisory changes “had a reciprocal effect on the economy” (Constâncio, 2014), we also examined developments in the market for large corporate loans. In particular, we analyzed loans granted to the same borrower by stress-tested Eurozone banks compared to banks outside the Eurozone. For the average Eurozone bank we found no evidence of a reduction in the supply of loans, but weakly capitalized banks did reduce loan volumes in anticipation of stricter supervision. However, our results should be interpreted with caution since the syndicated loan market is dominated by very large borrowers and might not perfectly reflect borrowing conditions in other markets.

Our results highlight a benefit of liquid securities holdings that is different from the usual arguments for liquidity regulation: In response to desired reductions in leverage, banks can sell securities holdings easily without resorting to adjustments in their loan portfolios. We found that for a given reduction of assets, banks reduce securities proportionately more than loans. However, the buffering function of securities is lost when sovereign debt is impaired: In the data, banks appear reluctant to sell securities when spreads are high.

Our finding that most of the adjustment took place on the asset side of the balance sheet—rather than through equity issuance or retained earnings—suggests a role for macro-prudential regulation. Banks may not internalize the spillover effects of their individual balance sheet adjustments to the financial system and the broader economy. In particular, regulators may want to strengthen banks’ incentives to raise equity rather than shed assets.
when phasing in new regulation. Such a mechanism would mitigate possible negative short-term effects such as asset sales and credit crunches. Our study does not evaluate the welfare implications of asset shrinkage in general equilibrium, which are necessary to assess the to characterize optimal policies. We consider the theoretical and empirical evaluation of such effects a challenging but fruitful avenue for future research.
Chapter 2

Taking Risk When Rates are Low?
Evidence from Life Insurance

2.1 Introduction

Federal Reserve Chairman Janet Yellen has highlighted the “potential for low interest rates to heighten the incentives of financial market participants to reach for yield and take on risk” (Yellen, 2014). In a similar spirit, Stein (2013) suggests that “a prolonged period of low interest rates [...] can create incentives for agents to take on greater duration or credit risk”. But what exactly is the channel that links intermediaries’ risk-appetite to interest rates?

In this paper, I focus on the behavior of life insurers, whose assets account for a large share of the financial system. In the first quarter of 2016, U.S. life insurers held $6.3 trillion in financial assets. For comparison, the U.S. banking system accounts for $17.7 trillion in financial assets. Moreover, life insurers held 20.2% of all corporate and foreign bonds\(^1\). Therefore, it is plausible that life insurers’ investment behavior significantly affects the price of credit.

Life insurance products contain assumptions about future reinvestment rates and, as

\(^1\)Calculations are based on the Federal Reserve Board’s Financial Accounts of the United States (Flow of Funds). The banking system is defined as U.S.-chartered depository institutions, foreign banking offices in the U.S., banks in U.S.-affiliated areas, and credit unions.
a result, expose insurers to declining reinvestment rates. I present evidence that insurers only partially hedge such risks. Imperfect hedging implies that low interest rates reduce life insurers’ profitability.

Drawing on security-level transaction data, I analyze life insurers’ corporate bond acquisitions between 2009 and 2015. Insurers have bought riskier bonds as bond yields have declined: In panel regressions, I find that the yield on BBB-rated corporate bonds is positively correlated with the credit ratings of bond acquisitions. The results are consistent with the hypothesis that risk-attitudes are linked to interest rates.

The conventional view is that “risk-shifting” explains the correlation between low yields and elevated risk-taking (Rajan, 2005). Risk-shifting incentives emerge when firms approach bankruptcy (Jensen and Meckling, 1976). When bankruptcy is a non-negligible possibility, creditors become marginal claimants in bad states of the world whereas equity holders remain marginal claimants in good states. As a result, equity owners have an incentive to engage in activities with large payoffs in good states irrespective of their costs in bad states. This logic can be applied to life insurers: Contracts on the liability side of their balance sheet embed return assumptions that are often fixed for more than a decade while assets tend to be reinvested more frequently. As a result, low returns may threaten firms’ survival and generate incentives to buy riskier assets.

Most U.S. life insurers, however, are not close to bankruptcy. In a 2014 report on life insurers’ solvency, the rating agency Fitch argues that “[F]or the typical life insurer, the impact of low interest rates rarely poses an immediate solvency concern, but the impact on earnings and statutory capital can be felt over time” (Fitch Ratings, 2014). Therefore, it is unlikely that risk-shifting can account for the observed correlation between risk-taking and interest rates.

In order to reconcile these facts, I present an alternative view based on earnings-targeting. Executives’ tendency to manage earnings has been widely documented (e.g. Burgstahler and Dichev, 1997; Bergstresser and Philippon, 2006). DeGeorge et al. (1999), for example, present evidence that the earnings distribution exhibits bunching at three natural benchmarks: zero
earnings, analyst expectations, and recent performance. Low interest rates compress the earnings of the life insurance sector—including the earnings of well-capitalized firms. If managers are averse to such margin compression, then they might take on more risk even if they are well-capitalized.

In order to differentiate between risk-shifting and earnings-targeting in the data, I exploit cross-sectional implications: If risk-shifting drives life insurers’ propensity to buy higher-yielding assets when interest rates are low, then this effect should be concentrated among firms with weak capital positions. This pattern is not present in the data. Even financially strong firms without a reasonable chance of defaulting on policy-holders increased the riskiness of their bond portfolios. By contrast, if earnings-targeting matters, then the relationship between risk-taking and interest rates should be concentrated in public firms. This prediction is borne out in the data, which lends support to the hypothesis that low interest rates affect risk-taking via an earnings channel.

The results have a number of policy implications. First, the findings suggest that a recruitment channel of monetary policy is active for non-bank financial intermediaries. Hanson and Stein (2015) argue that commercial banks take on more duration risk when short-term interest rates fall. In segmented markets, this implies that expansionary monetary policy can influence long-term rates via reductions in the term premium. One of the most striking features of the low interest-period following the Great Recession is the compression in credit spreads. Given that U.S. commercial banks are not active in the corporate bond market, it is necessary to shift attention to non-bank financial intermediaries in order to understand corporate bond pricing. Insurance companies are major buyers of corporate debt and, at the same time, holders of long-maturity treasury and mortgage-backed securities. Therefore, life insurers’ investment behavior is particularly relevant for understanding spillovers from the Federal Reserve’s conventional and unconventional monetary policies into the corporate bond market.

Second, intermediaries’ earnings—and not only their equity capital—appear to be an important state variable that affects risk-attitudes and ultimately the price of risk in the
economy. Even in a well-capitalized system, the exposure of earnings to declining rates may generate incentives to buy riskier assets. This effect gives the Federal Reserve an additional lever to affect risk premia without necessarily incurring the cost of widespread insolvencies.

Third, the results of this paper suggest a mechanism through which the effective risk-aversion of a large fraction of fixed income investors becomes time-varying. It is well known that bond returns move in a predictable fashion over time (Greenwood and Hanson, 2013). Moreover, the pricing of corporate credit predicts business cycle fluctuations (Gilchrist and Zakrajšek, 2012; Lopez-Salido et al., 2015). This paper presents one channel that can explain why expected bond returns may fall with interest rates.

The interaction of earnings pressure and risk-taking has been documented in other settings: When state guaranty fund laws were enacted, insurers started taking more risk, but the relationship is only present for public insurers (Lee et al., 1997). More recently, U.S. life insurers have started using off-balance sheet vehicles to minimize risk-based capital. Again, this practice is concentrated in public firms and not common for mutual insurers (Koijen and Yogo, 2016). A similar pattern is present in the banking industry. In an instrumental variable setting, Scharfstein and Falato (2015) show that public banks take more risk than private banks. Moreover, the effect is more pronounced in periods of low interest rates and low credit spreads.

Taken together, the evidence on earnings-pressure and risk-taking suggests that investors do not fully adjust their return expectations when risk-taking changes. While increased risk-taking may increase average profitability, it also increases the riskiness of earnings. The fact that investors do not seem to take this increase in risk into account is inconsistent with the Modigliani-Miller irrelevance result. A similar pattern has been found in banking, where the cost of capital does not react sufficiently to leverage changes relative to what standard theories would predict (Baker and Wurgler, 2015).

Domanski et al. (2015) argue that dynamic hedging of duration mismatches can explain why insurers buy longer term securities when interest rates fall, thereby amplifying a decline in long-term interest rates. A negative correlation of interest rates and maturities is also
present in the data for U.S. life insurers’ bond acquisitions presented here. However, convexity hedging can neither explain changes in credit risk nor their cross-sectional distribution.

Several studies have shown that regulatory incentives are a powerful force shaping insurance companies’ portfolios: Coarse risk-based capital requirements incentivize companies to hold the riskiest bonds within each risk category (Becker and Ivashina, 2015). In addition, coarse classifications also influence insurers’ trading behavior since downgraded bonds become less attractive when the downgrade leads to a reclassification (Ellul et al., 2011). Regulation also affects the liability side of insurers’ balance sheet: During the financial crisis of 2008, insurers sold policies below actuarial costs due to statutory accounting rules combined with financial (and product market) frictions (Koijen and Yogo, 2015).

This paper proceeds as follows: Section 2.2 discusses life insurers’ vulnerability to declining interest rates. Section 2.3 contains a model of risk-taking that illustrates both risk-shifting and earnings-targeting. Section 2.4 explains the data construction and presents summary statistics. Section 2.5 presents the methodology for distinguishing risk-shifting and earnings-targeting in the data. The results follow in section 2.6. Finally, section 2.7 concludes.

2.2 Exposure to Unexpectedly Low Reinvestment Rates

Life insurance executives consider low interest rates a threat to their business: In a 2015 survey, Goldman Sachs Asset Management asked 267 insurance CIOs and CFOs to select the investment risk that they are most concerned about. 66% of respondents considered “low yields” their most important investment risk (Siegel and Morbi, 2015, p. 14).

In a contribution to the Actuary Magazine, the head of life reinsurance for Zurich Insurance Group states the following:

Many of these products were sold in times of higher interest rates, so the product guarantees reflected the current interest rate environment. I have seen guarantees of 3, 3.5, and even 4 percent on some of these products. While this in itself is not the problem, it becomes a problem if insurance companies did not match their liabilities well. Given that these products may have a duration in excess of 30 years, perfect matching was not possible. (Klein, 2013, p. 15)
These concerns are echoed by regulators. In 2012, the National Association of Insurance Commissioners (NAIC) published a report arguing that “life insurers face a considerable amount of interest rate risk” (Bruning et al., 2012). Interest rate guarantees are of particular importance when trying to understand insurers exposure to prolonged periods of low interest rates. Even variable rate products often feature guarantees that act as a floor on required investment returns. In 2010, 95 percent of life insurance policies and 70 percent of all annuity contracts had a guarantee of 3% or higher (Berends et al., 2013). These guarantees can, in theory, be hedged through interest rate derivatives. In practice, however, insurers do not fully match assets and liabilities.

Stock returns offer an indirect way of capturing life insurers exposure to declining interest rates. If life insurers carry residual interest rate risk on their books then low interest rates are bad news for investors. Figure 2.1 compares the development of the aggregate stock market to an index of public life insurance companies. In the recent low interest-period, life insurance stocks strongly underperformed the market.
Berends et al. (2013) conduct a more formal analysis of the relationship of life insurers’ stock prices and interest rates. They find a positive correlation between ten year interest rates and life insurers’ excess returns, consistent with a negative duration gap. In its 2016 Global Financial Stability Report, the IMF also finds that insurers equity returns are negatively correlated with interest rates and that this negative correlation has become stronger during low interest rate period following the Great Recession (International Monetary Fund, 2016).

In 2014, the European Insurance and Occupational Pensions Authority conducted a stress test that contained a low-yield scenario similar to the Japanese experience in the 1990s and 2000s. The tests revealed that many insurers would be severely strained in such a scenario. This confirms that a typical European life insurer does not fully hedge interest rate exposures. (EIOPA, 2014).

Anecdotal evidence also suggests that life insurers are exposed to low interest rates. In its 2014 annual report, MetLife discusses the exposure to low interest rates in its retail segment as follows:

Our retained asset accounts have minimum interest crediting rate guarantees which range from 0.5% to 4.0%, all of which are currently at their respective minimum interest crediting rates. While we expect to experience margin compression as we re-invest at lower rates, the interest rate derivatives held in this portfolio will partially mitigate this risk (MetLife, Inc., 2015, p.11).

In other words, the firm expects lower earnings due to legacy guarantees, which it has not fully hedged. Prudential describes its exposures similarly in its 2012 annual report:

The reinvestment of scheduled payments and pre-payments at rates below the current portfolio yield, including in some cases, at rates below those guaranteed under our insurance contracts, will impact future operating results to the extent we do not, or are unable to, reduce crediting rates on in-force blocks of business, or effectively utilize other asset-liability management strategies described below, in order to maintain current net interest margins (Prudential Financial, Inc., 2015, p. 13).

A key regulatory metric is firms’ Adequacy of Investment Income (IRIS Ratio 4). The figure is computed by dividing net investment income by required interest. Required interest,
in turn, is designed to capture the funds needed purely to satisfy past commitments (i.e. excluding other costs such as personnel). A low ratio “may result from a low yield, or from interest guarantees or other interest requirements that may be too high for the investment environment of the insurer” (National Association of Insurance Commissioners, 2014, p. 38). Figure 2.2 plots an empirical density estimate for life insurers’ Adequacy of Investment Income both in 2008 and in 2014. As the plot shows, the low interest-period starting in 2008 correlates with a leftward shift in the distribution, suggesting that insurers are struggling to earn enough to cover their commitments.

Following Bruning et al. (2012), I use the weighted average valuation rate as a proxy for insurers’ interest guarantees. The typical weighted average valuation rate has slowly dropped from around 4.3% in 2006 to 3.9% in 2013. This slow drop reflects the long-dated nature of most life insurance products.

Both the weighted average valuation rate and the ratio of required interest to assets are plotted in figure 2.3b, along with net portfolio yields and acquisition yields in corporate
(a) Benchmark Interest Rates

(b) Return on Invested Assets vs. Legacy Liabilities

Figure 2.3: Spread Compression
Yields on corporate bond acquisitions have dropped from 6.8% to 4.0% between 2008 and 2014. As a consequence, net portfolio yields have declined from 5.5% to 5.0% over the same period. The two proxies for insurers interest exposure on the liability side, by contrast, have changed much more slowly. Between 2008 and 2013, for example, weighted average valuation rates have fallen from around 4.1% to 3.9%. Since portfolio yields have fallen faster than commitments on the liability side, insurers’ earnings have come under pressure.

2.3 Model

In this section, I present a model that illustrates how both risk-shifting and earnings-targeting can generate elevated risk-taking when interest rates fall. The model makes cross-sectional predictions that help discern the two channels. These predictions will be taken to the data in the following section.

There are two players, a risk-averse saver and a risk-neutral annuity provider. The timing is as follows: The saver receives labor income \( w_0 \) in period 0, which is saved for retirement. The saver consumes a pension \( c_2 = \bar{c} \) in period 2, provided by the annuity company. In order to provide the annuity, the owner of the annuity company invests the labor income \( w_0 \) as well as his own equity \( e_0 \). The form of the contract \((w_0, \bar{c})\) is taken as exogenous in the model, though contracts of this form arise naturally when savers are infinitely risk-averse.

