How Do Banks Adjust to Stricter Supervision?

Maximilian Eber and Camelia Minoiu *

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Abstract

We exploit a discontinuity in the assignment of banks to the European Central Bank's new supervisory framework and a major stress test 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 7 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 mainly reduce their reliance on wholesale funding. Using data on the issuance of large corporate loans, we find that very weak banks also reduce the supply of credit. The evidence emphasizes banks' reluctance to adjust capital when target leverage changes and suggests that macroprudential considerations matter for stress-testing in practice.

JEL Classifications: C21, E51, G21, G28

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*Maximilian Eber is affiliated with Harvard University (maximilianeber@fas.harvard.edu). Camelia Minoiu is affiliated with the International Monetary Fund and The Wharton School Financial Institutions Center (cminoiu@wharton.upenn.edu). We thank Viral Acharya, Jose Berrospide, Sam Hanson, Xavier Jaravel, Deborah Lucas, Jean-Marie Meier, Matteo Maggiori, Steven Ongena, Helene Rey, David Scharfstein, Andrei Shleifer, Jeremy Stein, Sascha Steffen, as well as conference and seminar participants at the Boston Fed, ECB, HBS, IMF, LBS, and Norges Bank for helpful comments. The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management.

1 Introduction

> *Now what has been a restriction and we recognised that from the start, is that these [stress test] 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 2007-2008 financial crisis, the supervision and regulation of the financial sector have been tightened significantly. But how do financial intermediaries adjust their balance sheets when faced with greater regulatory scrutiny? Do they become safer by boosting their capital buffers? Do they cut back on lending, potentially harming the real economy? Or does financial regulation leave their behavior 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," a major stress test, provides us with both conditions. First, the new regime centralized supervision for a sizable part of the banking system at the European Central Bank (ECB) and was designed to be "intrusive, tough, and fair."[1] Second, only banks with assets above a sharp cutoff were affected by the new regime and subject to the stress test. 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 supervisory 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 reduction in leverage is mainly driven by asset shrinkage, suggesting that banks are averse to raising equity in the short run. In addition, we show the behavior of banks around the cutoff is similar to that of banks in the unrestricted sample, which includes observations far from the discontinuity. In the unrestricted sample, banks that were facing tighter supervision and were subject to the stress test also reduced leverage. For these banks, too, asset shrinkage drove the reduction in leverage. This result gives us confidence that we are documenting a behavior that applies more generally.

In addition, we document a decline in the supply of corporate loans that is limited to weak banks. Given that balance sheet changes represent stocks, which might vary due to sales of legacy portfolios, we cannot conclude from banks' asset shrinkage that there was a credit crunch. We address this concern with disaggregated data on the issuance of syndicated loans. Controlling for loan

[1] Daniele Nouy, Chair of the Supervisory Board of the SSM, in an interview with the Times of Malta (October 5, 2014).

demand, we find evidence for a reduction in loan supply only for banks with very low levels of capital.

Our results highlight 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—the pass-through of balance sheet contractions to securities is lower for countries with impaired sovereign debt.

Our findings inform the debate on macroprudential policies. 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." Two externalities are associated with asset shrinkage: fire sales and credit crunches. Poorly capitalized banks do not take these externalities into account when they choose between equity issuance and assets sales. Applying this logic to stress tests, regulators focus on the level of capital in the financial system as a whole in addition to individual banks' capital ratios when assessing the health of the banking sector (Greenlaw et al., 2012). While we do not conduct a thorough welfare analysis, our results highlight banks' reluctance to adjust equity in the short run. We speculate that the transition to a new supervisory framework in the Eurozone could have benefitted from additional measures to address banks' tendency to shrink assets and to enhance their incentives to raise equity.

Our paper fits into the broad literature on bank regulation and stress tests, which highlights the trade-offs between greater regulatory scrutiny and the potential detrimental effects on financial intermediation and the real economy. The stress test literature can be divided into three strands. First, there is a large body of theoretical work on optimal public disclosure of stress test results.[2] Second, there are event studies of asset prices around the announcement of stress test results.[3] Third, and most closely related to our analysis, recent studies examine the effects of stress tests on bank credit and the real economy (Calem et al., 2016; Gropp and Wix, 2016; Mésonnier and Monks, 2015). The central finding is that undercapitalized banks appear to restrict lending when stress-tested. We expand the literature in two ways. First, we take a more general view of balance sheets and examine the adjustment in major components of both assets and liabilities. Second, we propose an identification strategy that allows us to estimate the causal impact of stricter supervision on bank balance sheets.

The fact that banks deleverage in the face of 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,

[2]See Goldstein and Sapra (2014) for a survey.

[3]See, for example, Petrella and Resti (2013); Candelon and Sy (2015) and Sahin and de Haan (2015).

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 analysis. Moreover, their sample only covers local banks with assets below $500 million. By contrast, our sample covers a significant share of Eurozone bank assets and includes systemic banks. Given that business models and the regulatory environment vary with bank size, it is important to investigate the effects of tighter supervision for large banks as well.

The paper proceeds as follows. In section 2, we propose a simple theory of bank balance sheet adjustment in the presence of costly bank capital. Section 3 describes the institutional background around the ECB's Comprehensive Assessment and the new regulatory framework. In Section 4, we discuss our data. We present our identification strategy and the main estimates in Section 5. The special role of securities in balance sheet adjustment and the impact on lending are discussed in Section 6. Section 7 concludes.

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 reveals the conditions under which 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 held before the tests. Second, the Comprehensive Assessment also included an Asset Quality Review, an exercise in which banks were forced to mark down overvalued assets; this process further reduces the available capital in banks' books. Third, a major rationale for streamlining supervision at the ECB was the significant discretion of national regulators in enforcing existing rules. Such rules 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.[4] Both margins of adjustment involve costs: Selling illiquid assets may be associated with fire sales and, in addition, might

[4] For simplicity, we abstract from discussing adjustment on the riskiness of assets, but in the empirical analysis we check the impact on average risk weights.

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 the 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.

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 E relative to assets A than is nominally required ($\tilde{\kappa}$). We use γ as a measure of regulatory lenience such that the effective capital requirement is

$$\frac{E}{A} \geq \tilde{\kappa}\,(1-\gamma)$$

We interpret the transfer of supervision to the ECB as a reduction in leniency γ. 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 κ 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

$$WACC\left(\frac{E}{A}\right) = \frac{E}{A} r_e + \left(1 - \frac{E}{A}\right) r_d \tag{1}$$

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: tax-advantages of debt financing (Modigliani and Miller, 1958, 1963; Miller, 1977); managerial incentives of (short-term) debt (Diamond and Rajan, 2001); a money premium on (short-term, safe) debt (Gorton, 2010; Stein, 2012; Krishnamurthy and Vissing-Jorgensen, 2012); and the low-risk anomaly (Baker and Wurgler, 2015). We follow Kashyap et al. (2010) and introduce a catch-all term δ 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 $r_e - r_f = \beta_E\left(r_m - r_f\right)$. Note that the equity beta is given by $\beta_E = \frac{A}{E}\beta_A$ where β_A is the firm's asset beta. Substituting this into the WACC formula (1), the banks' cost of capital is given by

$$WACC\left(\frac{E}{A}\right) = \left(r_f + \beta_A r_m\right) + \frac{E}{A}\delta \equiv \bar{r} + \frac{E}{A}\delta \tag{2}$$

The term $\bar{r} = r_f + \beta_A r_m$ captures the cost of capital in a frictionless benchmark case. Equation (2) is a crucial ingredient for our model given that 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 banks and investors. Their model endogenously generates a downward sloping demand curve for banks' 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:

$$c_E\left(E_t, E_{t-1}\right) = \frac{1}{2}c_e \times \left(E_t - E_{t-1}\right)^2 \tag{3}$$

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

$$c_E\left(A_t, A_{t-1}\right) = \frac{1}{2}c_a \times \left(A_t - A_{t-1}\right)^2 \tag{4}$$

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 $f\left(A\right) + A\epsilon$ where $E\left[\epsilon\right] = 0$ and $Cov\left[\epsilon, r_m\right] = \beta_A Var\left[r_m\right]$. Hence, the expected return is $f\left(A\right)$ and its beta is β_A. We further assume a simple quadratic functional form for $f\left(.\right)$,

$$f\left(A\right) = \varphi_0 A - \frac{1}{2}\varphi A^2 \tag{5}$$

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

$$\pi\left(A_t, E_t; A_{t-1}, E_{t-1}\right) = f\left(A_t\right) - \left(1+\bar{r}\right)A_t - E_t\delta - c_E\left(E_t, E_{t-1}\right) - c_A\left(A_t, A_{t-1}\right) \tag{6}$$

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

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

which implies that

$$A_0 = \frac{1}{\varphi} (\varphi_0 - (1 + \bar{r} + \kappa_0 \delta)), \; E_0 = \kappa_0 A_0 \tag{7}$$

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 10-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 δ of 4.5%.