There are two assets: a safe investment (storage) that yields \( R_t \) in period \( t + 1 \) and a risky investment that yields \( f(k_t) \) with probability \( \rho \) and zero otherwise. The crucial feature of the model is reinvestment risk in period 1. When contracts are written in period 0, the annuity provider knows \( R_0 \) but not \( R_1 \). Since savers are risk-averse, it is efficient for this risk to be absorbed by the risk-neutral annuity provider. For simplicity, there is no risky investment in period 0 and the gross return in period zero is assumed to be one. Therefore, the annuity provider’s only choice variable is the amount of capital that is invested in the

\[\text{2The construction of portfolio and acquisition yields is discussed in section 2.4.}\]
risky technology in the interim period, $k_1$, as a function of the realized interest rate $R_1$. The annuity providers’ payoff is given by

$$\pi(k_1) = \begin{cases} f(k_1) + R_1(e_0 + w_0 - k_1) - \bar{c} & \text{with prob. } \rho \\ R_1(e_0 + w_0 - k_1) - \bar{c} & \text{with prob. } 1 - \rho \end{cases}$$

where $e_0 + w_0 - k_1$ are the resources that are devoted to the safe investment.

### 2.3.1 Baseline Model without Frictions

In the frictionless setup described so far, the optimal amount of risky investment is described by the first-order condition

$$\rho f'(k_1^\ast) - R_1 = 0 \quad (2.1)$$

The first term describes the expected gross return of the risky investment and the second term is the hurdle rate. Without any frictions, the expected return of the risky investment equals the return of the safe investment. This is natural since the risk-neutral annuity provider prices all assets.

**Proposition 6.** (Interest Rate Channel) A decline in the safe interest rate $R_1$ stimulates investment in the risky asset, $k_1^\ast$, and leads to lower expected earnings.

**Proof.** See appendix. \qed

**Corollary 7.** (Cross-Section) Investment in the risky asset $k_1^\ast$ is independent of equity $e_0$ and the level of guaranteed commitments $\bar{c}$.

In the frictionless setup, a decline in the safe interest rate induces annuity providers to substitute towards the risky asset until the marginal returns are equalized. This implies that the optimal level of risky investment is purely forward-looking and independent of equity $e_0$ or past commitments $\bar{c}$. The effect is similar to the typical interest rate channel that is present in many macroeconomic models.

In the next part, two frictions are added, limited liability and earnings targeting. In order to assess the effect of those two frictions, it is useful to define a relevant benchmark:
Definition 8. (*Elevated risk-taking*) A policy function $\tilde{k}_1 (R_1)$ exhibits elevated risk-taking if $\tilde{k}_1 (R_1)$ exceeds the policy function in the benchmark case, which is implicitly defined by (2.1).

2.3.2 Limited Liability

Suppose the annuity provider has limited liability, i.e. the firm cannot lose more than its equity. In this scenario, the annuity provider’s expected payoff is given by

$$E [\max \{ \pi (k_1), 0 \}]$$

Bankruptcy occurs in the bad state if investment returns from the safe project are insufficient to cover the fixed commitment. Mathematically, the condition for bankruptcy in the bad state\(^3\) is given by

$$R_1 (e_0 + w_0 - k_1) < \bar{c}$$

The first-order condition becomes

$$\begin{cases} 
\rho f'' (k_1) = R_1 & \text{if } R_1 (e_0 + w_0 - k_1) > \bar{c} \\
 f'' (k_1) = R_1 & \text{if } R_1 (e_0 + w_0 - k_1) \leq \bar{c}
\end{cases}$$

The first case is relevant when bankruptcy never occurs. In this scenario, the problem is the same as in the frictionless case. The second case is relevant when bankruptcy occurs in the bad state. In this scenario, the annuity provider attaches too much weight to the good state since losses are limited at 0. This effect is known as risk-shifting. Since bankruptcy becomes more likely when the safe rate is low, risk-shifting amplifies the interest rate channel.

**Proposition 9.** (*Risk-Shifting Channel*) As interest rates fall, the annuity provider invests more in the risky asset. Moreover, there is a unique cutoff $R^*_{RS}$ such that for $R < R^*_{RS}$, risk-taking is elevated relative to the frictionless benchmark case.

**Proof.** See appendix

\(^3\)For simplicity, the firm is assumed to earn enough from the risky project such that bankruptcy never occurs in the good state. This is true as long as $f (k_1) + R_1 (e_0 + w_0 - k_1) \geq \bar{c}$.  

50
Corollary 10. (Cross-Section: Overhang of Guarantees) The region in which risk-taking is elevated is reached earlier if the level of guarantees is high, i.e. $R_{RS}^*$ is increasing in $\bar{\epsilon}$.

Proof. See appendix

The insurance company can only default when the investment returns are insufficient to cover the guaranteed commitments $\bar{\epsilon}$. All else equal, it is therefore more likely that the company defaults when commitments are high.

Corollary 11. (Cross-Section: Equity) The region in which risk-taking is elevated is reached earlier if the level of equity is low, i.e. $R_{RS}^*$ is decreasing in $e$.

Proof. See appendix

If the annuity company is so well capitalized that bankruptcy is not a realistic outcome in the bad state, then the risk-shifting model coincides with the frictionless model. A well-capitalized insurance sector is therefore unlikely to exhibit elevated risk-taking. The following sub-section introduces a different type of friction that may affect risk-taking even when insurers are solvent.

### 2.3.3 Earnings Targeting

This section adds executives’ desire to beat an external performance benchmark $\bar{\pi}$, which could be given by past earnings or net income of zero. The reduced-form benchmarking function is given by

$$\Gamma (\pi) = \begin{cases} 
\gamma (\pi - \bar{\pi}) & \text{if } \pi \geq \bar{\pi} \\
0 & \text{if } \pi < \bar{\pi}
\end{cases}$$

---

4See Burgstahler and Dichev (1997) and Bergstresser and Philippon (2006) for evidence of earnings management. The model remains agnostic about the microfoundations of such the benchmark. The theoretical literature on earnings management uses different approaches for micro-founding earnings management, for example signal jamming (Stein, 1989) or the need to incentivize managers who suffer from moral hazard (Goldman and Slezak, 2006).
where \( \gamma(\cdot) \) is an increasing and weakly concave function. Managers’ internalize the equity owners’ preferences, but their payoff is augmented by the benchmarking function

\[
\pi(k_1) + \Gamma(\pi(k_1))
\]

The fact that \( \Gamma(\cdot) \) is zero if executives miss the benchmark is designed to capture the “big bath” phenomenon: There is no point in missing a benchmark narrowly, so executives realize large losses in bad years (Murphy, 2013). Consider the simple case in which \( \gamma(x) = \hat{\gamma}x \). The parameter \( \hat{\gamma} \) can be interpreted as a measure of earnings pressure, which tends to be higher for public firms than for private firms. Similarly to the bankruptcy case, attention is restricted to cases in which the benchmark is always met in the good state but may be missed in the
bad state.\(^5\) Then, the first order condition is given by

\[
\begin{align*}
    \rho f'(k_1) &= R_1 \quad \text{if } R_1 (e_0 + w_0 - k_1) > \bar{\pi} + \bar{c} \\
    \rho f''(k_1) &= \frac{1+\rho^2}{1+\gamma} R_1 \quad \text{if } R_1 (e_0 + w_0 - k_1) \leq \bar{\pi} + \bar{c}
\end{align*}
\]

**Proposition 12.** (Earnings Channel) As interest rates fall, the annuity provider takes more risk. Moreover, there is a cutoff \(R_{ET}^*\) such that for \(R < R_{ET}^*\), risk-taking is elevated relative to the frictionless case.

**Proof.** (see appendix) \(\square\)

**Corollary 13.** (Cross-Section: Overhang of Guarantees) In the earnings-targeting model, risky investment \(k_1^*\) is weakly increasing in the level of past commitments \(\bar{c}\).

**Proof.** (see appendix) \(\square\)

**Corollary 14.** (Cross-Section: Benchmarking) Risky investment \(k_1^*\) is weakly increasing in earnings pressure \(\bar{c}^\gamma\).

**Proof.** (see appendix) \(\square\)

In the model, annuity providers are exposed to falling interest rates. As earnings drop, it becomes likely that executives miss their benchmark in a bad year. This, in turn, generates incentives to take more risk in order to meet the benchmark at least in the good state. If the benchmark is given by historical profits under high interest rates, then even small changes in the interest rate may suffice to push the company into the region with elevated risk-taking.

### 2.3.4 Testable Implications

Table 2.1 compares the empirical predictions of the model. In the frictionless scenario, the annuity company’s effective risk-aversion is independent of its liabilities. As a consequence, there should be no cross-sectional relationship between legacy contracts and risk-taking. By contrast, both risk-shifting as well as earnings-targeting imply that firms with an overhang of

\(^5\) The relevant condition is \(f(k_1) + R_1 (e_0 + w_0 - k_1) - \bar{c} \geq \bar{\pi}\).
fixed guarantees are more likely to exhibit elevated risk-taking. If risk-shifting drives firms’ effective risk-aversion in low-interest periods, then one would expect weakly capitalized firms to be more prone to buying riskier assets when interest rates drop. Finally, if earnings-targeting affects firms’ asset allocation decisions, then the effect should be concentrated in public firms for whom earnings pressure tends to be highest. These predictions will be taken to the data in the following sections of the paper.

2.4 Data and Summary Statistics

This section explains the source and construction of the data that will be used in subsequent analyses. The data can be separated into balance sheet and regulatory variables at the firm-year level, macroeconomic time series (at daily and annual frequency), and a granular dataset on each firm’s bond trades (at the bond-day level). The main dataset stems from regulatory submissions, with auxiliary data sourced from Mergent’s Fixed Income Securities Database (bond characteristics and ratings), FINRA’s TRACE database (bond yields and liquidity measures), A.M. Best (Financial Strength Ratings), and the Federal Reserve Bank of St. Louis (macroeconomic variables).

2.4.1 Balance Sheets and Regulatory Variables

Much like commercial banks, insurance companies submit detailed balance sheets to their regulator. In contrast to bank call reports, however, those filings are annual. SNL Financial, a
data provider, collects these submissions and makes them available to subscribers. Similarly to a bank holding company, an insurance group may own multiple statutory entities. For example, the MetLife group consists of the Metropolitan Life Insurance Company as well as the New England Life Insurance Company and the American Life Insurance Company, among others. I aggregate insurance companies at the group level in order to capture the main decision-making unit. Groups are identified by their NAIC Group Number. In order to aggregate ratios, I use asset-weighted averages. Moreover, I only look at general account assets, which include the typical life insurance products (e.g., term life, whole life, and annuities). By contrast, asset management products are often held in accounts that are legally separated from insurers main balance sheets. Moreover, the majority of separate accounts assets are stocks and not bonds (Berends et al., 2013), which are the focus of this paper.

Regulatory submissions include a breakdown of assets by asset type (e.g., loans vs. bonds), issuer (e.g., federal government vs. industrial), bond type (e.g., residential mortgage-backed securities vs. issuer obligations), maturity, and credit quality. Credit quality is submitted on the basis of regulatory bins. I translate those bins to the more conventional scale by Standard and Poor’s following Becker and Ivashina (2015). For ease of interpretation, I sum up all types of government bonds (federal, state, municipal, and foreign). Moreover, I form a new category of corporate bonds that combines the classes “industrial” and “utility”.

Two measures of insurers’ solvency are collected: The first measure of solvency is capital and surplus over net admitted assets (in general accounts). This corresponds to the leverage measure in Koijen and Yogo (2016). The ratio is measured in 2008. Some firms have very high ratios of capital and surplus to assets. These are mostly small companies that do not reflect the aggregate market. In order to avoid spurious results due to the right tail, I separate

---

6 Aggregating insurance groups in this fashion is important. In unreported results, I have run similar specifications at the disaggregated level, which yields mixed results.

7 General account balance sheets are identified by a “C” in front of their SNL company key.
firms into high and low capital by defining an indicator variable as follows:

\[
\text{Low Capital}_i = I \left\{ \frac{\text{Capital and Surplus}_{i,2008}}{\text{Net Admitted Assets}_{i,2008}} < \text{median} \left( \frac{\text{Capital and Surplus}_{i,2008}}{\text{Net Admitted Assets}_{i,2008}} \right) \right\}
\]

The second measure of solvency is based on credit ratings. A.M. Best, an information provider for the insurance industry, rates companies based on their “financial strength”. Financial strength is defined as the ability to honor commitments towards policyholders. This captures the notion of solvency that is relevant for risk-shifting: If losses in bad states are borne by policyholders but equity holders capture the gains in good states, then management faces an incentive to substitute risky for safe assets. Financial strength ratings are defined on a discrete scale that ranges from “A++” (highest) to “F” (lowest). As is customary with credit ratings, I transform this scale into a numeric scale in which a unit corresponds to one rating notch. Financial strength is measured in 2008. For ease of interpretation, I define an indicator for low financial strength as follows:

\[
\text{Low Rating}_i = I \left\{ \text{Financial Strength Rating}_{i,2008} < \text{median} \left( \text{Financial Strength Rating}_{2008} \right) \right\}
\]

In addition to solvency measures, I also collect three measures of firms’ overhang of high-interest legacy contracts. Bruning et al. (2012) propose the weighted average valuation rate (WAVR) as a proxy for insurers’ interest rate guarantees. Valuation rates are used to discount future liabilities in reserve calculations. Because valuation rates are not updated as time passes, firms’ reserves reveal the legacy of assumptions on investment returns. The weighted average valuation rate is based on a moving average of corporate bond yields at the time when contracts are written, as well as the duration of the contract. Concretely, I use an indicator variable for high values of the weighted-average valuation rate:

\[
\text{High WAVR}_i = I \left\{ \text{WAVR}_{i,2008} < \text{median} \left( \text{WAVR}_{2008} \right) \right\}
\]

In addition to the weighted average valuation rate, I propose another measure of exposure based on regulatory filings. Similar to the CAMELS system for banks, insurance regulators
use a set of key metrics called IRIS ratios (National Association of Insurance Commissioners, 2014). The distribution of IRIS benchmarks over time is plotted in the appendix. The fourth IRIS ratio measures firms’ adequacy of investment income. It is defined as

\[
\text{Ratio 4: Adequacy of Investment Income} = \frac{\text{Net Investment Income}}{\text{Interest Required}} \tag{2.2}
\]

The ratio is plotted in figure 2.2. As with capitalization measures, I separate insurance companies into two groups based on their adequacy ratings in 2008:

\[
\text{Low Ratio 4}_i = \mathbb{1} \{ \text{Ratio 4}_{i,2008} < \text{median} (\text{Ratio 4}_{2008}) \}
\]

Finally, I calculate a measure of firms’ interest margin,

\[
\text{Margin}_{it} = \text{Net Yield on Invested Assets}_{it} - \text{WAVR}_{it}
\]

Summary statistics for balance sheet variables are presented in table B.2. The main sample comprises a balanced panel of 242 insurance companies. The largest three insurance companies in the dataset are the Metropolitan Life Insurance Company, Prudential Insurance Company of America, and the Teachers Insurance and Annuity Association of America. As is typical for size distributions, the variable net total assets has a thick right-tail: the median companies’ assets are just below $3 billion while the largest groups’ net total assets exceed $200 billion. The median firm’s ratio of capital and surplus to assets is 10.2%. Adequacy of investment income is at 150% for the median firm. The median firm’s weighted average valuation rate is 4.3%. Finally, the median firm has a financial strength rating of 13, which corresponds to an “A” rating on A.M. Best’s scale.

2.4.2 Macroeconomic Time Series

Macroeconomic time series are downloaded from the Federal Reserve Bank of St. Louis’s economic data website (FRED). In particular, I download the effective federal funds rate (FEDFUNDS), the 10-Year Treasury Constant Maturity Rate (DGS10), and Moody’s Seasoned Baa Corporate Bond Yield (DBAA). In graphs, all macroeconomic variables are plotted at
daily frequency. When combined with annual data, the daily variables are averaged over the
calendar year. I also download yields on treasury securities of 1, 2, 3, 5, 10, 20, and 30 year
maturity at daily frequency. Finally, I download the S&P 500 Index as well as the S&P 500
Life and Health Index from 2007 onwards at daily frequency from SNL Financial.

2.4.3 Bond Trades

Insurance companies report annual bond acquisitions on Schedule D Part 3 of their regulatory
filings, including the date of purchase. Sales are reported on Schedule D Part 4. Finally, bonds
that were bought and sold within the year are reported on Schedule D Part 5. SNL Financial
provided those schedules for the universe of U.S. life insurers for the time period 2002–2015.
The variables of interest are the date of purchase, the volume of the acquisition, as well as
the CUSIP number of the bond. After obtaining and parsing the schedules for the period
2002-2014, the data are cleaned in the following way: First, all observations without dates,
CUSIPs, or trade volumes (“Actual Cost”) are deleted. Second, observations for which the
reported date does not fall within the reporting year are deleted. Third, I only keep general
account assets, consistent with the portfolio data.

Mergent’s Fixed Income Securities Database (FISD) provides bond characteristics. In
particular, I use a given bond’s maturity date to calculate the time-to-maturity at the date
of acquisition. In addition, I obtain the bond’s rating at the time of acquisition, the amount
outstanding, and the bond type (e.g., corporate debt). I keep only trades marked as corporate
debt (CDEB) in the Mergent database. Ratings from different agencies are converted to
numerical ratings (in notches) following Becker and Ivashina (2015).

Using FINRA’s TRACE database, I calculate measures of bond liquidity as well as yields in
the quarter of acquisition. I follow Dick-Nielsen (2013) in cleaning the database. The most
important steps are dropping duplicates, dropping same-day reversals, adjusting reports
involving same-day cancellations and corrections, filtering out implausible observations, and
deleting agency transactions. For a given maturity and yield, I calculate the spread over
the safe rate by interpolating over observed treasury yields at the relevant maturity. Bond
liquidity measures are calculated analogously to Dick-Nielsen et al. (2012). The most common indicators are turnover (daily average trading volume), Amihud’s and Roll’s measure, the number of trades per day, as well as the interquartile range. As is well-known in the literature, the post-crisis decline in corporate bond liquidity is visible only in some indicators but not others. Adrian et al. (2015) and Fender and Lewrick (2015) show that after 2008 the average trade size has decreased while the number of trades has increased. This may be due to traders’ equilibrium responses to declining bond market liquidity, which are reflected in apparent declines in bid-ask spreads (Adrian et al., 2015). Price-based measures have to be evaluated with this caveat in mind. Figure B.2 in the appendix shows the Amihud and Roll measures as well as turnover relative to the amount outstanding and the share of zero trading days for insurance companies’ corporate bond acquisitions. Similar to the literature on the aggregate bond market, price-based measures (Amihud, Roll) fail to capture the decline in liquidity following the 2008/2009 financial crisis. Quantity-based measures (Turnover, Zero trading days), by contrast, suggest a decline in liquidity after the crisis. These are the measures that will be used in subsequent analyses.

Since some of the analyses that follow strive to link insurance company characteristics (e.g. solvency) to bond acquisitions, it is helpful to aggregate the bond trades for each insurer-year. To do so, I take a weighted average of bond characteristics (yield, maturity, etc.), weighting each observation by its share in total acquisition volume for the year. I drop acquisition portfolios with less than 10 transactions and portfolios for which corporate bonds constitute less than 10% of total acquisition volume. All variables are winsorized at the 1% level before aggregation to avoid results that are (potentially) driven by miscoded outliers. Summary statistics for acquisition portfolios are presented in table B.1. The median acquisition portfolio has a yield of 4.3%, a maturity of 11 years, a spread of 1.7% over treasury securities of the same maturity, and a rating of 19.7 (where 20 corresponds to BBB+ on Standard and Poor’s scale).
2.4.4 Insurers’ Investment Portfolios

In this subsection, insurers’ aggregate investment portfolio is broken down into its components. Corporate bonds form the backbone of life insurers’ portfolios, which motivates the closer look in section 2.5. The graphs in this section are generated by summing up individual balance sheets to obtain an aggregate balance sheet of the sector.

Figure 2.5 breaks down the aggregate portfolio by asset type. Bonds form the most important asset type in life insurers’ portfolios. In 2014, US$ 2.7 trillion out of US$ 3.7 trillion were invested in bonds. Other significant asset classes are mortgage loans and alternative investments (“other”). Given the dominance of bond portfolios, most of this paper will focus on this part of insurers’ balance sheets.

Figure 2.6 breaks down the aggregate bond portfolio further. Within bonds, “Issuer Obligations” form the dominant component (top-left panel). These include sovereign and corporate bonds. Other major categories are residential and commercial mortgage-backed securities. The top-right panel breaks down the aggregate bond portfolio by issuer type.
Figure 2.6: Breakdown of Life Insurers’ Bond Portfolios
The vast majority of bonds are corporate bonds (classified as “Industrial” or “Utilities”). In 2014, life insurers owned slightly more than US$ 2 trillion in corporate bonds. Other major categories are government and agency debt. The bottom-left panel breaks down bond holdings by rating category. Insurance companies hold predominantly investment-grade bonds. This is due to the favorable regulatory treatment of bonds in the NAIC 1 (AAA to A) and NAIC 2 (BBB) class. Very few bonds in the portfolio are rated BB or lower. During the low interest-period (2010–2014), the proportion of NAIC 2 bonds (BBB) relative to NAIC 1 (AAA to A) bonds has increased, a pattern that will be discussed in more detail in the following section. Finally, the bottom-right panel breaks downs bond holdings by maturity. The most common maturity class is 5 to 10 years, though both shorter and longer maturities are common. The share of short-maturity bonds (less than 5 years) has decreased in the recent low interest-period (2010-2014).

2.5 Methodology

Since most assets in insurance portfolios have maturities of 5 to 10 years, portfolio characteristics are very slow-moving. Looking at the flow of new acquisitions (rather than the overall portfolio) allows to paint a more precise and current picture of insurance companies’ investment behavior. This section describes the methodology for analyzing insurers’ corporate bond acquisitions. In order to find out whether low interest rates induce insurers to buy riskier bonds, I first test whether it is indeed the case that insurers buy riskier bonds when interest rates drop. These tests are based on a fixed-effects model described in section 2.5.1. In order to test which mechanism drives risk-taking, I explore cross-sectional implications of the theory using a two-way fixed-effects model described in section 2.5.2.
2.5.1 Acquisition Characteristics and Interest Rates

In order to test whether low interest rates correlate with changes in the characteristics of insurers’ bond acquisitions, I run a fixed-effects model

\[ y_{it} = \alpha_i + \beta \times \text{Baa}_t + \epsilon_{it} \]  

(2.3)

where \( y_{it} \) refers to a portfolio characteristic in insurer \( i \)'s acquisition portfolio at time \( t \), \( \text{Baa}_t \) refers to the yield on Moody’s Baa index, and \( \alpha_i \) is a firm fixed-effect. The portfolio characteristics of interest are returns (yield, spread), credit rating, maturity, and liquidity (turnover, zero trading days). In order to account for the fact that some insurers are larger than others, the regression is weighted by firms’ assets. The fixed-effects capture all time-invariant firm characteristics. Due to differing business models, some insurers might buy safer bonds on average, for example. Standard errors are clustered at the insurer level to allow for serial correlation across periods within a firm.

2.5.2 Cross-Sectional Implications

After establishing the correlation of interest rates and bond characteristics, I restrict attention to credit risk. Credit risk is measured by a given acquisition portfolio’s average credit rating. In line with the model, I test the following hypotheses:

- **Hypothesis 1**—Firms with high legacy guarantees buy risker bonds when interest rates fall.
- **Hypothesis 2**—Firms that are closer to bankruptcy buy riskier bonds when interest rates fall.
- **Hypothesis 3**—Firms with more earnings pressure buy riskier bonds when interest rates fall.

Hypothesis 1 is in line with both the risk-shifting channel as well as the earnings-targeting channel, but inconsistent with the frictionless baseline model. Hypothesis 2 is only consistent with the risk-shifting model. Hypothesis 3 is only consistent with the earnings-targeting model.
Hypothesis 1: Overhang of Legacy Contracts

If the overhang of interest guarantees from legacy contracts drives firms’ risk-taking, then firms with a stronger overhang should exhibit higher risk appetite during the low-interest phase. In practice, I sort firms into two groups: The first group exhibits an overhang measure above the median and the second group exhibits an overhang measure below the median. This strategy can be interpreted as a difference-in-differences estimate with continuous treatment intensity. The strategy is similar to the approach employed by Kashyap and Stein (2000) and Jimenez et al. (2012) for banks. The estimation sample covers the period 2009 to 2014. Exposure to the treatment is measured at the onset of the low-interest period in 2008.

In practice, I estimate the following panel model:

\[
y_{it} = \alpha_i + \gamma_t + \beta \times \text{Overhang}_i \times \text{Baa}_t + \epsilon_{it}
\]

where \(\alpha_i\) is a firm fixed-effect, \(\gamma_t\) is a year fixed-effect, and \(\epsilon_{it}\) is an error term. The outcome variable, \(y_{it}\), is the weighted average (numerical) bond rating of the acquisition portfolio. The variable \(\text{Baa}_t\) refers to the yield reported by Moody’s for its Baa corporate bond index.

Three proxies are employed for firms’ overhang of legacy contracts: the weighted average valuation rate, \(\text{WAVR}_i\), firms’ adequacy of investment income (IRIS Ratio 4), \(\text{Ratio 4}_i\), and firms’ margin given by the difference between the net yield on the current portfolio and the weighted average valuation rate, \(\text{Margin}_i\). The firm and time fixed-effects account for firms’ typical bond acquisitions over the sample as well as for time-varying changes in portfolio characteristics across the industry such as structural shifts in bond ratings through the cycle. Regressions are weighted by assets to take into account that some firms are much larger than others. Standard errors are clustered by firm to address serial correlation at the firm level.

A positive coefficient \(\beta\) implies that low rates (–) and a high level of overhang (+) lead to lower ratings, relative to what one would expect given the time-invariant firm characteristics \(\alpha_i\) as well as the time-varying macro characteristics \(\gamma_t\). This is what one would expect if either the risk-shifting channel or the earnings-targeting channel drives portfolio choices.
Hypothesis 2: Solvency

I apply the same strategy as before in order to test whether low solvency is associated with more risk-taking when interest rates fall. However, the overhang measures are replaced by solvency measures, resulting in specification 2.5:

\[ y_{it} = \alpha_i + \gamma_t + \beta \times \text{Solvency}_i \times \text{Baa}_t + \epsilon_{it} \] (2.5)

Two measures of firms’ solvency are employed: statutory capital and financial strength ratings. A positive coefficient on \( \beta \) implies that low rates (-) and low solvency (+) lead to lower ratings, relative to what one would expect given the time-invariant firm characteristics \((\alpha_i)\) as well as the time-varying macro characteristics \((\gamma_t)\). This is what one would expect if the risk-shifting channel drives portfolio choices.

Hypothesis 3: Earnings Pressure

Finally, I test whether earnings pressure is associated with more risk-taking when interest rates fall. I introduce three indicator variables for whether a firm is a public, private, or mutual company. Given that those three firm types are collectively exhaustive, I omit the time fixed-effect and estimate

\[ y_{it} = \alpha_i + \beta_1 \times \text{Public}_i \times \text{Baa}_t + \beta_2 \times \text{Private}_i \times \text{Baa}_t + \beta_3 \times \text{Mutual}_i \times \text{Baa}_t + \epsilon_{it} \] (2.6)

The null hypothesis for the associated Wald test is \( \beta_1 = \beta_2 = \beta_3 \). If earnings pressure drives the results, then one would expect to find that \( \beta_1 > \beta_2 \geq \beta_3 \). This finding would be consistent with higher earnings pressure in public firms leading firms to buy lower rated bonds (-) as interest rates fall (-), relative to private and mutual companies. Given that public firms tend to be larger than private and mutual firms, I also add a specification in which I control for the interaction of the Baa rate and insurance companies’ size.
<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>Yield</th>
<th>Maturity Spread Bondrating Turnover Ztd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baa b</td>
<td>0.689</td>
<td>✤✤✤</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year FE</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Observations</td>
<td>834</td>
<td>834</td>
</tr>
<tr>
<td>R²</td>
<td>0.808</td>
<td>0.302</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.770</td>
<td>0.663</td>
</tr>
</tbody>
</table>

Table 2.2: Fixed Effects Model (2009-2014)

Firm FE: Standard errors clustered at firm-level.
Year FE: Standard errors clustered by assets.
Ztd: refers to Zero Trading Days.

p < 0.1; ** p < 0.05; *** p < 0.01
2.6 Results

2.6.1 Acquisition Characteristics and Interest Rates

Figure 2.7 illustrates that insurers buy lower-rated bonds in periods with low bond yields (2012-2014). The figure plots the average benchmark yield from Moody’s Baa Corporate Bond Index against the weighted average rating of life insurers’ aggregate corporate bond acquisitions. A numerical rating of 19 corresponds to an S&P rating of BBB. The positive relationship implies that low yields correlate with low acquisition ratings.

More generally, figure B.3 in the appendix presents the time series of portfolio characteristics across the entire sample. In the recent low interest period (2009-2014), yields and spreads declined, ratings worsened, maturities rose, and acquisitions tended to be more illiquid when measured by turnover and zero trading days.

Table 2.2 presents the results of estimating specification 2.3, which confirm the visual evidence in figure 2.7. Periods with low bond yields are periods in which insurers tend to buy bonds with low ratings: A one percentage point fall in the Baa benchmark yield is associated with a 0.52 notch reduction in the average rating of insurers’ bond acquisitions (column...
4). Reductions in the benchmark yield are also correlated with lower turnover (column 5) and more zero trading days (column 6). All estimates are significant at the 1% level. The correlations presented here are consistent with life insurance companies “reaching for yield”, although the magnitude of the overall effect is relatively small.

2.6.2 Cross-Sectional Implications

Table 2.3 presents the results for the tests of the hypothesis that legacy contracts on the liability side of the balance sheet affect the riskiness of bond acquisitions (Hypothesis 1). Column (1) adds an interaction for firms with high weighted-average valuation rates (High WAVR) to the basic fixed-effects model of table 2.2. A 1 percentage point drop in the Baa rate (Baa) is associated with a drop in acquisition ratings of 0.21 notches for firms with low weighted-average valuation rates, but a drop of 0.62 notches for firms with high valuation rates. The difference between the two coefficients (0.41 notches) is significant at the 1% level. Column 2 repeats the exercise with additional time fixed-effects (specification 2.4). The coefficient on the interaction term remains stable at 0.41 notches. In columns (3) and (4), the same analysis is repeated for a different overhang measure: firms’ Adequacy of Investment Income (High Ratio 4). For firms with a ratio above the median (i.e. with more adequate investment income), a one percentage point drop in Baa rates is associated with a drop of 0.27 notches in acquisition ratings. This coefficient rises to 0.59 (0.27 + 0.32) for firms with ratios below the median (i.e. less adequate investment income). The difference of 0.33 notches per percentage point is significant at the 5 percent level. Finally, columns (5) and (6) repeat the analysis for a continuous overhang measure, namely the difference between firms net yield on invested assets and their weighted-average valuation rate (Margin). A one percentage point decrease in the Baa rate is associated with a drop of 0.50 notches in acquisition ratings for the average firm. For firms with a margin that is one standard deviation below the mean, this coefficient rises to 0.69 notches per percentage point. The interaction term is statistically significant at the 5% level. In sum, table 2.3 suggests that the composition of firms’ legacy liabilities correlates with the riskiness of their bond acquisitions in low interest periods.
### Table 2.3: The Role of Legacy Contracts (2009-2015)

<table>
<thead>
<tr>
<th></th>
<th>Bondrating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Baa$_t$</td>
<td>0.213**</td>
</tr>
<tr>
<td></td>
<td>(0.091)</td>
</tr>
<tr>
<td>Baa$_t$ × High WAVR$_t$</td>
<td>0.409***</td>
</tr>
<tr>
<td></td>
<td>(0.131)</td>
</tr>
<tr>
<td>Baa$_t$ × Low Ratio 4$_t$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Baa$_t$ × Margin$_t$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Firm FE: Yes, Yes, Yes, Yes, Yes, Yes  
Year FE: No, Yes, No, Yes, No, Yes  
Observations: 973, 973, 973, 973, 973, 973  
R²: 0.725, 0.753, 0.718, 0.745, 0.721, 0.748  
Adjusted R²: 0.679, 0.709, 0.671, 0.701, 0.674, 0.704

* *p<0.1; **p<0.05; ***p<0.01  
Standard errors clustered at firm-level.  
Regressions weighted by assets.
Table 2.4: Solvency is Irrelevant for Risk-Taking (2009-2015)

Table 2.4 investigates whether risk-shifting can explain the previous results (Hypothesis 2). Columns (1) and (2) present the interaction term of leverage (as measured by capital and surplus scaled by assets) and the Baa rate. Column (2) corresponds to specification 2.5, which includes both firm and time fixed-effects. The interaction term between solvency and the Baa rate is negative as expected, but both small and statistically insignificant. Similarly, columns (3) and (4) present the interaction term of an indicator variable for low financial strength ratings. Again, the coefficients are economically small and statistically insignificant. The results do not support the hypothesis that risk-shifting drives the riskiness of firms’ bond acquisitions.