The timing is as follows: The initial capital requirement, κ_0, is in force before period 0. Between period 0 and period 1, the regulator unexpectedly announces a new effective capital requirement of κ, 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

$$f'(A_t^*) - (1 + \bar{r}) - c'_A(A_t^*, A_{t-1}) - \kappa \lambda_t + \beta \frac{dV(A_t^*, E_t^*)}{dA_t} = 0 \tag{8}$$

$$-\delta - c'_E(E_t^*, E_{t-1}) + \lambda_t + \beta \frac{dV(A_t^*, E_t^*)}{dE_t} = 0 \tag{9}$$

$$\lambda_t (E_t^* - \kappa A_t^*) = 0 \tag{10}$$

Shrinking assets is associated with suboptimal scale and adjustment costs. However, it allows the bank to avoid raising equity (equation 8). The optimal choice of equity weighs the cost of issuing additional equity against the need to hit the capital requirement (equation 9). By the envelope theorem, we find that

$$\frac{d}{dA_t} V(A_t, E_t) = c'_A(A_{t+1}^*, A_t), \; \frac{d}{dE_t} V(A_t, E_t) = c'_E(E_{t+1}^*, E_t) \tag{11}$$

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 λ_t will be binding as long as the gross return function is sufficiently concave, i.e. $\varphi \geq \varphi^* \Rightarrow \lambda_t > 0\ \forall t$ where φ^* 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 3, 4, 5, 8, 9, and 11 leads to the following result:

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

$$A_t = \tilde{A} + \left(A_1 - \tilde{A}\right) r^{t-1}$$

where $\tilde{A} = \frac{1}{\varphi}\left(\varphi_0 - (1 + \bar{r} + \kappa\delta)\right)$ 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. $\tilde{A} < A_0 \iff \delta > 0$.*

Proof. $A_0 - \tilde{A} = (\kappa - \kappa_0)\,\delta > 0 \iff \delta > 0$ using the fact that $\kappa > \kappa_0$. □

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

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

Applying a similar logic as before yields lemma 4:

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

$$A_1 = w_0 \left(\frac{\psi_0}{\psi} A_0 \right) + (1 - w_0)\, \tilde{A} \tag{12}$$

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

It might be natural to interpret expression 12 as a weighted average of initial assets A_0 and long-run assets $\tilde{A}$, 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 $\tilde{A}$. In fact, under many parameterizations, assets overshoot their long-run value (i.e. $A_1 < \tilde{A} < A_0$), 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*

$$\frac{c_a + \kappa_0 \kappa c_e}{c_a + \kappa^2 c_e} < \frac{\varphi_0 - (1 + \bar{r} + \kappa\delta)}{\varphi_0 - (1 + \bar{r} + \kappa_0\delta)} \tag{13}$$

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

Proof. Consider an increase from κ_0 to $\kappa > \kappa_0$. It follows that $\tilde{A} < A_0$ and $A_0 - A_1 > A_0 - \tilde{A} \iff A_1 - \tilde{A} > 0$. From 12, $A_1 - \tilde{A} \propto \frac{\psi_0}{\psi} A_0 - \tilde{A}$. Plugging in for ψ_0, ψ, A_0, and $\tilde{A}$ yields 13. □

The overshooting result might seem surprising. Yet the intuition can be straightforwardly conveyed in a stylized case without adjustment costs in assets $(c_a = 0)$ and no change in the long-run value of assets $(\delta = 0)$. Condition 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 yo 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 κ 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, 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 shrink to meet the increase in capital requirements.

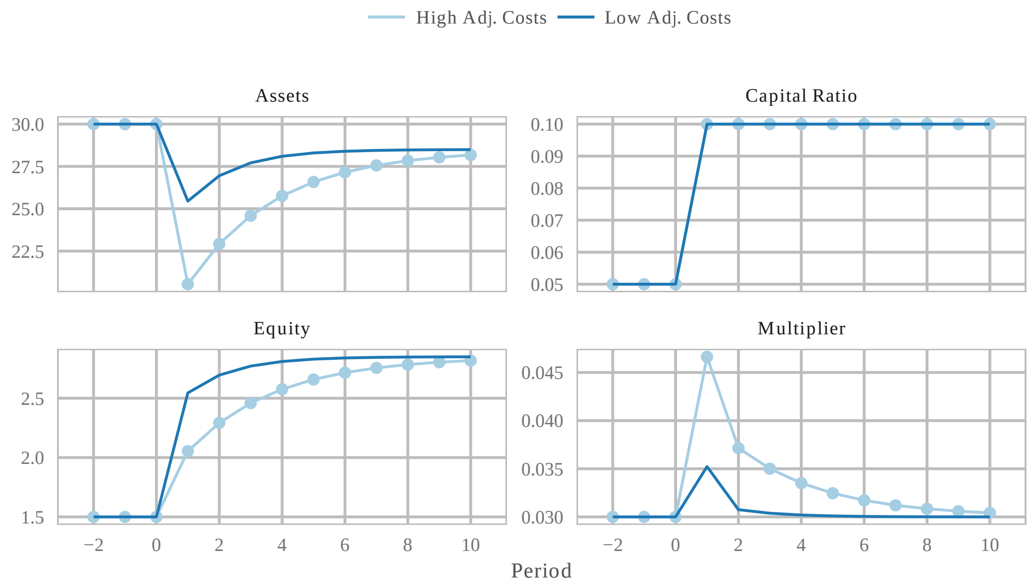


Figure 1: *Overshooting of Assets in the Short Run*

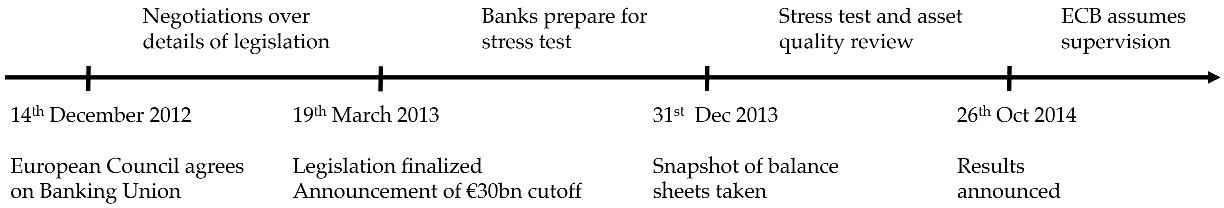
The model guides our subsequent empirical analysis. We ask the following questions. Did the tightening of the supervisory environment have any bite at all? Do banks perceive equity adjustments as costly and shrink their balance sheets to reduce leverage in the transition? Or do they simply meet target leverage by substituting debt with equity, leaving assets unaffected? Before taking these hypotheses to the data, we discuss the institutional background around the introduction of the Eurozone' SSM and the Comprehensive Assessment.

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 exploit in our empirical analysis.