Table 2.5 separates firms by their ownership structure. Column (2) presents the results for specification 2.6. The correlation between bond ratings and the Baa rate is particularly strong (0.58) for public firms and weakest for mutual firms (0.27), with private firms in between.
### Table 2.5: Private versus Public Firms (2009-2015)

(0.34). A Wald test indicates that this difference in coefficients is statistically significant ($F = 2.45, p = 0.09$). Since public firms tend to be much larger, column (4) adds an additional term for firm size. The coefficients are stable, which suggests that the indicator variable for public firms captures an effect that is not purely driven by firm size.

In sum, firms with a legacy of high interest contracts have tilted their acquisitions towards lower credit quality bonds. The fall in credit quality is most pronounced for public firms. This is in line with a model in which legacy liabilities create earnings-pressure when interest rates fall and insurers’ try to lean against the fall in earnings by purchasing higher-yielding...
2.7 Conclusion

This paper investigates the hypothesis that life insurers take more risk when interest rates are low. There is evidence that insurers are exposed to declining interest rates through the assumptions embedded in their liabilities. If those liabilities are imperfectly matched with assets, then changes in the interest rate environment—such as a prolonged period of low rates—reduce earnings and may ultimately threaten solvency. After collecting extensive data on both insurers’ portfolios and corporate bond acquisitions, I show that the U.S. life insurance industry has tilted its fixed income purchases towards assets with lower ratings, longer maturities, and less liquidity in the low interest-period following the financial crash of 2008. These findings are consistent with a “reach for yield”, although the economic magnitude of the effects is limited. Then, I investigate the mechanism that drives risk-taking. Using a cross-sectional approach, I find that risk-shifting does not seem to be relevant. Instead, the results suggest that earnings pressure from fixed legacy commitments makes firms take on more risk when rates drop unexpectedly.

The findings imply that a recruitment channel of monetary policy operates for a large fraction of the fixed income market. For life insurers, a decline in long-term interest rates appears to decrease their effective risk-aversion. Therefore, unconventional monetary policies such as forward guidance and quantitative easing may be amplified through the behavior of insurance companies. This “recruitment channel” of monetary policy appears to be unrelated to solvency issues and, therefore, even a highly capitalized insurance sector would behave in this way. Moreover, the results suggest that intermediaries’ earnings are an important macroeconomic state variable. As a result, capital regulation can avoid widespread insolvencies, but it will not necessarily affect insurers propensity to take more risk when interest rates fall.

The results also suggest that time-varying expected bond returns are partially a consequence of institutional incentives. It would be useful to understand whether other fixed
income investors such as pension funds and asset managers act in a similar way. The analysis presented here can be applied to other intermediaries with significant interest exposure. For example, banks with floating rate loans financed by zero-interest deposits are exposed to monetary policy. Low interest rates compress their net interest margins, which leads to earnings pressure. It would be interesting to see whether these banks also originate riskier loans. Further investigations of interest exposures and risk-taking are left for future research.
Chapter 3

Bailouts and Banking Unions

3.1 Introduction

One of the major construction sites of European unification is the banking union, which comprises joint bank supervision, resolution, and recapitalization (Véron and Wolff, 2013). But why is it necessary to move these tasks from a national to a supranational level? In order to answer this question, this paper presents a model of the bank-sovereign interaction in an international setting. The model implies that financially-integrated countries benefit from coordinating their financial policies by forming such a union.

Two ingredients lie at the heart of the model: First, the financial sector suffers from a debt overhang problem, which generates a motive for government bailouts. Second, financial intermediaries have international portfolios, linking them to foreign sovereigns and banks. Therefore, developments abroad spill over to the domestic economy. A banking union allows countries to internalize those spillovers and share fiscal capacity more efficiently.

International spillovers matter in practice. First, consider the case of Greek sovereign debt. At the onset of the European sovereign debt crisis in 2011, a Greek default would have severely hurt the French and German financial systems since those countries’ financial intermediaries held large amounts of Greek sovereign debt. In this case, fiscal consolidation
benefits foreign financial institutions. By contrast, consider the case of Austria’s bank bailouts. When the Austrian authorities decided to support their banks, this benefitted large parts of Eastern Europe because Austrian banks are very active in this region. The international spillovers were most likely positive, even though the Austrian government sacrificed its AAA rating over the bailouts (Groendahl, 2012). The two examples illustrate how financial integration creates mutual dependencies across countries, which a banking union helps to internalize.

The model presented in this paper implies that uncoordinated bailouts may be too large or too small. A debt-funded bailout in which the sovereign sacrifices its own balance sheet to recapitalize the financial system affects foreign banks in two ways. First, if they are exposed mainly through bank-to-bank linkages, then the foreign country benefits from such a bailout. Conversely, if they are exposed mainly through bank-to-sovereign linkages, then the deterioration in the sovereign’s creditworthiness hurts foreign banks. Since the spillovers of a bailout can be positive or negative, the internationally optimal solution may involve a larger or a smaller transfer from the sovereign to its banks.

In the model, uncoordinated bailouts will be funded excessively through debt issuance rather than tax increases. At a national optimum, the government weighs the benefits of further transfers to the financial sector against the costs of raising additional funds. Governments can raise funds either through debt issuance or through distortionary taxation. Since debt issuance hurts foreign creditors by diluting their claims, the funding mix for a given transfer tends to involve too much debt and too little taxation relative to the (international) social optimum.

Finally, the model suggests that countries benefit from jointly funding bank recapitalizations. States of the world in which banks are hit by negative shocks are states in which additional fiscal resources are particularly valuable. However, raising large amounts of money in times of crisis is difficult. Therefore, common recapitalization schemes—such

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1Popov and Van Horen (2013) present a formal analysis of the international transmission of sovereign distress in Europe. They analyze data from the syndicated loan market and show that banks’ holdings of distressed debt by Portugal, Ireland, Italy, and Spain affected the quantity of funds lent.
Figure 3.1: Cross-border Positions within the Eurozone. The graph shows total cross-border claims of banks located in the Euro area against counterparties in other parts of the Euro area. Source: Bank of International Settlements, Locational Banking Statistics, March 2016.

as the one proposed for the European Union—are beneficial as they allow governments to economize on distortionary taxes.

How is the need for a banking union related to the use of a common currency? In the case of the Eurozone, the introduction of a common currency was associated with strong financial integration. Figure 3.1 documents the remarkable increase in cross-border bank exposures within the Euro area after the introduction of a common currency in 1999. The results of this paper imply that financial integration should be accompanied by joint financial policies. If one takes the effect of currency unions on financial integration for granted, then currency unions benefit from banking unions.

The results also apply to other financially-integrated economic areas, even if they do not use a common currency. Gross asset flows have increased remarkably across the world over the last decade (Obstfeld, 2012; Gourinchas and Rey, 2007; Gourinchas et al., 2012). But more
financial integration leads to more spillovers from governments’ interventions. As financial systems become ever more connected, supranational coordination of bailout policies becomes increasingly relevant.

There is a large literature on the interaction between sovereigns and banks (e.g. Reinhart and Rogoff, 2009; Acharya et al., 2013; Gennaioli et al., 2014), but very few papers emphasize the international dimension of this interaction. Bolton and Jeanne (2011) present a model in which the price of sovereign debt affects the international financial system and Uhlig (2014) looks at risk-shifting to the common central bank in a monetary union. Neither of those models, however, captures the two-way feedback between sovereign and bank balance sheets, which is crucial for understanding, for example, the developments in Iceland, Ireland, or Spain during the recent financial crisis. In independent work, Mengus (2014) and Farhi and Tirole (2015) have developed international models of the sovereign-bank interaction. While this paper focuses on a symmetric setup, their models assume a core-periphery structure in which one countries’ debt is safe and the other country’s debt is risky. Both models provide a rationale for why the safe country might transfer resources to the risky country’s banks, which is similar in spirit to the model presented here.

The paper proceeds as follows: Section 3.2 presents the model’s setup, followed by a characterization of the resulting equilibrium in section 3.3. Section 3.4 analyzes the international transmission of shocks to bank and government liabilities, bailouts, and the influence of the structure of international exposures. Section 3.5 shows that countries benefit from coordinating their financial policies and from sharing fiscal resources for the purposes of bank bailouts. Finally, section 3.6 concludes.

3.2 Model Setup

This section presents the setup of the model. Within each of the two countries, there is a financial sector that provides services to the real economy. However, the financial sector suffers from a debt overhang problem. To alleviate the debt overhang, the government may transfer resources to the financial sector, thereby increasing the supply of financial services
to the economy. The government’s intervention is costly since taxation is inefficient. The tradeoff between the cost of raising funds and the benefit of further bailouts is central to the model. Evaluating this tradeoff on a national level leads to suboptimal allocations, which motivates the introduction of a banking union.

Figure 3.2 illustrates the key channels of the model. Within each country, the mechanics are based on the one-country model of Acharya et al. (2013). Banks are exposed to sovereigns and sovereigns treat banks as contingent liabilities, which generates a bank-sovereign “doom loop”. In addition, this paper allows for international bank-to-bank and bank-to-sovereign exposures as well as for transfers across countries.

The setup is symmetric in both countries. Values that are specific to the foreign country marked with a star (e.g. $T^*$) whereas values for the home country are denoted without a star (e.g. $T$).

**International Exposures in the Financial Sector**

Banks hold a fraction of all outstanding domestic and foreign government debt. The share that the home country holds of its own sovereign debt $B$ is denoted by $a$ while the remaining fraction $(1 - a)$ is held by the foreign bank. Symmetrically, the home bank also holds a share $(1 - a)$ in the foreign sovereign’s bonds $B^*$. Sovereign bond prices are denoted by $P$ and $P^*$, respectively. Banks are also exposed to each other, for example due to interbank lending. A fraction $\beta$ of bank liabilities is held by domestic residents whereas $(1 - \beta)$ is held by foreign
banks. Since the model is symmetric, this implies that the domestic bank holds foreign bank
liabilities with market value \((1 - \beta) P_B^* L^*\) on its balance sheets, where \(P_B^*\) is the price of a
claim on foreign bank liabilities with face value one and \(L^*\) is number of outstanding claims.
Finally, banks may receive a transfer \(T\) from the government. The non-stochastic value of
bank balance assets is given by

\[
V = \alpha PB + (1 - \alpha) P_B^* B + (1 - \beta) P_B^* L^* + T
\]

Banks also hold other risky assets \(\tilde{A}\) with cumulative distribution function \(F_{\tilde{A}}\) on their balance
sheet. This implies that the bank’s probability of being solvent is

\[
\rho = \Pr (\tilde{A} + V \geq L)
\]

The market value of domestic bank liabilities is therefore

\[
P_BL = \Pr (\tilde{A} + V \geq L) L + \Pr (\tilde{A} + V \leq L) (E[\tilde{A} | \tilde{A} + V \leq L] + V)
\]

In order to generate a net worth channel in the banking sector, this paper follows the autarkic
model by Acharya et al. (2013) and focuses on debt overhang. It is worth stressing that other
banking models that feature a net worth channel, for example that of Holmstrom and Tirole
(1997), would have similar implications. Taking the probability of solvency as given, the
financial sector’s management chooses financial services supply, \(s\), in order to maximize
expected profits conditional on survival. The optimization problem is given by

\[
\max_{\{s\}} E [\rho \times w \times s - c(s)]
\]

where \(s\) denotes the quantity of financial services in the home country, \(w\) denotes the price
of financial services, and \(c(\cdot)\) is the cost function for financial services provision. The cost
function is assumed to be increasing and convex. It follows that the first-order conditions
are sufficient and uniquely define the supply curve for financial services. A transfer to the
financial system, \(T\), increases the probability of being solvent and thereby raises the supply
of financial services.
International linkages also affect the domestic economy:

A rise in the foreign sovereign bond price, for example due to tax increases abroad, affects the domestic economy’s banking sector via its holdings of foreign sovereign debt. The capital gain then propagates through the economy due to an outward shift in credit supply.

**Non-Financial Sector**

The non-financial sector chooses how much to produce using its endowment of capital, $K_0$, and financial services. In addition, the non-financial sector invests in capital for the future, $K_1$. Future capital has a stochastic continuation value, $\tilde{C}(K_1)$, and costs $K_1 - K_0$ to install. The stochasticity of investment is modeled via a shock $\epsilon$ that satisfies

$$\tilde{C}(K_1) = C(K_1)\epsilon, \ E[\epsilon] = 1, \ \epsilon \geq 0$$

Investment is taxed at rate $\theta$—set by the government in advance—which distorts firms’ investment decisions. The optimization problem of the non-financial sector is given by

$$\max_{\{s, K_1\}} E_0 \left[ f(K_0, s) \times s + (1 - \theta)\tilde{C}(K_1) - (K_1 - K_0) \right]$$

Assuming that $f(., .)$ and $C(.)$ are increasing and strictly concave ensures that a unique optimum exists. It is straightforward to show that investment is decreasing in the tax rate, which renders taxation distortionary. Distortionary taxation of investment can be interpreted as a simple way of capturing the idea that it is costly for the government to raise revenue. In a model with labor income, the inefficiency could also be introduced via income taxation.

**Consumers**

Consumers are risk-neutral, there is no discounting, and consumers own the economy. In particular, they own the equity and the debt of the banking sector, the non-financial sector, and they consume excess government revenues. They are also willing to buy newly-issued sovereign debt, which ensures that bonds are priced according to their expected value.
Government Finances

The government has to finance a bailout by issuing new bonds, \( N \), which are backed by future tax revenues, pay no coupon, and trade at a discount. One could think of this as the residual sum that is needed after spending all current tax revenues, which are ignored here for simplicity. In addition, the government has outstanding legacy bonds, \( B \). In the second stage, governments pay to bondholders whatever they collect, so we explicitly allow for partial defaults. Since firms’ chosen future capital stock is a function of the tax rate, tax revenues are given by

\[
\theta \times \tilde{C}(K_1(\theta)) = \theta \times \underbrace{\tilde{C}(K_1(\theta))}_{L(\theta)} \times e = L(\theta)e
\]

where \( e \) is a random shock that captures fluctuations in the macroeconomic environment and \( L(\theta) \) is a deterministic Laffer curve for expected tax revenues.\(^2\)

For the rest of the paper, assume that the government never sets taxes on the right-hand side of the Laffer curve, that is

\[
0 \leq \theta \leq \theta_{\text{max}} = \arg \max_{\theta} E[\theta \tilde{C}(K_1(\theta))]
\]

This assumption guarantees that \( L(\theta) \) is increasing over the relevant range. For a given transfer to the financial sector, \( T \), the government has to issue enough new debt \( N \) in order to finance the transfer:

\[
P \times N = T
\]

Moreover, the government commits to \( \theta \) in the beginning and pays out bondholders whatever it collects (at most face value). Government bonds with face value one thus trade at a price

\[
P = E\left[\min\left\{1, \frac{L(\theta)e}{B+N}\right\}\right] \text{ subject to } P \times N = T \tag{3.1}
\]

which implicitly defines \( P \) as a function of \( T \) and \( \theta \). In general, this equation has no closed form solution but it can be shown that bond prices are decreasing in transfer \( T \) and increasing

\(^2\) For the problem to be well-behaved, we also need to assume that the probability density function \( f_e \) is increasing over the relevant range such that default costs are convex. This is true, for example, for the truncated normal distribution as long as the likelihood of default is not too large.
in the tax rate $\theta$.