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 (Van Rompuy et al., 2012). On December 14, 2012, the European Council agreed on a three-pronged approach. First, the largest Eurozone banks would be subject to the SSM, which implied a transfer of regu-

Figure 2: *Timeline of Events*



latory oversight from national regulators to the ECB. Second, the Council decided to establish the European Stability Mechanism as a joint source of financing for bank bailouts. Third, the Council passed new legislation on the resolution of failed banks with the aim to improve bankruptcy procedures in the case of significant cross-border banking activities (Véron, 2013; Véron et al., 2013).

A stepping stone on the way toward the SSM was the Comprehensive Assessment—a major stress test that evaluated the financial health of the Eurozone banking system. The Comprehensive Assessment was carried out before the ECB assumed its new supervisory role and comprised a review of asset quality (the so-called Asset Quality Review) and a stress test (the Comprehensive Assessment). The process covered bank assets worth €22tn, corresponding to around 80% of the Eurozone banking system.

Figure 2 presents a timeline of events. The SSM was agreed on in December 2012 and snapshots of bank balance sheets were taken by regulators at the end of December 2013. The criteria for eligibility to participate in the stress test, which emphasized bank size and degree of systemic importance, were announced on March 19, 2013. The stress test was carried out during 2014 and its results were announced in October 2014. Therefore, banks had about one year—from March until December 2013—to adjust their balance sheets in preparation for the assessment. It is this adjustment period that we evaluate, specifically by comparing banks' balance sheets at end-2013 with end-2012.

3.1 Assignment of Banks to the Stress Test

As mentioned, one of the criteria for banks to be part of the new supervisory regime and undertake the Comprehensive Assessment was a sharp asset cutoff. The cutoff allows us to establish a plausible counterfactual for how banks would have behaved had they not been subjected to stricter supervision.

The criteria for inclusion in the Comprehensive Assessment reflect a trade-off between coverage

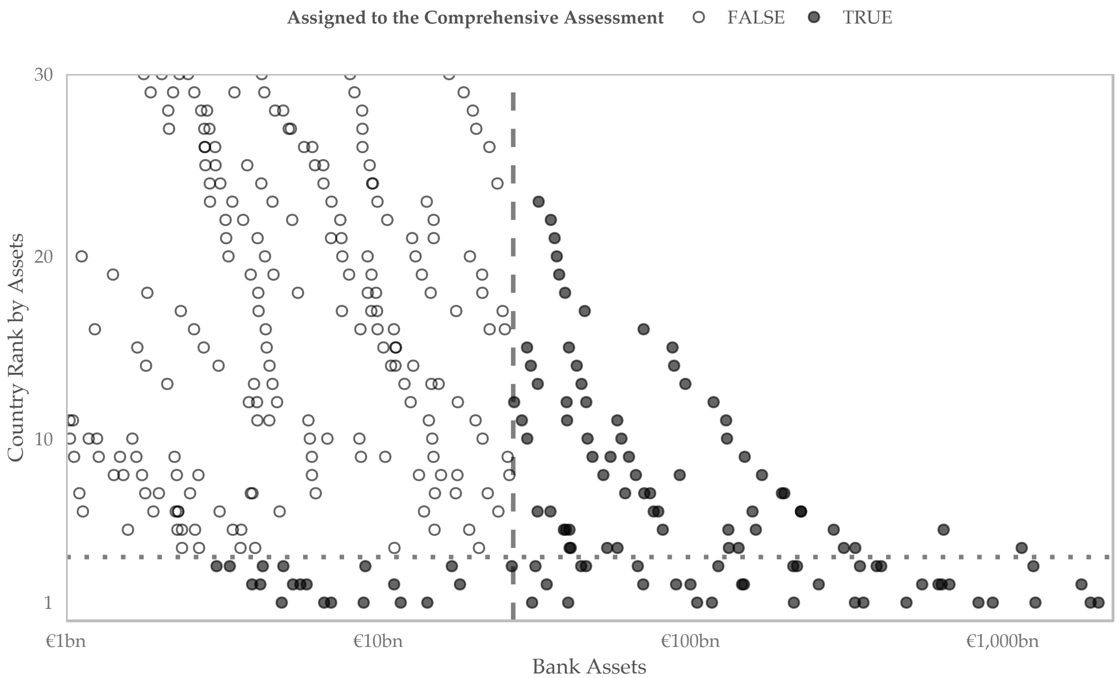


Figure 3: *Banks were assigned to the Comprehensive Assessment based on size and country rank*

and the cost of conducting the assessment (ECB, 2014). The following two criteria[5] were sufficient for inclusion and are relevant for our empirical strategy:

1. bank assets exceed €30bn (asset cutoff);[6]
2. the bank is among the three largest credit institutions of its home country (rank condition).

In Figure 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 dotted line corresponds to the rank condition. Banks below this line are assigned to the Comprehensive Assessment because they are among the three largest banks in their home country.

[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.

We construct our counterfactual by comparing banks to the left and to the right of the €30bn asset cutoff within the same country. To implement this comparison we need to restrict the sample to countries that had banks on both sides 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 the following countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain.

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 large universal bank and one from a regional lender. 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 econometric estimates.

UniCredit, Italy's biggest bank by assets, recorded a loss of €14bn in 2013. To put this number in perspective, UniCredit's annual revenues were €24bn and its assets amounted to €846bn in the same year.[7] The loss was mainly driven by 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.[8]

Regional banks also adjusted their balance sheets in 2013. 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 subject to the stress test. In 2013, the year before the stress test, the bank shrank its balance sheet by 8.4%, mainly by reducing its securities portfolio. Even more strikingly, the bank trimmed its risk-weighted assets to €10.9bn, down from €17.1bn a year before.[9] In its 2013 annual report, the bank's management emphasizes that it was well-prepared for the stress test by stating, "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." Put differently, the bank deemed itself well-prepared for the new regulatory regime because it had sold securities and thereby increased its capital ratios.

The anecdotal evidence thus 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 (accessed November 9, 2015).

[8]"UniCredit falls to record €14bn loss before stress tests", Financial Times, March 1, 2014 (accessed November 9, 2015).

[9]apoBank, Annual Financial Report 2013 (downloaded accessed November 9, 2015)

4 Data and Descriptive Statistics

We concentrate on banks' behavior in the year just before the Comprehensive Assessment by closely examining changes in bank balance sheets between end-2012 and end-2013. We also document that stress-tested banks are systematically different from non-tested banks; this observation motivates our empirical strategy in the following section.

4.1 Sample Construction

In this subsection, we discuss the sources and the construction of our data. We collect annual Eurozone bank balance sheets from SNL Financial 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 assemble a panel of bank balance sheets for the period 2012–2015.[10] We add 10-year government bond yields from the ECB's long-term interest rate statistics.[11] Given that 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 ECB (2014). We also add data on banks' capital ratios under the baseline and the adverse scenario. We lose one institution, LCH.Clearnet, which is not covered by SNL.

We carefully clean our sample as follows. We consolidate the balance sheets of Wüstenrot Bausparkasse (ID 4257337) and Wüstenrot Bank AG Pfandbriefbank (ID 4143295) as the company was assigned to the Comprehensive Assessment based on holding company assets (ECB, 2013), while SNL reports the two 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 covered by SNL. As a result, we filter out all institutions in the dataset that were not assigned to the Comprehensive Assessment even though their assets exceeded €30bn. Deleted entities include, for instance, Portigon AG, Heta Asset Resolution AG, and BancoPosta.

Then, from SNL's list of Eurozone financial institutions we assemble a clean sample of control observations in three steps. First, we remove all banks that are subsidiaries of stress-tested banks

[10] 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).

[11] Estonia does not have any comparable bonds outstanding, so we drop it when analyzing the relationship between balance sheet adjustments and yields.

as well as holding companies of stress-tested banks. For several banks, we carefully check their corporate structure to avoid such double-counting. Second, we apply an economic filter to the data since SNL reports data for banks as well as non-bank financial institutions. We re remove entities that are not classified as "bank" or "savings bank/thrift/mutual". We also remove very small banks with assets below €500m and banks whose fiscal year ends in months other than December. Third, we require institutions to have a loans-to-assets ratio 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.

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 the outlierse are reporting errors for smaller banks, for example due to changes in the level of consolidation of reported balance sheets. We define bank size as the natural logarithm of total assets, where assets are denominated in millions of Euros.

Our preferred measure of banks' leverage is the ratio of total assets to tangible common equity. We prefer this unweighted leverage ratio to regulatory capital for several reasons. To start with, there is little ambiguity in the accounting treatment of common equity, given that its main components are shareholders' equity, retained earnings, and paid-in capital.[12] By contrast, capital concepts such as Tier 1 capital and total regulatory capital (Tier 1 plus Tier 2) may include hybrid equity instruments such as preferred debt, as well as goodwill and deferred tax assets. Unlike shareholder equity, these components have limited loss-absorbing ability and their accounting treatment varies by country. We also prefer an unweighted leverage ratio because asset risk-weighs can be distorted by regulation can be manipulated (Mariathasan and Merrouche, 2014; Behn et al., 2014). For instance, asset risk weights are zero for sovereign debt, which turned risky for several European sovereigns in the period under consideration (Korte and Steffen, 2015). Total assets do not suffer from these shortcomings. It is also frequently argued that (unweighted) leverage provides a more useful basis for assessing bank solvency than do regulatory capital ratios (e.g., Acharya et al., 2014; Steffen, 2014). Therefore, we focus on this concept of leverage in our analysis.

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 compared to 2012, so we examine changes in several variables of interest over 2012-2013 and control for initial characteristics (at end-2012). Summary statistics are reported in Appendix Table 9. 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%.

[12]Instead of adding up these components, tangible common equity is obtained by subtracting intangible assets, goodwill, and preferred equity from total shareholder equity. The ratio of total assets to tangible common equity employed in this paper comes closest in spirit to Basel III's leverage ratio.(Kapan and Minoiu, 2015)

4.2 Descriptive Statistics

Here we present descriptive statistics for banks that were subject to the stress test and for banks that were not. In Table 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. These systematic differences in bank characteristics imply that we cannot naively compare stress-tested banks to non-tested banks since the two groups are significantly different on observable characteristics. Therefore, we cannot simply attribute differences in bank behavior to the change in the supervisory regime—we need an identification strategy.

In addition to observable differences between the two groups, we have to be wary of unobserved confounding factors that may 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 treated banks more than the control group due to their size and funding structure. For instance, Basel III introduces additional capital buffers for very large and systemically-important banks. In addition, it penalizes reliance on short-term wholesale funding by monitoring two new measures of liquidity: the Liquidity Coverage Ratio and the Net Stable Funding Ratio (NSFR). These measures disproportionately affect treated banks due to their funding models and may thus explain part of the reduction in banks' reliance on wholesale debt in our data.

In light of these issues we need an elaborate empirical strategy to isolate the effect of tighter supervision on bank balance sheets. We resort to a regression discontinuity design that exploits the sharp asset cutoff separating banks that were subject to tighter supervision from banks that were not. Under weak conditions, our estimates have a causal interpretation as the average treatment effect on a bank at the discontinuity.

(Share of Assets, in %)	Stressed	Not Stressed	Difference	t-statistic	p-value	
Deposits	49.98	67.25	−17.27	−9.61	0.00	***
Wholesale Funding	44.27	24.56	19.71	10.28	0.00	***
Tangible Common Equity	4.72	8.05	−3.34	−7.85	0.00	***
Loans	58.18	60.07	−1.89	−1.16	0.25	
Securities	24.45	24.03	0.42	0.32	0.75	

Table 1: *On average, stress-tested banks are more levered and rely more on wholesale funding*

5 Regression Discontinuity Design

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

5.1 Identification

To identify the effect of tighter supervision on bank behavior, we use regression discontinuity design (RDD), a standard method in the treatment effects literature[13] that has also become popular in financial economics.[14] The strategy allows us to overcome confounding selection effects by focusing on comparable banks around the assignment cutoff.

Intuitively, the treatment effect is estimated 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 are assumed to have behaved in similar ways. In our case, we allow for the fact that large banks might have adjusted to Basel III or any concurrent macroeconomic shocks 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.

In the RDD sample, 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

$$\tau \equiv \lim_{a \downarrow 0} E\left[y_i | A_i = a\right] - \lim_{a \uparrow 0} E\left[y_i | A_i = a\right] \tag{14}$$

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, τ_i varies across banks and the estimand τ in equation (14) can be interpreted as the average treatment effect (ATE) on the subpopulation of banks at the cutoff (Hahn et al., 2001).

[13] Lee and Lemieux (2010) provide survey of RDD applications in economics.
[14] For example, see Keys et al. (2008, 2012); Bubb and Kaufman (2014); Howell (2015).

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),

$$m(a) = E[Y_i | A_i = a]$$

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

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

The locally-linear regression estimate at point a to the left of the cutoff is defined by

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

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

$$\hat{\tau} = \hat{\alpha}_+(0) - \hat{\alpha}_-(0) \tag{15}$$

which is the empirical analogue to expression (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 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 Cutoff_i denotes the bank i's distance to the cutoff.

We add country fixed effects to this specification. Therefore, we estimate the ATE 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 in a given country.

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

$$y_i = \beta \times \text{Stressed}_i + (\gamma_1 \times \text{Cutoff}_i + \gamma_2 \times \text{Cutoff}_i \times \text{Stressed}_i) + \theta_{j(i)} + \epsilon_i, \quad |\text{Cutoff}_i| < h \tag{16}$$

	Dependent Variable: Annual Change in %						
	Leverage	Assets	Equity	Wholesale	Deposits	Loans	Securities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Stressed	-6.80^{*}	-4.30^{**}	2.50	-10.88^{***}	-0.31	-0.33	-12.44^{**}
	(3.97)	(1.95)	(3.45)	(4.06)	(2.57)	(1.88)	(6.28)
Cutoff	-0.40	-0.76^{*}	-0.37	0.27	-0.86^{*}	-0.63	-0.85
	(0.73)	(0.44)	(0.76)	(1.03)	(0.46)	(0.41)	(1.49)
Stressed x Cutoff	-2.31	-1.07	1.24	-1.13	0.02	-0.95	-2.58
	(2.35)	(1.14)	(1.96)	(2.39)	(1.52)	(1.25)	(3.34)
Country FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Bandwidth	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Observations	612	612	612	612	612	612	612
Adjusted R^2	0.35	0.17	0.34	0.18	0.30	0.19	0.23

Table 2: *Benchmark Regression Discontinuity Design*

where $\theta_{j(i)}$ denotes the country fixed effect. In table 2, we present benchmark estimates for a bandwidth of 3.0.[15] 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, with a reduction of 12.4%. On the liability side, the changes in scale are matched by a disproportionate reduction in wholesale financing (of -10.9%). We find small and noisy estimates for loans and deposits. For equity we find a sizeable yet imprecisely estimated positive effect of 2.5%.

5.2 Estimation on the Full Sample

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 have sophisticated risk-management in place, requiring a more muted adjustment. At the same time, large banks may be experiencing an even tougher regulatory environment under Basel III due to their systemic importance and market-dependent funding models. In addition, large banks' balance sheets may be particularly weak due to their relationships with distressed sovereigns, requiring a more dramatic adjustment. To gauge the external validity of our RDD results, we estimate the treatment effect using OLS on the full sample of Eurozone banks, while controlling for observable differences between treated and untreated banks.

[15]The automatic bandwidth selection algorithm of Imbens and Kalyanaraman (2011) selects bandwidths in a similar range (table 10), although for a triangular kernel. We provide estimates for a wide range of bandwidths in the Appendix.

In our baseline setup, we estimate the following specification in the full sample:

$$y_i = \beta_1 \times \text{Stressed}_i + x_i'\gamma + \theta_{j(i)} + \epsilon_i$$

where y_i is an outcome variable for bank i, representing the annual change in balance sheet characteristics of interest during 2012-2013, Stressed_i is an indicator for whether bank i was stress-tested, x_i is a vector of control variables, θ_j is a country fixed effect, and ϵ_i is an error term. The set of covariates comprises bank size, the wholesale funding ratio, the loan ratio, and the capital ratio (at end-2012). 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 included due to its importance in driving banks' lending behavior (e.g. Peek and Rosengren, 1997).