In order to induce repayment of government debt, the government faces punishment $D$ when it pays back less than it has promised. This is a compact way of capturing governments’ long-term incentives as discussed in the sovereign debt literature (Aguiar and Amador, 2014). Given that we rarely see full dilution of existing bondholders, it is assumed throughout that default costs are large enough to discourage governments from doing so, such that an interior optimum with positive bond prices and finite new issuance is obtained.

Finally, note that government policy can be summed up by two variables: the size of the transfer to banks, $T$, and the tax rate $\theta$. The government balances the marginal benefit of a transfer to banks and the costs of funding this transfer. Funds can be raised by taxing the non-financial sector or by issuing additional debt, thereby diluting existing claim-holders. Taxes are distortionary and, hence, costly. Issuing debt increases the default probability for a given tax rate and is, therefore, costly as well.

### Welfare

Expected welfare is evaluated after government policy has been determined and before the resolution of uncertainty. The value of the financial sector, $W_{FS}$, consists of operating profits and the value of assets net of liabilities (which include the transfer)

$$W_{FS} = w \times s - c(s) + E[A_1] + V - L$$

The non-financial sector’s value, $W_{NF}$, is defined similarly and given by

$$W_{NF} = f(K_0, s) - w \times s + (1 - \theta)E[C(K_1)] - (K_1 - K_0)$$

Finally, the value of the official sector is

$$W_G = \left( L(\theta) - B - \frac{T}{P(\theta, T)} \right) \left( \int_{x_0}^{\infty} x \times f_\epsilon(x)dx \right) - D \times \int_{0}^{\frac{B+T}{P(\theta, T)}} f_\epsilon(x)dx$$

where the first term represents the tax surplus in good states of the world and the second term represents expected default costs. The national welfare statistic for the domestic country
Endogenous Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$, $\rho^*$</td>
<td>Bank solvency</td>
</tr>
<tr>
<td>$P$, $P^*$</td>
<td>Sovereign bond price</td>
</tr>
<tr>
<td>$s$, $s^*$</td>
<td>Financial services (quantity)</td>
</tr>
<tr>
<td>$w$, $w^*$</td>
<td>Financial services (price)</td>
</tr>
<tr>
<td>$K_1$, $K_1^*$</td>
<td>Investment</td>
</tr>
<tr>
<td>$f(K_0, s)$, $f(K_0, s^*)$</td>
<td>Output</td>
</tr>
<tr>
<td>$N$, $N^*$</td>
<td>New bond issuance</td>
</tr>
</tbody>
</table>

Exogenous Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$, $\theta^*$</td>
<td>Tax rate</td>
</tr>
<tr>
<td>$T$, $T^*$</td>
<td>Transfer to banks</td>
</tr>
</tbody>
</table>

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Share sovereign debt held by the country’s own banks</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Degree of interbank exposure</td>
</tr>
<tr>
<td>$L$, $L^*$</td>
<td>Bank liabilities</td>
</tr>
<tr>
<td>$B$, $B^*$</td>
<td>Outstanding government liabilities</td>
</tr>
<tr>
<td>$K_0$</td>
<td>Initial capital stock</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Variance of the investment payoff</td>
</tr>
<tr>
<td>$\sigma_A$</td>
<td>Variance of bank assets</td>
</tr>
<tr>
<td>$A_0$</td>
<td>Mean of bank assets</td>
</tr>
</tbody>
</table>

Table 3.1: Summary of Selected Model Parameters and Variables

Then becomes

$$W = W_{FS} + W_{NF} + W_G$$

Table 3.1 summarizes the model’s parameters and variables that will be examined in more detail below.
3.3 Equilibrium Characterization

This section characterizes the equilibrium that the model generates. We are interested in comparative statics with respect to the tax rates \( \theta \) and \( \theta^* \) as well as the transfers \( T \) and \( T^* \). Therefore, endogenous variables will be denoted as a function of the government policies that determine their equilibrium values.

A key element of the model is the inefficiently low provision of financial services—a “credit crunch”—due to debt overhang in the financial sector. This inefficiency motivates the government to transfer resources to the banking sector after negative shocks in order to alleviate the debt overhang problem. The first-order conditions of the non-financial and the financial sector are given by

\[
\frac{\partial f(s, K)}{\partial s} = w, \quad \rho w = c'(s)
\]

which leads to the equilibrium condition

\[
\frac{\partial f(s, K)}{\partial s} = \frac{c'(s)}{\rho}
\]  

(3.2)

The marginal benefit of financial services to the non-financial sector exceeds the marginal cost to the financial sector if \( \rho \) is less than one (debt overhang). The welfare implications are summed up by lemma 15.4

**Lemma 15.** Without transfers, financial services provision is inefficiently low relative to the first-best allocation if \( \rho(\theta, \theta^*, T, T^*) < 1 \).

*Proof. (see appendix)*

The government has two tools at its disposal. First, it can raise money in the bond market to transfer resources \( T \) to the banking sector. However, such new issuance dilutes existing bondholders since there is a chance that tax revenues in the future are not sufficient to cover

---

3. Since the model’s mechanics within each country are based on the (autarkic) model of Acharya et al. (2013), some of the lemmas are similar in spirit. This paper adds an international dimension, which generates implications for banking union.

4. This finding is analogous to the autarky version in Acharya et al. (2013) except that solvency is now a function of foreign policies \( \theta^* \) and \( T^* \).
all outstanding liabilities. By using its second tool, increasing the tax rate $\theta$, the government can counteract the decrease in bond prices. Those comparative statics can be shown by differentiating the bond-pricing equation 3.1 (remark 3.3.1).

Remark 3.3.1. The bond price $P(\theta, T)$ is increasing in the tax rate, $\theta$, and decreasing in the transfer, $T$.

Proof. (see appendix)

When the government issues new debt to bail our the financial sector, it sacrifices its own balance sheet. This has knock-on effects on the financial sector, which holds this debt. Moreover, foreign banks also suffer from this deterioration in bond prices, which in turn affects domestic banks negatively. Nevertheless, it can be shown that for any transfer $T$ the direct effect dominates the indirect effects (Lemma 16).

Lemma 16. Bank solvency $p(\theta, \theta^*, T, T^*)$ is increasing in the transfer and the tax rate.

Proof. (see appendix)

In an autarkic model ($\alpha = \beta = 1$), the change in solvency collapses to

$$\frac{dp}{dT} = 1 + B \frac{dP(\theta, T)}{dT} \geq 0$$

which captures the direct transfer and a moderating effect through the decrease in government bond prices. The derivation in the appendix shows that the change in bank solvency in the international model satisfies

$$\frac{dp}{dT} \propto \frac{\text{transfer}(+) \ + \ \text{direct holdings}(-) \ + \ \text{indirect holdings}(-)}{1 - \psi \psi^*} > 0 \quad (3.3)$$

This expression features an additional term in the numerator and in the denominator. The added term in the numerator accounts for the bank’s indirect exposure to its own sovereign through foreign banks, which hold an additional share $(1 - \alpha) P(\theta, T) B$ of the sovereign
The degrees of connectivity are given by

\[
\psi = (1 - \beta) \left( 1 - \rho \left( \theta, \theta^*, T, T^* \right) \right) < 1 \tag{3.4}
\]

\[
\psi^* = (1 - \beta) \left( 1 - \rho^* \left( \theta, \theta^*, T, T^* \right) \right) < 1 \tag{3.5}
\]

The first factor, \((1 - \beta)\), measures how much of the bank debt is held internationally. The second factor is the likelihood of insolvency, which measures the degree to which bank debt is impaired. Debt-holders take a hit from decreased asset values only in states of the world in which the debtor is insolvent whereas in solvent states of the world, this decrease only affects equity owners.

The added term in the denominator captures the accelerator effects from cross-exposures. When domestic bank solvency improves, this has a positive effect on foreign bank solvency, which further improves domestic bank solvency. This feedback loop increases in strength with the degree of cross-exposures.

Finally, we establish the impact on financial services provision in equilibrium after a change in the government’s policy variables. Since both a transfer as well as an increase in taxes raises bank solvency, it is left to show that the supply of financial services shifts out when solvency improves. This follows directly from equation 3.2 and the result is summed up in lemma 17.\footnote{This finding is the international version of Lemma 1 in Acharya et al. (2013). While the lemma is similar, its proof is rather different due to the international transmission of bailouts and, in particular, the second-round effects through cross-exposures to foreign banks.}

**Lemma 17.** The provision of financial services in equilibrium, \(s(\theta, \theta^*, T, T^*)\), is increasing in the transfer and the tax rate.

**Proof.** (see appendix) \(\square\)

To summarize, the government may channel resources to the financial sector via a bailout. The bailout can be backed up by tax increases in which case there is no effect on sovereign bond prices. However, the government can also keep taxes unchanged and accept the deterioration in its credit quality. This creates the “doom loop” in which banks are insolvent,
governments step in to provide funds, and governments become less solvent in the process thereby further reducing the strength of bank balance sheets. This model features an additional feedback loop via foreign banks. A deterioration in sovereign’s credit affects foreign banks and, indirectly, hits domestic banks as well since those are creditors of foreign banks.

3.4 Transmission of Shocks and Bailout Policies Across Borders

This section illustrates how shocks and bailouts in the foreign country affect the financial sector in the home country. Negative shocks abroad propagate to the domestic economy because domestic banks are exposed to both foreign banks and foreign sovereigns. Government bailouts abroad have ambiguous effects: On the one hand, they improve foreign banks’ condition and, therefore, help domestic banks. On the other hand, they may be associated with a deterioration in the foreign sovereign’s balance sheet, thereby reducing the domestic bank’s net worth. Those findings illustrate that even a simple model of the bank-sovereign nexus generates rich interactions in an international setting.

3.4.1 Shocks to foreign government liabilities hurt the domestic country

Define the shock \( \delta \) as a reduction in future tax revenues for any tax rate \( \theta \), which implies that the foreign bond price is given by

\[
P^* (\theta^*, T^*) = E \left[ \min \left\{ 1, \left( \frac{L(\theta^*) - \delta}{B^* + \frac{T}{P^*(\theta^*, T^*)}} \right) e \right\} \right]
\]

which is decreasing in \( \delta \). The shock propagates to the domestic economy via the banking sector’s balance sheet. When foreign government liabilities increase, then the bond price of foreign government debt falls. This fall in the bond price has an effect through direct holdings of foreign debt as well as through indirect holdings via foreign banks. Both channels lead to a capital loss affecting domestic welfare. In addition to a capital loss, there is a knock-on effect on financial services provision. The supply of financial services is inefficiently low if the banking sector suffers from debt overhang. Capital losses further weaken bank
balance sheets and, hence, reduce financial services provision even more. In sum, shocks to foreign government spill over negatively to the domestic economy, which is summarized in proposition 18.

**Proposition 18.** A shock to foreign government liabilities reduces welfare in the home country.

**Proof.** (see appendix)

The derivation in the appendix shows that the change in welfare can be written as

\[
\frac{dW}{d\delta} = \left(1 + \left(\frac{\partial f}{\partial s} - s'P^0\right) \frac{ds}{dV} \frac{dV}{d\delta} \frac{dP^0}{d\delta}\right) < 0
\]

which has an intuitive interpretation. The first term in brackets captures the direct welfare effect from the capital loss. The second term captures additional welfare losses from under-provision of financial services. Finally, note that the capital losses \(dV\) include losses through holdings of foreign sovereign debt, indirect losses through exposure to foreign banks, and an accelerator effect through the feedback loop between domestic and foreign bank solvency, similarly to equation 3.3.

Figure 3.3 illustrates the transmission mechanism for various levels of interconnectedness. When government liabilities in the foreign economy increase, the value of foreign bonds falls. This reduces bank solvency abroad and worsens the credit crunch in the foreign country. In the home country, there are two effects: first, the direct effect through banks’ sovereign debt holdings and, second, the indirect effect through their exposure to foreign banks. The foreign country exports its credit crunch to the domestic economy, where output falls as well.

An example of this mechanism is the failure of the Belgian bank Dexia. In 2011, the bank held more than €20bn in European peripheral sovereign debt — a sum that exceeded its equity base. Then, the so-called private sector involvement (PSI) during the Greek restructuring led to a 21% impairment charge, severely hurting Dexia’s balance sheet (Pignal *et al.*, 2011).
Figure 3.3: Impact of a Shock to Foreign Government Liabilities

Value Relative to Baseline

Cross-border Sovereign Exposure

<table>
<thead>
<tr>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
</tr>
</thead>
</table>

Shock to Foreign Government Liabilities

Foreign
- Investment
- Output
- Financial Services
- Bank Solvency

Home
- Investment
- Output
- Financial Services
- Bank Solvency

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Figure 3.4: Impact of a Shock to Bank Government Liabilities
3.4.2 Shocks to foreign bank liabilities hurt the domestic country

Similarly to foreign government liabilities, the domestic economy is exposed to foreign bank liabilities via the banking sector balance sheet. When foreign bank liabilities increase, the value of foreign bank’s bonds falls due to increased risk of insolvency. This in turn reduces the net worth of domestic banks as they are exposed to foreign banks. Both the capital loss and the increase in debt overhang hurts the domestic economy, which motivates proposition 19.

**Proposition 19.** A shock to foreign bank liabilities reduces welfare in the home country.

**Proof.** (see appendix)

Figure 3.4 illustrates the transmission of shocks to foreign bank liabilities for various levels of interconnectedness. The mechanics are analogous to the transmission of shocks to foreign government liabilities: bank solvency falls, which leads to a contraction in the supply of financial services and, ultimately, reduces output. An example for this mechanism is the failure of German bank Hypo Real Estate (HRE). HRE was heavily exposed to foreign assets via its Irish subsidiary Depfa. HRE was subsequently bailed out at immense fiscal and political costs by the German government (Wilson, 2009).

3.4.3 Foreign tax-funded bailouts benefit the domestic country

A tax-funded bailout increases the solvency of the financial sector abroad without harming the sovereign bond price. Therefore, the only spillover to the home country is via foreign bank solvency, which increases. This leads to a positive capital gain through bank-to-bank exposures and an increase in credit supply, which moves financial services provision towards first-best. Therefore, a tax-funded bailout abroad has unambiguously positive effects on the domestic country, as summarized in proposition 20.

**Proposition 20.** A tax-funded bailout in the foreign country increases welfare in the home country.

**Proof.** (see appendix)
The transmission of tax-funded bailouts across borders is illustrated in figure 3.5. The top row summarizes the effects in the foreign country. A tax-funded bailout is associated with an increase in bank solvency and associated increases in output at the cost of reduced investment. The bottom row shows the spillover effects on the domestic economy. The capital gain due to healthier foreign banks also increases bank solvency in the domestic economy. This, in turn, shifts out the supply curve for financial services with an associated increase in output. The spillover effects are stronger when cross-border linkages are more pronounced.