We continue to find a strong effect of tighter supervision on leverage (table 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 of significance. Looking at the components of leverage, we find that asset shrinkage accounts for most of the overall effect (-4.5%). Both coefficients are statistically significant at the 1% level of significance. The point estimates for equity and deposit growth are imprecisely estimated, as they were in the RDD exercise. However, we do find a large reduction in wholesale funding (-8.0%), which is significant too 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 RDD. Banks reacted to the prospect of tighter supervision by reducing leverage through asset sales. Asset sales primarily involved reducing securities holdings, and the proceeds were largely used to repay wholesale debt.

	Dependent Variable: Annual Change in %						
	Leverage	Assets	Equity	Wholesale	Deposits	Loans	Securities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Stressed	−6.74***	−4.53***	2.20	−8.04***	−1.83	−1.23	−10.31**
	(2.53)	(1.20)	(2.44)	(2.97)	(1.52)	(1.22)	(4.46)
Bank Size	0.24	−0.56***	−0.79**	−0.11	−0.65**	−0.55***	−1.74**
	(0.35)	(0.21)	(0.38)	(0.53)	(0.26)	(0.21)	(0.77)
Wholesale/Assets	−0.04	−0.11***	−0.07**	−0.12***	0.04	−0.11***	−0.09
	(0.03)	(0.02)	(0.03)	(0.05)	(0.03)	(0.02)	(0.07)
Equity/Assets	0.79***	−0.004	−0.80***	−0.15	0.13	−0.02	−0.59*
	(0.18)	(0.11)	(0.15)	(0.24)	(0.12)	(0.11)	(0.31)
Loans/Assets	0.04*	−0.01	−0.05**	0.05	−0.01	−0.05***	0.09*
	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.06)
Country FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	1,280	1,280	1,280	1,280	1,280	1,280	1,280
Adjusted R^2	0.38	0.26	0.41	0.15	0.34	0.28	0.28

Table 3: *Stress Tested Banks Reduced Leverage by Shrinking Assets*

5.3 Robustness and Falsification Tests

Here we assess the robustness of our regression discontinuity design and present falsification tests. We show that the estimates are not particularly sensitive to the chosen bandwidth and kernel, and that the identification strategy passes a range of validity and falsification tests. This gives us confidence that our estimates are not spurious and do indeed reflect banks' reaction to changes in the supervisory regime.

Bandwidth Choice

Choosing a bandwidth for locally-linear regressions involves a bias-variance tradeoff. A small bandwidth reduces the estimator's bias but also increases its variance due to a smaller effective sample size. Imbens and Kalyanaraman (2011) derive a data-driven procedure to choose a bandwidth given this tradeoff. The bandwidth that is optimal under an asymptotic mean squared error criterion at the cutoff.

In Table 10, we implement the Imbens-Kalyanaraman approach that is analogous to our benchmark specification (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 2. In anticipation of tighter supervision, 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 securities portfolios (−13.5%) than their loan books.

We also report estimates for our benchmark specification for a wide range of bandwidths in Table 11. As we graduallly 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 large reduction in leverage for those banks that were assigned to the Comprehensive Assessment. On average, the balance sheet adjustment favors sales of securities and repayment of wholesale debt rather than increases in equity.

Covariates are Balanced at the Discontinuity

The crucial assumption of the RDD is the continuity of the conditional expectation function through the cutoff. The assumption implies that in the absence of treatment there are no discontinuities at the cutoff value, neither for outcomes nor for other variables. This assumption 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

$$\begin{aligned} y_i^{(1)} &= \beta^{(1)} \times \text{Stressed}_i + \left(\gamma_1^{(1)} \times \text{Cutoff}_i + \gamma_2^{(1)} \times \text{Cutoff}_i \times \text{Stressed}_i\right) + \theta_{j(i)}^{(1)} + \epsilon_i^{(1)} \\ &\vdots \\ y_i^{(k)} &= \beta^{(k)} \times \text{Stressed}_i + \left(\gamma_1^{(k)} \times \text{Cutoff}_i + \gamma_2^{(k)} \times \text{Cutoff}_i \times \text{Stressed}_i\right) + \theta_{j(i)}^{(k)} + \epsilon_i^{(k)} \end{aligned} \tag{17}$$

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 $\boldsymbol{\beta} = (\beta^{(1)}, \ldots, \beta^{(k)})$ is zero using a χ^2 test statistic (Imbens and Lemieux, 2008). The approach takes into account that we are testing multiple hypotheses and that the error terms $\boldsymbol{\epsilon}_i = (\epsilon_1^{(1)}, \ldots, \epsilon_i^{(k)})$ 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 loans ratio, and the securities ratio.

Bandwidth	Obs	Treated Obs	χ^2	p-value
Inf	1223	80	24.14	0.00
3.50	884	73	16.02	0.01
3.00	612	67	6.25	0.28
2.50	397	62	3.27	0.66
2.00	248	54	1.13	0.95
1.50	143	41	7.32	0.20
1.00	74	34	5.03	0.41

Table 4: *Covariate Balance Around the Cutoff*

Table 4 shows that banks are indeed similar around the cutoff. While we find significant differences between stress-tested and non-tested banks when we estimate the system on the full sample ($h = \infty$), these differences vanish when 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 ($\boldsymbol{\beta} = \mathbf{0}$) exceeds 20% for all bandwidths below 3.00.

Placebo test within untreated banks

If our identification strategy is valid, then (a) we should not find any discontinuous effects at random points of the size distribution and (b) we should find a discontinuous effect 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 contamination, 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 2. The results are presented in Table 5. We estimate quantitatively small effects of our placebo stress test. Estimates are statistically indistinguishable from zero for all outcome variables.

	Dependent Variable: Annual Change in %						
	Leverage	Assets	Equity	Wholesale	Deposits	Loans	Securities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Stressed	1.19	−0.17	−1.36	1.57	−1.04	−1.02	−0.43
	(1.00)	(0.70)	(1.09)	(1.78)	(0.88)	(0.74)	(2.24)
Cutoff	−0.68	−0.37	0.32	−1.53	0.92	0.31	−0.42
	(1.24)	(0.90)	(1.37)	(2.29)	(1.21)	(0.98)	(2.86)
Stressed x Cutoff	−0.22	−0.08	0.13	0.36	−0.98	−0.56	0.24
	(1.46)	(1.04)	(1.61)	(2.67)	(1.38)	(1.11)	(3.27)
Country FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Bandwidth	2	2	2	2	2	2	2
Observations	1,088	1,088	1,088	1,088	1,088	1,088	1,088
Adjusted R^2	0.37	0.21	0.44	0.14	0.36	0.25	0.31

Table 5: *Placebo Test with Untreated Banks*

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

We documented that banks shrank their balance sheets in anticipation of the stress tests. Here we look for heterogeneity in this adjustment within the sample of stress-tested banks. In particular, we expect relatively stronger banks to react less to the prospect of tighter supervision than weaker banks. Since only a handful of banks actually failed the stress test, we calculate a continuous "buffer" measure for all banks.

Banks could fail the stress test in two ways: by having a common equity Tier 1 (CET1) ratio below 8% in the baseline scenario or by having a CET1 ratio below 5.5% in the adverse scenario. (Note that common equity Tier 1 capital, a measure of regulatory capital adopted under Basel

III, captures capital with high loss-absorption ability much like tangible common equity). We calculate bank i's buffer as

$$\text{buffer}_i = min\left\{\text{CET1 Ratio}_i^{baseline} - 8\%, \text{CET1 Ratio}_i^{adverse} - 5.5\%\right\}$$

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 (in assets, loans, securities) on banks' buffer and the control variables from our benchmark specification. The specification is given by

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

As shown in Table 6, banks with a smaller buffer reduced assets, loans, and securities more than did firms with higher buffers. A one percentage point decrease in banks' 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 of significance. These results hold even though we are controlling for initial capitalization, which stacks the cards against us finding an effect of the ex-post buffer measure.

	Dependent Variable: Annual Change in %		
	Assets	Securities	Loans
	(1)	(2)	(3)
Buffer (%)	0.60***	2.55***	0.84***
	(0.21)	(0.90)	(0.23)
Bank Size	−1.77**	−6.13***	−1.46**
	(0.70)	(1.87)	(0.60)
Wholesale/Assets	−0.02	0.02	0.03
	(0.05)	(0.20)	(0.07)
Equity/Assets	−0.94**	−2.68***	−1.01**
	(0.40)	(1.04)	(0.40)
Loans/Assets	0.10	0.45**	0.02
	(0.08)	(0.21)	(0.08)
Country FE	*No*	*No*	*No*
Constant	*Yes*	*Yes*	*Yes*
Observations	97	97	97
Adjusted R^2	0.14	0.20	0.13

Table 6: *Ex-Post Buffer Predicts Ex-Ante Asset Shrinkage*

6 Extensions

In this section we present two main extensions: (a) we look into banks' adjustment of securities portfolios to detect whether there is a link between sovereign distress and sales of government securities; and (b) we analyze data on corporate loans to establish whether banks cut lending in the face of tighter supervision.

6.1 Pass-Through and the Role of Securities

Our main estimates showed that banks disproportionately adjusted the securities portfolios. Here we look more closely into this pattern. In particular, we exploit heterogeneity in sovereign health across Eurozone countries during the period of analysis to link sovereign distress with securities

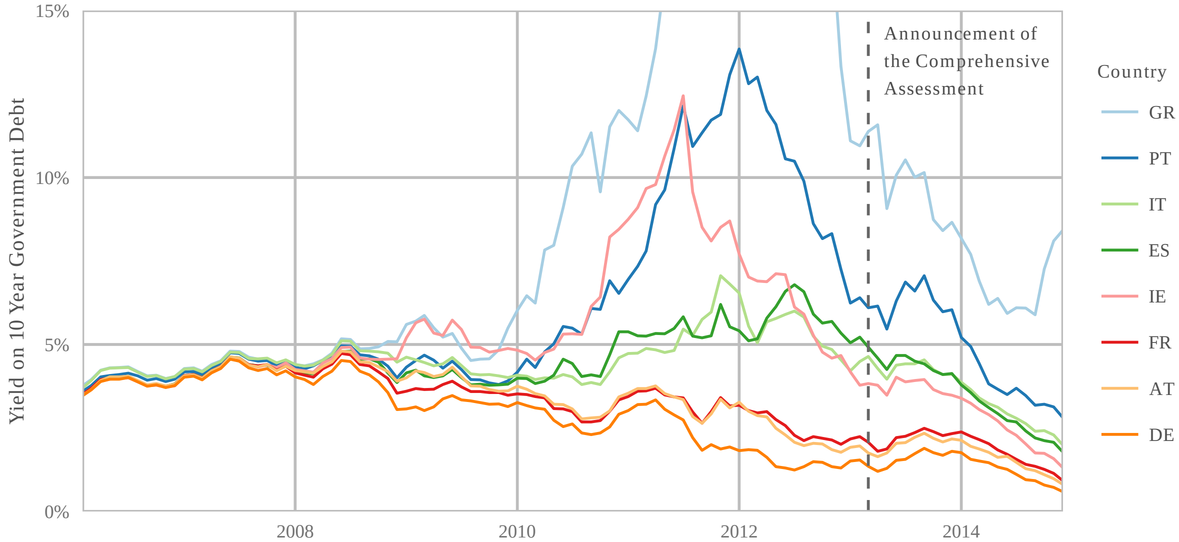


Figure 4: *Periphery Sovereign Debt was in Distress During the Adjustment Period*

sales by banks facing tighter supervision. We show 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 the Eurozone was the concurrent weakness of sovereigns in the periphery (Greece, Ireland, Italy, Portugal, and Spain). Figure 4 shows yields on 10-year government bonds for selected Eurozone countries. When the Comprehensive Assessment was announced at the end of 2012, spreads were high and periphery sovereign debt was trading at substantial discounts compared to pre-crisis (2010) levels.

During the period of analysis, Eurozone banks held about 6-7 percent of assets (and a large share of securities portfolios) in sovereign debt (Gennaioli et al., 2014). 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, for at least two reasons. 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

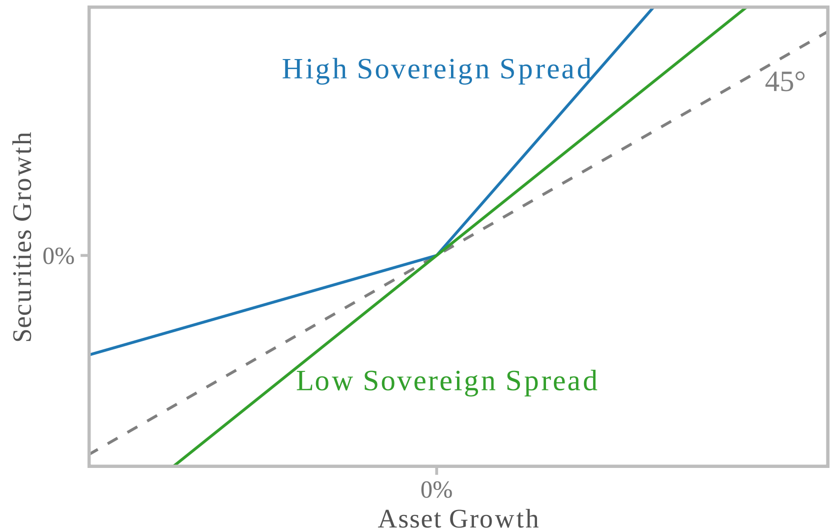


Figure 5: *Pass-Through Function from Assets to Securities: High vs. Low Yields*

average of loan growth ($\Delta L/L$), securities growth ($\Delta S/S$), and the growth rate of other assets ($\Delta O/O$):

$$\frac{\Delta A}{A} = \frac{L}{A}\frac{\Delta L}{L} + \frac{S}{A}\frac{\Delta S}{L} + \frac{O}{A}\frac{\Delta O}{O} \approx w_l \frac{\Delta L}{L} + w_s \frac{\Delta S}{S} \tag{18}$$

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 with the following linear model:

$$\frac{\Delta S_i}{S_i} = \gamma_0 + \gamma \times \frac{\Delta A_i}{A_i} + \epsilon_i \tag{19}$$

If pass-through were completely neutral, 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 $\tilde{z}$. We therefore estimate the model

$$\frac{\Delta S_i}{S_i} = \begin{cases} \beta_1 \times \Delta A_i / A_i + \epsilon_i & \text{if } \Delta A_i \geq 0 \cap z_{j(i)} \geq \tilde{z} \rightarrow \text{Expansion, High Yield} \\ \beta_2 \times \Delta A_i / A_i + \epsilon_i & \text{if } \Delta A_i < 0 \cap z_{j(i)} \geq \tilde{z} \rightarrow \text{Contraction, High Yield} \\ \beta_3 \times \Delta A_i / A_i + \epsilon_i & \text{if } \Delta A_i \geq 0 \cap z_{j(i)} < \tilde{z} \rightarrow \text{Expansion, Low Yield} \\ \beta_4 \times \Delta A_i / A_i + \epsilon_i & \text{if } \Delta A_i < 0 \cap z_{j(i)} < \tilde{z} \rightarrow \text{Contraction, Low Yield} \end{cases} \quad (20)$$

Figure 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 19 and 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. $\gamma > 1$.
- **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 7 presents the results of this exercise. First, we find a high pass-through of asset adjustments to securities, consistent with 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, consistent with Hypothesis 2. When banks operate in a high-yield environment, 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 β_3 and β_4 are equal. Overall, the results are consistent with the notion that impaired sovereign debt is both an attractive asset to buy and an unattractive asset to sell. For completeness, we report specifications that include a constant in columns (2) and (4), which does not affect our conclusions.