3.4.4 Foreign debt-funded bailouts have ambiguous effects on other countries

Debt-funded bailouts have two competing effects on other countries. On the one hand, they increase bank solvency, with positive spillover effects. On the other hand, they reduce the government’s solvency, which is bad for other countries’ banks if they hold government debt. Which effect dominates depends on whether bank-to-sovereign linkages or bank-to-bank linkages are more important.

The derivation in the appendix shows that the change in domestic bank solvency satisfies

\[
\frac{d\rho}{dT^*} \propto \begin{cases} < 0 & (1 - \alpha) B^* \frac{dP^*}{dT^*} + \psi^* \left(1 + \alpha B^* \frac{dP^*}{dT^*}\right) \\ > 0 & \psi^* \end{cases}
\]

where the degrees of connectivity \(\psi\) and \(\psi^*\) are defined as in equations 3.4 and 3.5. The first term in the numerator captures exposure to the foreign sovereign via direct debt holdings. This effect is negative since the bond price deteriorates. The effect is stronger when the share of holdings \((1 - \alpha)\) is large. The second term captures the indirect effect through foreign bank solvency, which is positive (lemma 16). Connectivity is given by \(\psi^* = (1 - \beta) (1 - \rho^*)\). Therefore, the magnitude of the second term is increasing in bank-to-bank linkages \((1 - \beta)\) and decreasing in foreign bank solvency \(\rho^*\). Finally, the numerator captures the accelerator effect seen before: When domestic bank solvency improves, this further improves foreign bank solvency, and vice versa. The ambiguity for foreign debt-funded bailouts is summarized in proposition 21.
Figure 3.5: Transmission of a Debt-Financed Bailout in the Foreign Country
Proposition 21. A debt-funded bailout in the foreign country increases welfare in the home country if bank-to-bank linkages dominate, but decreases welfare if sovereign-to-bank linkages dominate.

Proof. (See appendix)

Figure 3.6 illustrates the effect of a debt-financed bank bailout in the foreign economy. First, consider the effect on the foreign country (top row). The bailout weakens the sovereign’s balance sheet and, therefore, depresses the foreign bond price. The transfer to the banking system alleviates the debt overhang problem and leads to increased output. Second, consider the effect on the home country (bottom row). If cross-border bank exposures \((1 - \beta)\) are small (light color), then the effect of lower sovereign bond prices dominates. The capital loss weakens bank balance sheets in the home country and further depresses financial services provision and output. Conversely, if cross-border bank exposures are large (dark color), then the effect of stronger banks in the foreign country dominates. This in turn strengthens domestic bank balance sheets, alleviates the debt overhang problem, and yields gains in output.

To sum up, bailouts can have very different effects on other countries, depending on how they are financed (tax versus debt) and how the two countries are connected (sovereign-to-bank versus bank-to-bank linkages). Tax-financed bailouts by the foreign country generally benefit the home country. Debt-financed bailouts by the foreign government, by contrast, may or may not benefit the home country, depending on whether the foreign government or foreign banks are more important for the home country’s financial system.

3.5 Introducing a Banking Union

This section illustrates how forming a banking union benefits financially-integrated areas. First, coordinating the size of bailouts is beneficial given the bank-to-bank and sovereign-to-bank spillovers. Second, coordinating the funding structure also improves the allocation: In contrast to debt-funded bailouts, tax-funded bailouts avoid a deterioration of the government’s balance sheet. Saving the government’s balance sheet has positive repercussions for
Figure 3.6: Transmission of a Debt-Financed Bailout in the Foreign Country
banks in other countries while the costs accrue locally. Therefore, a socially-optimal policy tilts the funding structure away from debt and towards more taxes. Third, committing to jointly funding bailouts allows governments to share fiscal capacity more efficiently.

For illustrative purposes, consider a very simple setup in which either the domestic or the foreign country is hit by a shock to bank solvency with equal probability. Since both countries are risk-neutral, the social planner’s ex-ante problem is to choose a system of bailouts \((\theta, \theta^*, T, T^*)\) conditional on the shock that maximizes joint welfare given by

\[
W(\theta, \theta^*, T, T^*) + \lambda W^* (\theta, \theta^*, T, T^*)
\]

where \(\lambda\) represents the Pareto weight on the foreign country.

**3.5.1 Benefits from Coordinating the Size and Funding Structure of Bailouts**

First, we show that countries benefit from coordinating their bailout policies \((\theta, \theta^*, T, T^*)\). A national (interior) optimum\(^6\) in the domestic country is defined by

\[
\frac{d}{d\theta} W(\theta, \theta^*, T, T^*) = 0
\]

\[
\frac{d}{dT} W(\theta, \theta^*, T, T^*) = 0
\]

and the foreign country’s (interior) optimum is similarly described by

\[
\frac{d}{d\theta^*} W^*(\theta, \theta^*, T, T^*) = 0
\]

\[
\frac{d}{dT^*} W^*(\theta, \theta^*, T, T^*) = 0
\]

\(^6\)For brevity, this section focuses on interior optima in which all policy parameters are positive. There are cases in which the optimal bailout or the optimal tax rate could be zero, for example when the banking sector is fully solvent. In this case, the equations below should be replaced by the Kuhn-Tucker complementary slackness conditions with policy variables \((\theta, \theta^*, T, T^*)\) restricted to non-negative values.
By contrast, the social planner takes into account the international spillovers, leading to a system of first-order conditions for an interior optimum given by

\[
\frac{d}{d\theta} W(\theta, \theta^*, T, T^*) + \lambda \frac{d}{d\theta} W^*(\theta, \theta^*, T, T^*) = 0
\]

\[
\frac{d}{d\theta^*} W(\theta, \theta^*, T, T^*) + \lambda \frac{d}{d\theta^*} W^*(\theta, \theta^*, T, T^*) = 0
\]

\[
\frac{d}{dT} W(\theta, \theta^*, T, T^*) + \lambda \frac{d}{dT} W^*(\theta, \theta^*, T, T^*) = 0
\]

\[
\frac{d}{dT^*} W(\theta, \theta^*, T, T^*) + \lambda \frac{d}{dT^*} W^*(\theta, \theta^*, T, T^*) = 0
\]

From propositions 20 and 21, we know that increasing the size of the bailout \(T\) (without additional tax increases) has ambiguous effects on welfare abroad. Moreover, tax hikes (without additional transfers) are associated with positive spillover effects through their impact on government solvency:

\[
\frac{\partial W}{\partial \theta} \geq 0, \quad \frac{\partial W}{\partial \theta^*} \leq 0, \quad \frac{\partial W^*}{\partial \theta} \geq 0, \quad \frac{\partial W^*}{\partial \theta^*} \leq 0
\]

When both bank and sovereign debt is impaired and exposures are positive, the inequalities are strict. It follows that the social planner’s solution diverges from the national optima. Therefore, countries benefit from committing to joint determination of bailout policies \((\theta, \theta^*, T, T^*)\)—a key element of a banking union.

### 3.5.2 Benefits from International Transfers

In addition to coordinated bailout policies, symmetric countries also benefit from a system of state-contingent transfers. Using a joint pool of money to bail out banks is beneficial since raising funds is associated with tax distortions. Those distortions are minimized at low tax rates and pooling resources allows governments to smooth out the pattern of taxation.

Suppose the home country is hit by a shock to bank liabilities. All else equal, the home country will have higher taxes and higher expected default costs than the foreign country in this state since it needs to fund a transfer to the banking system. Consider a (tax-funded) transfer from the low-tax country (foreign) to the high-tax country (home). For a given
bailout and government bond price, this transfer allows the high-tax country to reduce the cost of distortionary taxation. Since the costs of taxation are convex, those gains exceed the losses in the donor country. In expectation, symmetric countries benefit from installing such a system.

In practice, the European Union has introduced the European Financial Stability Fund (EFSF), which was later replaced by the European Stability Mechanism (ESM). Those programs are used to fund bank bailouts jointly, which can be interpreted as a fiscal insurance scheme against shocks emanating from the banking system.

### 3.5.3 Summary

If countries are symmetric ex-ante, they gain from committing to an insurance mechanism that channels funds from the fiscally unconstrained country to the banking sector with insufficient net worth. Ex-post, the country providing the transfer loses, as is the case with all forms of insurance. This implies that an appropriate institutional structure has to ensure implementation credibly and calls for an institutional framework that makes these transfers as automatic as possible in order to avoid renegotiation.

Symmetry ex-ante is a strong assumption that is unlikely to be met in any practical application. The discussions around “legacy assets” in the Eurozone vividly illustrate this point. But even for asymmetric countries, the above argument holds: some form of insurance that allows countries to share scarce fiscal capacity will be beneficial, much in the same way as there is a mutually beneficial insurance contract for two agents with different risk profiles, as long as those risks are imperfectly correlated.

Finally, it is worth emphasizing that the insurance benefit in this model is not a consequence of risk-aversion. Consumers have linear utility in order to abstract from this argument. Instead, the curvature of the objective function is due to the market failure at low levels of sovereign and bank net worth.
3.6 Discussion and Extensions

Financial integration creates new international linkages between countries that motivate corrective measures. In particular, bailouts involve significant externalities that can be positive or negative, depending on how such transfers are funded and depending on the network structure of exposures. Tax-funded bailouts always benefit other countries because they do not pay the taxes but reap some of the benefits via their interbank exposures. Debt-funded bailouts can be positive or negative for other countries: On the one hand, they improve the condition of the financial sector, which benefits other countries if they are connected via interbank linkages. On the other hand, such bailouts might decrease the value of sovereign debt and, hence, lower the net worth of other countries’ banks. If countries are mainly connected via interbank linkages, then bailouts are associated with positive effects on other countries. By contrast, if countries are connected mostly via cross-holdings of sovereign debt, then debt-funded bailouts negatively affect other countries.

The analysis of a common recapitalization scheme suggests that for symmetric countries, a banking union is welfare enhancing. Such a scheme allows countries to pool resources that are scarce in bad times: the net worth of the sovereign as well as the net worth of the financial sector. This mitigates a market failures in states of the world in which bank or sovereign balance sheets are weak. The symmetric nature of the model allows to focus on efficiency considerations. There are no expected net transfers across countries in such a setup. In practice, the assumption of symmetric countries is of course unrealistic. Some of the fiercest criticism of the proposed policies in Europe come from politicians and citizens in “core” countries that expect to become net payers. While it seems unclear which countries will benefit from a banking union in ten or twenty years, it should be emphasized that banking unions will most likely lead to significant net transfers across countries—certainly ex-post. Nevertheless, in focusing on the economics of the problem, the analysis presented here allows to clearly isolate the active channels of a banking union without being distracted by distributional concerns.

Two extensions are left for further research: First, the network structure has been taken as
exogenous in this model. Endogenizing the links between countries would allow to evaluate of how such links are affected by the introduction of a banking union. For example, one would expect interbank linkages to become stronger in a world in which sovereigns insure each others’ financial systems because this reduces the risk of being exposed to a failing bank. Second, the tradeoff between enhanced risk-sharing in a banking union and the risk of misaligned incentives has been a prominent theme of policy discussions. Governments might become more lenient when regulating banks given that the bailouts will partially be funded by other countries. This is a rationale for implementing the banking union only after centralized supervisory mechanisms have been put in place. Moreover, governments might be more prone to default themselves, knowing that their own banking system will be bailed out by other countries. Building a model that calibrates these tradeoffs would be another interesting avenue for future research.
References


ROMPUY, H. V. (2012). Towards a Genuine Economic and Monetary Union. Report by the President of the European Council, EUCO 120/12.


Appendix A

Appendix to Chapter 1

A.1 Proofs

Proof of Lemma 1  (Sufficient condition for binding multipliers) The Lagrange Multipliers $\lambda_t$ will be binding as long as the gross return function is sufficiently concave, i.e. $\varphi \geq \varphi^* \Rightarrow \lambda_t > 0 \forall t$.

Proof. In period 1, we have

$$\lambda_1 = \delta + c_e (E_1 - E_0) - \beta c_e (E_2 - E_1)$$

$$= \delta + c_e \kappa \left( A_1 - \frac{k_0}{\kappa} A_0 \right) - \beta c_e \kappa (A_2 - A_1)$$

$$\delta + \left[ (1 + \beta (1 - r)) \left( c_e \kappa w_0 \frac{\psi_0}{\psi} \right) - c_e \kappa_0 \right] A_0 + \left[ (1 + \beta (1 - r)) c_e \kappa (1 - w_0) - \beta c_e \kappa (1 - r) \right] \check{A}$$

This is greater than zero as long as

$$\varphi \geq \varphi^*_1$$

$$\equiv \frac{\kappa c_e}{\delta} \left[ \frac{k_0}{\kappa} - w_0 (1 + \beta (1 - r)) \frac{\psi_0}{\psi} \right] \left( \varphi_0 - (1 + \check{r} + k_0 \delta) \right)$$

$$- \left[ 1 - w_0 (1 + \beta (1 - r)) \right] \left( \varphi_0 - (1 + \check{r} + \kappa \delta) \right)$$

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In period \( t \geq 2 \), we have

\[
\lambda_t = \delta + c \varepsilon (E_t - E_{t-1}) - \beta c \varepsilon (E_{t+1} - E_t)
\]

\[
= \delta + (c \varepsilon \kappa) (A_t - A_{t-1}) - \beta (A_{t+1} - A_t)
\]

\[
= \delta + \beta r^{t-1} (1 - \beta r) (1 - r) (c \varepsilon \kappa) (A_t - A_1)
\]

\[
= \delta + \beta r^{t-1} (1 - \beta r) (1 - r) (c \varepsilon \kappa) w_0 \left( \ddot{A} - \frac{\psi_0}{\psi} A_0 \right)
\]

If \( \ddot{A} \geq \frac{\psi_0}{\psi} A_0 \), this expression is always positive. Otherwise, we have

\[
\lambda_t = \delta - \beta r^{t-1} (1 - \beta r) (1 - r) w_0 c \varepsilon \kappa \left( \frac{\psi_0}{\psi} A_0 - \ddot{A} \right)
\]

which exceeds zero as long as

\[
\varphi \geq \varphi^*_2 \equiv \left( \frac{\kappa c \varepsilon}{\beta} \right) (1 - \beta r) r (1 - r) w_0 \left( \frac{\psi_0}{\psi} \left( \varphi_0 - (1 + \ddot{r} + \kappa_0 \delta) \right) - (\varphi_0 - (1 + \ddot{r} + \kappa \delta)) \right)
\]

Define \( \varphi^* = \max \{ \varphi^*_1, \varphi^*_2 \} \). Then, \( \varphi \geq \varphi^* \) is sufficient for non-negative Lagrange multipliers.

\[\square\]

**Proof of Lemma 2** (Path of Assets) The optimal path of assets for \( t \geq 2 \) is given by \( A_t = \dddot{A} + (A_{t-1} - \dddot{A}) r^{t-1} \) where \( \dddot{A} = \frac{1}{\varphi} (\varphi_0 - (1 + \ddot{r} + \kappa \delta)) \) is the long-run value of \( A_t \) and \( r \) determines the speed of convergence.

**Proof.** Combining equations (1.3), (1.4), (1.8), (1.9), and (1.11) yields a second-order difference equation in \( A_t \),

\[
A_t = \frac{\varphi_0 - (1 + \ddot{r} + \kappa \delta)}{\varphi} + \frac{c_a + \kappa^2 c_e}{\varphi} (A_{t+1} - A_t) - \beta \frac{c_a + \kappa^2 c_e}{\varphi} (A_t - A_{t-1})
\]

Defining \( \dddot{A} = \frac{1}{\varphi} (\varphi_0 - (1 + \ddot{r} + \kappa \delta)) \) as the long-run value of \( A_t \) and \( \varphi = \frac{1}{\psi} (c_a + \kappa^2 c_e) \) as a measure of adjustment costs, this can be re-written as

\[
\beta \varphi (A_{t+1} - \dddot{A}) - (1 + \psi + \beta \varphi) (A_t - \dddot{A}) + \psi (A_{t-1} - \dddot{A}) = 0
\]

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After discarding the explosive root, we find that
\[
(A_t - \bar{A}) = (A_1 - \bar{A}) r^{t-1} \text{ for } t \geq 1, \ 0 \leq r < 1
\]
where
\[
r = \frac{1}{2\beta\varphi} \left( (1 + \psi + \beta\psi) - \sqrt{(1 + \psi + \beta\psi)^2 - 4\beta\psi^2} \right)
\]

**Proof of Proposition 4** (Asset choice upon impact) Assets in period 1 are given by
\[
A_1 = w_0 \left( \frac{\psi}{\varphi} A_0 \right) + (1 - w_0) \bar{A} \text{ where } \psi_0 = \frac{1}{\varphi} (c_a + \kappa_0 \kappa c_e) \text{ and } \psi = \frac{1}{\varphi} (c_a + \kappa^2 c_e) \text{ are measures of adjustment costs and the weight on the initial period is given by } w_0 = \frac{\varphi}{1 + \psi + (1 - r) \beta \psi}.
\]

**Proof.** Using the envelope theorem again, the first-order conditions are
\[
f'(A_1) - (1 + \bar{r}) - c'_A (A_1 - A_0) - \kappa \lambda_1 + \beta c'_A (A_2 - A_1) = 0
\]
\[
-\delta - c'_E (E_1 - E_0) + \lambda_1 + \beta c'_E (E_2 - E_1) = 0
\]
\[
\lambda_1 (E_t - \kappa A_t) = 0
\]

Plugging in functional form assumptions and the assumption that the multipliers bind,
\[
(\psi_0 - \varphi A_1) - (1 + \bar{r}) A_1 - c_a (A_1 - A_0) - \kappa \lambda_1 + \beta c_a (A_2 - A_1) = 0
\]
\[
-\delta - c_e (\kappa A_1 - \kappa_0 A_0) + \lambda_1 + \beta \kappa c_e (A_2 - A_1) = 0
\]

Solve for \(A_1\),
\[
(1 + \psi + \beta\psi) A_1 = \bar{A} + \left( \frac{c_a + \kappa_0 \kappa c_e}{\varphi} \right) A_0 + \beta \psi A_2
\]
Define \(\psi_0 = \frac{1}{\varphi} (c_a + \kappa_0 \kappa c_e)\). Plug in \(A_2 = \bar{A} + (A_1 - \bar{A}) r\). Then,
\[
(1 + \psi + \beta\psi) A_1 = \bar{A} + \left( \frac{c_a + \kappa_0 \kappa c_e}{\varphi} \right) A_0 + \beta \psi (\bar{A} + (A_1 - \bar{A}) r)
\]
\[
(1 + \psi + (1 - r) \beta\psi) A_1 = \psi \left( \frac{\psi_0}{\psi} A_0 \right) + (1 + (1 - r) \beta\psi) \bar{A}
\]
\[
\iff A_1 = w_0 \left( \frac{\psi_0}{\psi} A_0 \right) + (1 - w_0) \bar{A}
\]
where \( w_0 = \frac{\psi}{1 + \psi + (1-r)\psi} \).
### A.2 Supplementary Tables

<table>
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<tr>
<th>Statistic</th>
<th>N</th>
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<th>St. Dev.</th>
<th>Pctl(25)</th>
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<th>Pctl(75)</th>
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**Table A.1: Summary Statistics**

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<th>(% Change)</th>
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<th>BW</th>
<th>N</th>
<th>Half-BW</th>
<th>Double-BW</th>
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<td>3.36</td>
<td>4.11</td>
<td>1220</td>
<td>-7.62</td>
<td>-7.48</td>
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**Table A.2: Automatic Bandwidth Selection, Triangular Kernel (IK-Approach)**
Appendix B

Appendix to Chapter 2

B.1 Proofs

Proof of proposition 6  (Interest Rate Channel) A decline in the safe interest rate $R_1$ stimulates investment in the risky asset, $k_1^*$, and leads to lower expected earnings.

Proof. Implicitly differentiating 2.1 yields $\frac{dk_1^*}{dR_1} = \frac{1}{\frac{1}{\rho} f(k_1^*)} < 0$. Differentiating $E[\pi(k_1^*)]$ using the envelope theorem yields $\frac{dE[\pi(k_1^*)]}{dR_1} = \frac{\partial E[\pi(k_1^*)]}{\partial R_1} = e_0 + w_0 - k_1^* \geq 0$. □

Proof of proposition 9  (Risk-Shifting Channel) As interest rates fall, the annuity provider invests more in the risky asset. Moreover, there is a unique cutoff $R_{RS}^*$ such that for $R < R_{RS}^*$ risk-taking is elevated relative to the frictionless benchmark case.

Proof. Risk-taking without default is given by $k_1(R) = f^{-1}\left(\frac{R}{\rho}\right)$. Risk-taking with default in the bad state is given by $k_1^{RS}(R) = f^{-1}(R)$, where $k_1(R)$ and $k_1^{RS}(R)$ are increasing given that $f(.)$ is strictly increasing and concave. $R_{RS}^*$ is defined by $R_{RS}^*\left(e_0 + w_0 - f^{-1}(R_{RS}^*)\right) = \bar{c}$. $R_{RS}^*$ is unique since the left-hand side is strictly increasing in $R$. For $R_1 \leq R_{RS}^*$, risk-taking is defined by $k_1^{RS}(R) = f^{-1}(R)$. Risk-taking is elevated in this region since $f^{-1}(R) > f^{-1}\left(\frac{R}{\rho}\right)$ for any $R$ and $\rho$. □
**Proof of corollary 10**  (Cross-Section: Overhang of Guarantees) The region in which risk-taking is elevated is reached earlier if the level of guarantees is high, i.e. $R^*_{RS}$ is increasing in $\bar{c}$.

**Proof.** Implicitly differentiate the cutoff condition $R^*_{RS} \left( e_0 + w_0 - f^{-1} \left( R^*_{RS} \right) \right) = \bar{c}$ w.r.t. $\bar{c}$ to find that

$$\frac{dR^*_{RS}}{d\bar{c}} \left( e_0 + w_0 - f^{-1} \left( R^*_{RS} \right) \right) + R^*_{RS} \left( - \left( f^{-1} \right)' \left( R^*_{RS} \right) \frac{dR^*_{RS}}{d\bar{c}} \right) = 1$$

re-arranging yields

$$\frac{dR^*_{RS}}{d\bar{c}} = \frac{1}{(e_0 + w_0 - f^{-1} \left( R^*_{RS} \right) - R^*_{RS} \left( f^{-1} \right)' \left( R^*_{RS} \right))} > 0$$

using the fact that $e_0 + w_0 - f^{-1} \left( R^*_{RS} \right) \geq 0$ and $\left( f^{-1} \right)' \left( R^*_{RS} \right) < 0$. $\square$

**Proof of corollary 11**  (Cross-Section: Equity) The region in which risk-taking is elevated is reached earlier if the level of equity is low, i.e. $R^*_{RS}$ is decreasing in $e$.

**Proof.** Implicitly differentiate the cutoff condition $R^*_{RS} \left( e_0 + w_0 - f^{-1} \left( R^*_{RS} \right) \right) = \bar{c}$ w.r.t. $e_0$ to find that

$$\frac{dR^*_{RS}}{de_0} \left( e_0 + w_0 - f^{-1} \left( R^*_{RS} \right) \right) + R^*_{RS} \left( 1 - \left( f^{-1} \right)' \left( R^*_{RS} \right) \frac{dR^*_{RS}}{de_0} \right) = 0$$

re-arranging yields

$$\frac{dR^*_{RS}}{de_0} = \frac{-R^*_{RS}}{e_0 + w_0 - f^{-1} \left( R^*_{RS} \right) - R^*_{RS} \left( f^{-1} \right)' \left( R^*_{RS} \right)} < 0$$

using the fact that $e_0 + w_0 - f^{-1} \left( R^*_{RS} \right) \geq 0$ and $\left( f^{-1} \right)' \left( R^*_{RS} \right) < 0$. $\square$

**Proof of proposition 12**  (Earnings Channel) As interest rates fall, the annuity provider takes more risk. Moreover, there is a cutoff $R^*_{ET}$ such that for $R < R^*_{ET}$ risk-taking is elevated relative to the frictionless case.

**Proof.** $R^*_{ET}$ is implicitly defined by $R^*_{ET} \left( e_0 + w_0 - \left( f^{-1} \right)' \left( \frac{1+\rho^*}{1+\rho} R^*_{ET} \right) \right) = \bar{p} + \bar{c}$. The proof is analogous to the proof of proposition 9. $\square$
Proof of corollary 13  
(Cross-Section: Overhang of Guarantees) In the earnings-targeting model, risky investment $k^*_1$ is weakly increasing in the level of past commitments $\bar{c}$.

Proof. Analogous to the proof of corollary 10.

Proof of corollary 14  
Risky investment $k^*_1$ is weakly increasing in earnings pressure $\bar{g}$.

Proof. If $R_1 > R_{ET}^*$, then risky investment is defined by $\rho f''(k_1) = R_1$. Therefore, $\frac{dk^*_1}{\bar{g}} = 0$ in this region. If $R_1 \leq R_{ET}^*$, then risky investment is defined by $\rho f''(k_1) = \frac{1 + \phi^2}{1 + \bar{g}} R_1$. The RHS is decreasing in $\bar{g}$. LHS is decreasing in $k_1$. Therefore, $\frac{dk^*_1}{\bar{g}} > 0$ in this region.
B.2 Supplementary Tables

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<th>Statistic</th>
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Table B.1: Summary Statistics, Acquisition Portfolios (2009-2014)

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Table B.2: Summary Statistics, Balance Sheets (2008)
B.3 Supplementary Figures

Figure B.2: Different Liquidity Measures over Time
Figure B.3: Corporate Bond Acquisitions over Time
Appendix C

Appendix to Chapter 3

C.1 Proofs

Lemma 22. Equilibrium investment $K_1(\theta)$ is decreasing in the tax rate.

Proof. The first-order condition is given by

$$(1 - \theta)E [\tilde{V}'(K_1)] - 1 = 0$$

which defines $K_1(\theta)$ implicitly. Differentiating and re-arranging yields

$$\frac{\partial K_1}{\partial \theta} = \frac{E [\tilde{V}'(K_1)]}{(1 - \theta)E [\tilde{V}''(K_1)]} < 0$$

where the last inequality follows from the concavity of the investment production function.

Proof of lemma 15. Without transfers, financial services provision is inefficiently low relative to the first-best allocation if $\rho < 1$.

Proof. The first-order conditions of the non-financial and the financial sector are given by

$$\frac{\partial f(s, K)}{\partial s} = w, \rho w = c'(s)$$
Therefore, in equilibrium, we find that
\[
\frac{\partial f (s (\rho), K)}{\partial s} = \frac{c'}{\rho} - c' (s) > 0
\]
which implies that the derivative of welfare with respect to financial services is positive:
\[
\frac{\partial f (s, K)}{\partial s} > 0
\]
Therefore, \( s \) is inefficiently low.

\[ \square \]

**Proof of remark 3.3.1** The bond price \( P (\theta, T) \) is increasing in the tax rate, \( \theta \), and decreasing in the transfer, \( T \).

**Proof.** The bond price satisfies
\[
P (\theta, T) = E \left[ \min \left\{ 1, \left( \frac{L (\theta)}{B + \frac{T}{P (\theta, T)}} \right) e \right\} \right]
\]
which can be re-written as
\[
P (\theta, T) = \frac{L (\theta)}{B + \frac{T}{P (\theta, T)}} \int_0^{\frac{\theta + T}{P (\theta, T)}} x \times f_e (x) dx + \int_{\frac{\theta + T}{P (\theta, T)}}^\infty f_e (x) dx
\]
This equation defines the price as an implicit function of \( \theta \) and \( T \). Differentiate using Leibniz’ Rule:
\[
\frac{dP (\theta, T)}{dT} = \left( \frac{d}{dT} \frac{L (\theta)}{B + \frac{T}{P (\theta, T)}} \right) \left( \int_0^{\frac{\theta + T}{P (\theta, T)}} x \times f_e (x) dx \right)
\]
\[
+ \left( \frac{L (\theta)}{B + \frac{T}{P (\theta, T)}} \right) \times \frac{B + \frac{T}{P (\theta, T)}}{L (\theta)} f_e \left( \frac{B + \frac{T}{P (\theta, T)}}{L (\theta)} \right) - f_e \left( \frac{B + \frac{T}{P (\theta, T)}}{L (\theta)} \right) \left( \frac{d}{dT} \frac{B + \frac{T}{P (\theta, T)}}{L (\theta)} \right)
\]
\[
= - \frac{L (\theta)}{\left( B + \frac{T}{P (\theta, T)} \right)^2} \left( \frac{1}{P (\theta, T)} - \frac{T}{P (\theta, T)^2} \frac{dP (\theta, T)}{dT} \right) \left( \int_0^{\frac{\theta + T}{P (\theta, T)}} x \times f_e (x) dx \right)
\]
Re-arranging yields
\[
\frac{dP(\theta, T)}{dT} = - \left[ \frac{L(\theta) \int_0^{\theta \frac{T}{\theta(T)}} x \times f_\epsilon(x) dx}{B + \frac{T}{\theta(T)}} - \frac{1}{P(\theta, T)} \frac{1}{B + \frac{T}{\theta(T)}} \right] 
\]
\[
= \frac{1 - L(\theta) \int_0^{\theta \frac{T}{\theta(T)}} x \times f_\epsilon(x) dx}{B + \frac{T}{\theta(T)}} \frac{1}{P(\theta, T)} \frac{1}{B + \frac{T}{\theta(T)}} < 1
\]
where the numerator is positive given the definition of the bond price:
\[
\frac{L(\theta) \int_0^{\theta \frac{T}{\theta(T)}} x \times f_\epsilon(x) dx}{B + \frac{T}{\theta(T)}} < \frac{L(\theta) \int_0^{\theta \frac{T}{\theta(T)}} x \times f_\epsilon(x) dx}{B + \frac{T}{\theta(T)}} + \int_{\theta \frac{T}{\theta(T)}}^\theta f_\epsilon(x) dx = P(\theta, T)
\]
A similar derivation holds for the tax rate:
\[
\frac{dP(\theta, T)}{d\theta} = \left( \frac{d}{d\theta} \frac{L(\theta)}{B + \frac{T}{\theta(T)}} \right) \left( \int_0^{\theta \frac{T}{\theta(T)}} x \times f_\epsilon(x) dx \right)
\]
\[
+ \left( \frac{L(\theta)}{B + \frac{T}{\theta(T)}} \times L(\theta) \frac{B + \frac{T}{\theta(T)}}{L(\theta)} \right) f_\epsilon \left( \frac{B + \frac{T}{\theta(T)}}{L(\theta)} \right) - f_\epsilon \left( \frac{B + \frac{T}{\theta(T)}}{L(\theta)} \right) \left( \frac{d}{d\theta} \frac{B + \frac{T}{\theta(T)}}{L(\theta)} \right)
\]
\[
= \left( \frac{L'(\theta)}{B + \frac{T}{\theta(T)}} + \frac{L(\theta)}{B + \frac{T}{\theta(T)}} \frac{\frac{T}{\theta(T)}}{B + \frac{T}{\theta(T)}} \frac{1}{P(\theta, T)} \frac{\partial P(\theta, T)}{\partial \theta} \right) \left( \int_0^{\theta \frac{T}{\theta(T)}} x \times f_\epsilon(x) dx \right)
\]
Re-arranging yields
\[
\frac{dP(\theta, T)}{d\theta} = \frac{\frac{L'(\theta)}{B + \frac{T}{\theta(T)}} \int_0^{\theta \frac{T}{\theta(T)}} x \times f_\epsilon(x) dx}{1 - \frac{L(\theta)}{B + \frac{T}{\theta(T)}} \int_0^{\theta \frac{T}{\theta(T)}} x \times f_\epsilon(x) dx} \frac{\frac{T}{\theta(T)}}{P(\theta, T)} \frac{1}{B + \frac{T}{\theta(T)}} < 1
\]
where the first inequality in the denominator follows from the definition of \( P(\theta, T) \) as
It is helpful to prove that even if the bank were to hold all government debt, then it would nevertheless benefit from a transfer.