6.2 Adjustment in Corporate Lending

Our last exercise examines whether the Comprehensive Assessment was associated with a reduction in the supply of bank credit. We focus on new corporate loans extended around the March 2013 stress test announcement date and present evidence consistent with a reduction in credit

	Securities Growth in %			
	(1)	(2)	(3)	(4)
γ: $\frac{\Delta A_i}{A_i}$	1.77***	1.65***		
	(0.14)	(0.14)		
β_1: $\frac{\Delta A_i}{A_i} \times (\Delta A_i \geq 0 \cap z_{j(i)} \geq \tilde{z})$			2.47***	2.32***
			(0.23)	(0.25)
β_2: $\frac{\Delta A_i}{A_i} \times (\Delta A_i < 0 \cap z_{j(i)} \geq \tilde{z})$			0.63***	0.86***
			(0.21)	(0.23)
β_3: $\frac{\Delta A_i}{A_i} \times (\Delta A_i \geq 0 \cap z_{j(i)} < \tilde{z})$			1.27***	1.02***
			(0.24)	(0.31)
β_4: $\frac{\Delta A_i}{A_i} \times (\Delta A_i < 0 \cap z_{j(i)} < \tilde{z})$			1.15***	1.50***
			(0.24)	(0.28)
$pr(\beta_1 = \beta_2)$	–	–	0.00	0.04
$pr(\beta_3 = \beta_4)$	–	–	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

Table 7: *Asymmetric Pass-Through from Assets to Securities*

supply only for very poorly-capitalized banks. While we cannot rule out a credit crunch in other segments of the market, our results suggest that the effects of banks' balance sheet adjustment on the real economy might have been limited.

We assemble a loan-level dataset on syndicated corporate loans from Thomson Reuters Loan Pricing Corporation's DealScan. Syndicates are groups of banks extending loans under a single loan agreement to individual firms. The average syndicated loan is very large with an average size of $500 million and syndicated loans represent a significant share of originating banks' loan portfolios. They account for a quarter of total C&I loans on the balance sheets of U.S. banks supervised by federal regulators, and for more than one third of C&I loans on the balance sheets of foreign banks in the U.S. (Ivashina and Scharfstein, 2010). Syndicated loans represent more than one third of cross-border loan claims of global banks (Cerutti et al., 2015) and many of the Eurozone banks in our sample are large participants in this market.[16]

We employ a difference-in-differences strategy that allows us to compare the lending behavior of

[16]Moreover, syndicated loan volume exhibits strong co-movement with total loan flows (Gadanecz, 2004).

large Eurozone domestic banks with large foreign banks in the Eurozone's syndicated loan market. (That is, our sample comprises only loans extended to non-financial firms in the Eurozone.) We use large foreign banks as a control group because we do not have enough control observations headquartered within the Eurozone.[17] Therefore, the identification 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. To separate loans supply from loan demand effects, we add firm fixed effects which absorb firm-level demand shocks that are common across the firms' creditors. This implies that we compare credit growth by a Eurozone and non-Eurozone bank *to the same Eurozone firm* around the stress test.

We construct our samples of stress-tested and non-tested banks starting from the list of 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 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 of analysis.

We compare loan growth by treated and control banks to the same firm broadly following the empirical approach of Khwaja and Mian (2008). Specifically, 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.[18] We estimate the following specification:

$$\Delta y_{ij} = \beta_j + \beta_1 \text{Stressed}_i + \beta_2 \text{Stressed}_i \times \text{Capital}_i + \gamma' z_i + \epsilon_{ij} \tag{21}$$

where Δy_{ij} is the log-change in syndicated bank credit extended by bank i to borrower j and Stressed_i is an indicator for Eurozone banks that were subject to the stress test. We control for credit demand using firm fixed effects (β_j), which allow us to exploit multiple bank relationships of individual firms and isolate loan supply. The regressions are estimated using OLS and the standard errors are clustered on bank.

We also consider variants of equation (21) in which we control for bank characteristics (z_i) such as bank size, the equity ratio, the wholesale ratio, and the loan ratio (i.e., the same controls measured

[17]The syndicated loan market is dominated by large banks. The banks within the Eurozone but outside the supervisory scope of the SSM tend to be small and are not active in syndicated loans.
[18]All loans signed in March 2013 are dropped from the analysis.

at end-2012 as in Table 3). Moreover, we test for heterogeneity in banks' responses based on their balance sheet health by adding an interaction term of the stress-test indicator with the initial capital ratio.

The results are reported in Table 8. There are three variants of each specification: First, we include only the treatment indicator (Stressed_i), 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_i becomes statistically significant only if we condition on banks' level of high-quality capital as measured by tangible common equity. As seen in columns 3, 6, and 9, only stress-tested banks with very weak capital positions (i.e., 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 poorly-capitalized banks. We cannot detect a widespread reduction in the supply of 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)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Window (around March 2013)	6m	6m	6m	9m	9m	9m	12m	12m	12m
Stressed	0.047	-0.052	-0.327**	0.050	-0.006	-0.210**	0.014	0.014	-0.172**
	(0.049)	(0.063)	(0.126)	(0.045)	(0.047)	(0.095)	(0.030)	(0.035)	(0.071)
Stressed x Capital			0.093**			0.067*			0.061***
			(0.046)			(0.034)			(0.022)
Capital		0.009	0.001		0.009	0.003		0.003	-0.002
		(0.015)	(0.017)		(0.008)	(0.008)		(0.006)	(0.006)
Wholesale/Assets		0.003	0.000		0.004	0.002		0.001	-0.000
		(0.003)	(0.004)		(0.002)	(0.002)		(0.002)	(0.001)
Loans/Assets		0.001	-0.002		0.004	0.002		0.002	0.000
		(0.003)	(0.003)		(0.003)	(0.002)		(0.002)	(0.001)
Observations	1,664	846	846	3,765	2,045	2,045	6,399	3,535	3,535
R-squared	0.853	0.850	0.851	0.762	0.765	0.766	0.710	0.705	0.706
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. banks	84	61	61	98	72	72	111	81	81
No. stress-tested banks	30	28	28	38	34	34	47	41	41

Table 8: *Loan-Level Results*

7 Conclusions

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 European Central Bank through its Single Supervisory Mechanism, which was accompanied by the Comprehensive Assessment, a major stress test. 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 reduced their leverage in anticipation of stricted supervision and the stress test. This decline in leverage was mainly achieved through a reduction in assets rather than an increase in equity. On the asset side, banks reduced securities the most. On the liability side, they 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 market 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 such effects, we also examined developments in the market for syndicated 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 did so for very poorly-capitalized banks.

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 sovereign 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 macroprudential 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 detrimental consequences 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.