**Remark C.1.1.** $T + B \times P(\theta, T)$ is increasing in $T$.

**Proof.** Differentiate to find that $\frac{d}{dT} (T + B \times P(\theta, T)) = 1 + B \frac{dp(\theta, T)}{dT}$. For notational simplicity, define the term

$$\gamma \equiv \frac{L(q)}{B + \frac{L}{P(q)}} \int_0^{B+L} x \times f(x)dx \in (0, 1)$$

which captures that the debt is impaired. Then, the derivative can be written as:

$$\frac{d}{dT} (T + B \times P(\theta, T)) = 1 - B \frac{\gamma \frac{1}{B + \frac{L}{P(q)}}}{1 - \gamma \frac{1}{B + \frac{L}{P(q)}}}$$

$$= \frac{1 - \gamma}{1 - \gamma \frac{1}{B + \frac{L}{P(q)}}}$$

$$> 0$$

The previous result is a consequence of government debt being senior to the residual claimants (tax payers). When the government issues additional debt and transfers it to debt-holders then it dilutes debt holders (which washes out) but also moves money away from tax payers in the state of the world in which it is solvent. The transfer washes out completely only if the government is always insolvent, i.e. $\gamma = 1$.

**Proof of lemma 16**  
**Bank solvency $\rho(\theta, T)$ is increasing in the transfer and the tax rate.**

**Proof.** First, note that for a given change in the foreign bank’s assets, the value of its liabilities moves less:

$$P^*_B(\theta, T) L^* = p r (\bar{A} + V^*(\theta, T) \leq L^*) \left( E [\bar{A} | \bar{A} + V^*(\theta, T) \leq L^*] + V^* \right)$$

$$+ p r (\bar{A} + V^*(\theta, T) \geq L^*) L^*$$
Differentiating,
\[ \frac{d}{dV^*} P^*_B (\theta, T) L^* = \int_{0}^{L^* - V^*} f_A (x) \, dx < 1 \]

Using this, the foreign bank’s liabilities are changing according to
\[
\frac{d}{dT} \frac{d}{dV} P^*_B (\theta, T) L^* = \frac{d}{dV^*} P^*_B (\theta, T) L^* \frac{dV^*}{dT} = \int_{0}^{L^* - V^*} f_A (x) \, dx \left( (1 - \alpha) B \frac{dP(\theta, T)}{dT} + (1 - \beta) L \frac{dP_B (\theta, T)}{dT} \right)
\]

Finally, the change in the non-stochastic part of domestic bank assets is given by
\[
\frac{dV (\theta, T)}{dT} = \alpha \frac{dP(\theta, T)}{dT} B + (1 - \beta) \frac{dP_B (\theta, T)}{dT} L^* + 1
\]
\[
= \alpha \frac{dP(\theta, T)}{dT} B + (1 - \beta) \left( \int_{0}^{L^* - V^*} f_A (x) \, dx \right) \left( (1 - \alpha) B \frac{dP(\theta, T)}{dT} + (1 - \beta) L \frac{dP_B (\theta, T)}{dT} \right) + 1
\]

Note that \( \frac{dP_B (\theta, T)}{dT} L = \left( \int_{0}^{L^* - V^*} f_A (x) \, dx \right) \frac{dV(\theta, T)}{dT} \). Therefore, we find that
\[
\frac{dV (\theta, T)}{dT} = 1 + \left( \alpha + (1 - \alpha)(1 - \beta) \left( \int_{0}^{L^* - V^*} f_A (x) \, dx \right) \right) \frac{dP(\theta, T)}{dT} B + \left( 1 - \beta \right)^2 \left( \int_{0}^{L^* - V^*} f_A (x) \, dx \right) \left( \int_{0}^{L^* - V^*} f_A (x) \, dx \right) \frac{dV (\theta, T)}{dT}
\]

Solving,
\[
\frac{dV (\theta, T)}{dT} = 1 + \left( \alpha + (1 - \alpha)(1 - \beta) \left( \int_{0}^{L^* - V^*} f_A (x) \, dx \right) \right) \frac{dP(\theta, T)}{dT} B > 0
\]
\[
= \frac{1 - (1 - \beta)^2 \left( \int_{0}^{L^* - V^*} f_A (x) \, dx \right) \left( \int_{0}^{L^* - V^*} f_A (x) \, dx \right)}{< 1} > 0
\]

where the last inequality follows from remark C.1.1. Finally, it is left to show that solvency is
increasing in , which is trivial since the probability of solvency is increasing in \( V(q, T) \),

\[
\frac{d}{dT} \mathbb{P}(\theta, T) = \frac{d}{dT} \mathbb{P}(\bar{A} + V(\theta, T) > L) = f_{\bar{A}} (L - V(\theta, T)) \frac{dV(\theta, T)}{dT} > 0
\]

which concludes the proof for the transfer. To prove that bank solvency is increasing in the tax rate, note that a similar derivation leads to

\[
\frac{dV(\theta, T)}{d\theta} = \alpha \frac{dP(\theta, T)}{d\theta} B + (1 - \beta) \frac{dP_B(\theta, T)}{d\theta} L^* = \left( \alpha + (1 - \alpha) (1 - \beta) \left( \int_0^{L^* - V^*} f_{\bar{A}}(x) \, dx \right) \right) \frac{dV(\theta, T)}{dT} > 0
\]

Re-arranging,

\[
\frac{dV(\theta, T)}{d\theta} = \frac{\alpha + (1 - \alpha) (1 - \beta) \left( \int_0^{L^* - V^*} f_{\bar{A}}(x) \, dx \right)}{1 - (1 - \beta)^2 \left( \int_0^{L^* - V^*} f_{\bar{A}}(x) \, dx \right) \left( \int_0^{L^* - V^*} f_{\bar{A}}(x) \, dx \right)} B \frac{dP(\theta, T)}{d\theta} > 0
\]

and as before solvency is increasing in \( V \), so we find that

\[
\frac{d}{d\theta} \mathbb{P}(\theta, T) = \frac{d}{d\theta} \mathbb{P}(\bar{A} + V(\theta, T) > L) = f_{\bar{A}} (L - V(\theta, T)) \frac{dV(\theta, T)}{d\theta} > 0
\]

which concludes the proof for the tax rate. \( \square \)

**Proof of lemma 17**  The provision of financial services in equilibrium is increasing in the transfer and the tax rate.

**Proof.** Taking as given the probability of bank-solvency, the first-order conditions for financial
services demand and supply are given by

\[ f'(s, K_0) - w = 0 \]
\[ \rho(\theta, \theta^*, T, T^*) w - c'(s) = 0 \]

which pins down the equilibrium values of \( w \) and \( s \) as a function of \( \rho(\theta, \theta^*, T, T^*) \). To make this dependency explicit, define the equilibrium value by \( s(\theta, \theta^*, T, T^*) \) and substitute out \( w \) to find

\[ \rho(\theta, T) f'(s(\theta, T)) = c'(s(\theta, T)) \]

Differentiate with respect to \( \theta \) and re-arrange to find

\[ \frac{\partial s(\theta, T)}{\partial T} = \frac{\frac{\partial f'(s(\theta, T))}{\partial T}}{c''(s(\theta, T)) - \rho(\theta, T) f''(s(\theta, T))} > 0 \]

using the fact that \( \frac{\partial f'(s(\theta, T))}{\partial T} > 0 \), \( c''(.) > 0 \) and \( f''(.) < 0 \). A similar derivation holds for \( \frac{\partial s(\theta, T)}{\partial T} \) using the fact that solvency is also increasing in the transfer \( T \).

**Proof of proposition 18**  
A shock to foreign government liabilities reduces welfare in the home country.

**Proof.** Welfare (ignoring constant terms) is given by

\[ W(\theta, \theta^*, T, T^*) = f(K_0, s(\theta, \theta^*, T, T^*)) - c(s(\theta, \theta^*, T, T^*)) + (1 - \theta) \tilde{V}(K_1(\theta)) - K_1(\theta) + V(\theta, \theta^*, T, T^*) + \left( L(\theta) - B - \frac{T}{P(\theta, T)} \right) \left( \int_{\theta}^{\theta^*} x \times f_\epsilon(x) dx \right) - D \int_{\theta}^{\theta^*} \frac{t}{T(T')} f_\epsilon(x) dx \]

It is sufficient to show that welfare is decreasing in the foreign bond price. First, consider the
effect on bank balance sheets:

\[
\frac{dV}{dP} = (1 - \alpha) B^* + (1 - \beta) \left( \frac{d}{dP} P_b^* L^* \right)
\]

\[
= (1 - \alpha) B^* + (1 - \beta) \left( \int_0^{L^*} f_A(x) dx \right) \frac{dV^*}{dP^*} 
\]

\[
= (1 - \alpha) B^* + (1 - \beta) \left( \int_0^{L^*} f_A(x) dx \right) \left( aB^* + (1 - \beta) \frac{d}{dP^*} P_b L \right)
\]

\[
= (1 - \alpha) B^* + (1 - \beta) \left( \int_0^{L^*} f_A(x) dx \right) \left( aB^* + (1 - \beta) \left( \int_0^{L^*} f_A(x) dx \right) \frac{dV}{dP^*} \right)
\]

Re-arranging yields

\[
\frac{dV}{dP^*} = \frac{(1 - \alpha) B^* + (1 - \beta) \left( \int_0^{L^*} f_A(x) dx \right) aB^*}{1 - (1 - \beta)^2 \left( \int_0^{L^*} f_A(x) dx \right) \left( \int_0^{L^*} f_A(x) dx \right) \frac{dV}{dP^*}}
\]

The change in welfare is given by

\[
\frac{dW}{d\delta} = \frac{dW}{dV} \frac{dV}{dP^*} \frac{dP^*}{d\delta}
\]

\[
= \left( \frac{\partial f}{\partial s} - c'(s) \right) \frac{ds}{dV} \frac{dV}{dP^*} \frac{dP^*}{d\delta} + 1 \right) \frac{dV}{dP^*} \frac{dP^*}{d\delta}
\]

\[
< 0
\]

which concludes the proof. \( \Box \)

**Proof of proposition 19**  A shock to foreign bank liabilities reduces welfare in the home country.

**Proof.** Add a shock term to the bank bond pricing equation,

\[
P_b^* L^* = pr (\bar{A} + V^* - \Delta \geq L^*) L +
\]

\[
pr (\bar{A} + V^* - \Delta \leq L^* + \Delta) \left( E [\bar{A} | \bar{A} + V^* - \Delta \leq L^* + \Delta] + V^* - \Delta \right)
\]
Then, we find that
\[
\frac{d}{d\Delta} P_B^* L^* = pr (\tilde{A} + V^* - \Delta \leq L^* + \Delta) \left( \frac{dV^*}{d\Delta} - 1 \right)
\]
\[
= pr (\tilde{A} + V^* - \Delta \leq L^* + \Delta) \left( \frac{dV^*}{dP_B L} \frac{dP_B L^*}{d\Delta} - 1 \right)
\]
\[
= pr (\tilde{A} + V^* - \Delta \leq L^* + \Delta) \left( 1 - \beta \left( \int_0^{L^*-V^*} f_A (x) \, dx \right) \frac{dP_B L^*}{d\Delta} - 1 \right)
\]
Re-arranging,
\[
\frac{d}{d\Delta} P_B^* L^* = - \frac{\left( \int_0^{L^*+\Delta-V^*} f_A (x) \, dx \right) \left( \int_0^{L^*-V^*} f_A (x) \, dx \right)}{1 - (1 - \beta) \left( \int_0^{L^*-V^*} f_A (x) \, dx \right) \left( \int_0^{L^*+\Delta-V^*} f_A (x) \, dx \right)}
\]
\[
< 0
\]

The shock to domestic welfare can be calculated similarly to before. First, note that everything works through the bank balance sheet, which deteriorates. This, in turn, leads to a one-for-one capital loss as well as a reduction in credit supply, with associated welfare costs:
\[
\frac{dW}{d\Delta} = \frac{dW}{dV} \frac{dV}{dP^*} \frac{dP^*}{d\Delta}
\]
\[
= \left( \frac{\partial f}{\partial s} \left|_{s > 0} \right. - c'(s) \frac{ds}{dV} \left|_{s > 0} \right. + 1 \right) \frac{dV}{dT} \frac{dT}{dP_B L^*} \frac{dP_B L^*}{d\Delta}
\]
\[
< 0
\]

**Proof of proposition 20**  
A tax-funded bailout in the foreign country increases welfare in the home country.

**Proof.** (Sketch) A tax-funded bailout is defined as a change in policy \((d\theta^*,dT^*)\) that leaves government bond prices unchanged and but results in a larger bailout. Such a policy increases bank solvency in the foreign country since \(\frac{d\theta^*}{dT} > 0\) and \(\frac{d\theta^*}{dT} > 0\) (lemma (16)). It also implies that foreign bank liabilities are worth more with a direct effect on domestic bank solvency. The mechanics are analogous to the proof of proposition (19).
Proof of proposition 21  A debt-funded bailout in the foreign country increases welfare in the home country if bank-to-bank linkages dominate, but decreases welfare if sovereign-to-bank linkages dominate.

Proof. From lemma 16, we know that a debt-funded bailout abroad decreases the sovereign bond price but increases foreign bank solvency. The impact on the home country’s bank balance sheet depends on whether the foreign exposures on the balance sheet gain or lose value. The change on the home bank’s balance sheet is given by

$$\frac{dV}{dT^*} = (1 - \alpha) \frac{d}{dT^*} (P^* B^*) + (1 - \beta) \frac{d}{dT^*} (P_B^* L^*)$$

$$= (1 - \alpha) \frac{d}{dT^*} (P^* B^*) + (1 - \beta) \frac{dV^*}{dT^*} (P_B^* L^*)$$

$$= (1 - \alpha) \frac{d}{dT^*} (P^* B^*) + (1 - \beta) \left( \int_{0}^{L-V^*} f_{\bar{A}}(x) \, dx \right) \frac{dV^*}{dT^*}$$

$$\times (1 + a B^* \frac{dP^*}{dT^*} + (1 - \beta) \frac{d}{dT} P_B L^*)$$

$$= (1 - \alpha) \frac{d}{dT^*} (P^* B^*) + (1 - \beta) \left( \int_{0}^{L-V^*} f_{\bar{A}}(x) \, dx \right)$$

$$\times (1 + a B^* \frac{dP^*}{dT^*} + (1 - \beta) \left( \int_{0}^{L-V} f_{\bar{A}}(x) \, dx \right) \frac{dV}{dT^*})$$

Re-arranging,

$$\frac{dV}{dT^*} = \frac{<0}{1 - (1 - \beta)^2 \left( \int_{0}^{L-V^*} f_{\bar{A}}(x) \, dx \right) \left( \int_{0}^{L-V} f_{\bar{A}}(x) \, dx \right)}$$

$$\left( (1 - \alpha) B^* \frac{dP^*}{dT^*} + (1 - \beta) \left( \int_{0}^{L-V^*} f_{\bar{A}}(x) \, dx \right) \left( 1 + a B^* \frac{dP^*}{dT^*} \right) \right)$$

$$\forall \alpha \neq 0$$

If sovereign-to-bank linkages are large (e.g. $\alpha = 0.5$, $\beta = 1$), then this expression is negative. Conversely, if bank-to-bank linkages dominate (e.g. $\alpha = 1$, $\beta = 0.5$), then this expression is positive. The welfare implications are monotone in $V$ as before.  \qed