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A Proofs

A.1 Proof of Lemma 1

In period 1, we have

$$\begin{aligned}
\lambda_1 &= \delta + c_e\left(E_1 - E_0\right) - \beta c_e\left(E_2 - E_1\right) \\
&= \delta + c_e\kappa\left(A_1 - \frac{\kappa_0}{\kappa}A_0\right) - \beta c_e\kappa\left(A_2 - A_1\right) \\
& \delta + \left[\left(1+\beta\left(1-r\right)\right)\left(c_e\kappa w_0\frac{\psi_0}{\psi}\right) - c_e\kappa_0\right]A_0 + \left[\left(1+\beta\left(1-r\right)\right)c_e\kappa\left(1-w_0\right) - \beta c_e\kappa\left(1-r\right)\right]\tilde{A}
\end{aligned}$$

This is greater than zero as long as

$$\begin{aligned}
\varphi &\geq \varphi_1^* \\
&\equiv \frac{\kappa c_e}{\delta}\left(\left[\frac{\kappa_0}{\kappa} - w_0\left(1+\beta\left(1-r\right)\right)\frac{\psi_0}{\psi}\right]\left(\varphi_0 - \left(1+\bar{r}+\kappa_0\delta\right)\right)\right. \\
&\quad \left. - \left[1 - w_0\left(1+\beta\left(1-r\right)\right)\right]\left(\varphi_0 - \left(1+\bar{r}+\kappa\delta\right)\right)\right)
\end{aligned}$$

In period $t \geq 2$, we have

$$\begin{aligned}
\lambda_t &= \delta + c_e\left(E_t - E_{t-1}\right) - \beta c_e\left(E_{t+1} - E_t\right) \\
&= \delta + \left(c_e\kappa\right)\left(\left(A_t - A_{t-1}\right) - \beta\left(A_{t+1} - A_t\right)\right) \\
&= \delta + r^{t-1}\left(1-\beta r\right)\left(1-r\right)\left(c_e\kappa\right)\left(\tilde{A} - A_1\right) \\
&= \delta + r^{t-1}\left(1-\beta r\right)\left(1-r\right)\left(c_e\kappa\right)w_0\left(\tilde{A} - \frac{\psi_0}{\psi}A_0\right)
\end{aligned}$$

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

$$\begin{aligned}
\lambda_t &= \delta - r^{t-1}\left(1-\beta r\right)\left(1-r\right)w_0 c_e\kappa\left(\frac{\psi_0}{\psi}A_0 - \tilde{A}\right) \\
&\geq \delta - r\left(1-\beta r\right)\left(1-r\right)w_0 c_e\kappa\left(\frac{\psi_0}{\psi}A_0 - \tilde{A}\right)
\end{aligned}$$

which exceeds zero as long as

$$\varphi \geq \varphi_2^* \equiv \left(\frac{\kappa c_e}{\delta}\right)\left(1-\beta r\right)r\left(1-r\right)w_0\left(\frac{\psi_0}{\psi}\left(\varphi_0 - \left(1+\bar{r}+\kappa_0\delta\right)\right) - \left(\varphi_0 - \left(1+\bar{r}+\kappa\delta\right)\right)\right)$$

Define $\varphi^* = max\left\{\varphi_1^*, \varphi_2^*\right\}$. Then, $\varphi \geq \varphi^*$ is sufficient for non-negative Lagrange multipliers.

A.2 Proof of Lemma 2

Combining equations (3), (4), (8), (9), and (11) yields a second-order difference equation in A_t ,

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

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

$$\beta\psi \left(A_{t+1} - \tilde{A}\right) - (1 + \psi + \beta\psi) \left(A_t - \tilde{A}\right) + \psi \left(A_{t-1} - \tilde{A}\right) = 0$$

After discarding the explosive root, we find that

$$\left(A_t - \tilde{A}\right) = \left(A_1 - \tilde{A}\right) r^{t-1} \text{ for } t \geq 1,\ 0 \leq r < 1$$

where

$$r = \frac{1}{2\beta\psi} \left((1 + \psi + \beta\psi) - \sqrt{(1 + \psi + \beta\psi)^2 - 4\beta\psi^2} \right)$$

A.3 Proof of Proposition 4

Using the envelope theorem again, the first-order conditions are

$$\begin{aligned} f'(A_1) - (1 + \bar{r}) - c'_A (A_1 - A_0) - \kappa\lambda_t + \beta c'_A (A_2^* - A_1) &= 0 \\ -\delta - c'_E (E_1 - E_0) + \lambda_t + \beta c'_E (E_2^* - E_1) &= 0 \\ \lambda_t (E_t - \kappa A_t) &= 0 \end{aligned}$$

Plugging in functional form assumptions and the assumption that the multipliers bind,

$$\begin{aligned} (\varphi_0 - \varphi A_1) - (1 + \bar{r}) A_1 - c_a (A_1 - A_0) - \kappa\lambda_1 + \beta c_a (A_2 - A_1) &= 0 \\ -\delta - c_e (\kappa A_1 - \kappa_0 A_0) + \lambda_1 + \beta\kappa c_e (A_2 - A_1) &= 0 \end{aligned}$$

Solve for A_1,

$$(1 + \psi + \beta\psi) A_1 = \tilde{A} + \left(\frac{c_a + \kappa_0 \kappa c_e}{\varphi} \right) A_0 + \beta\psi A_2$$

Define $\psi_0 = \frac{1}{\varphi}\left(c_a + \kappa_0 \kappa c_e\right)$. Plug in $A_2 = \tilde{A} + \left(A_1 - \tilde{A}\right) r$. Then,

$$\begin{aligned}
\left(1+\psi+\beta\psi\right) A_1 &= \tilde{A} + \left(\frac{c_a + \kappa_0 \kappa c_e}{\varphi}\right) A_0 + \beta\psi\left(\tilde{A} + \left(A_1 - \tilde{A}\right) r\right) \\
\left(1+\psi+\left(1-r\right)\beta\psi\right) A_1 &= \psi\left(\frac{\psi_0}{\psi} A_0\right) + \left(1+\left(1-r\right)\beta\psi\right)\tilde{A} \\
\iff A_1 &= w_0\left(\frac{\psi_0}{\psi} A_0\right) + \left(1-w_0\right)\tilde{A}
\end{aligned}$$

where $w_0 = \frac{\psi}{1+\psi+(1-r)\beta\psi}$.

B Additional Tables

Statistic	N	Mean	St. Dev.	Pctl(25)	Median	Pctl(75)
Leverage Growth	1,280	−5.95	11.32	−9.74	−4.79	−0.82
Assets Growth	1,280	1.98	7.41	−1.28	1.47	4.18
Equity Growth	1,280	7.93	11.42	2.77	6.04	10.17
Wholesale Funding Growth	1,280	−5.30	16.92	−15.04	−5.72	2.02
Deposits Growth	1,280	4.85	8.72	0.86	3.21	6.54
Loan Growth	1,280	2.16	7.80	−2.02	2.01	5.41
Securities Growth	1,280	6.84	25.59	−7.71	1.94	14.15
Deposit Ratio	1,280	65.94	15.87	56.71	70.88	77.55
Wholesale Funding Ratio	1,280	26.06	15.98	14.17	21.29	35.57
Equity Ratio	1,280	7.80	3.27	6.25	7.55	9.06
Loan Ratio	1,280	59.93	14.14	51.59	61.79	69.31
Securities Ratio	1,280	24.06	12.33	15.88	23.12	30.84
Bank Size (Log Assets)	1,280	7.64	1.39	6.67	7.26	8.10

Table 9: *Summary Statistics*

(% Change)	LATE	SE	BW	N	Half-BW	Double-BW	p	
Leverage	−7.36	3.36	4.11	1220	−7.62	−7.48	0.03	**
Assets	−5.03	1.70	4.16	1220	−3.53	−5.38	0.00	***
Equity	3.33	3.23	3.01	615	−1.57	2.18	0.30	
Wholesale	−12.99	3.82	2.83	542	−12.64	−12.62	0.00	***
Deposits	0.66	2.40	3.27	770	2.48	−0.60	0.78	
Loans	−0.32	1.74	3.36	808	2.13	−0.13	0.85	
Securities	−14.24	5.16	6.02	1223	−13.49	−14.20	0.01	***

Table 10: *Automatic Bandwidth Selection with a Triangular Kernel (Imbens and Kalyanaraman, 2011)*

Bandwidth	Annual Change in %	Leverage	Assets	Equity	Wholesale	Deposits	Loans	Securities
Inf	Estimate	-9.32	-5.47	3.85	-12.44	-0.77	0.14	-13.39
Inf	Standard Error	3.31	1.59	2.89	3.15	2.14	1.50	5.03
Inf	p-value	0.00	0.00	0.18	0.00	0.72	0.92	0.01
Inf	N	1223	1223	1223	1223	1223	1223	1223
-								
3	Estimate	-6.80	-4.30	2.50	-10.88	-0.31	-0.33	-12.44
3	Standard Error	3.74	1.82	3.26	3.73	2.41	1.73	5.91
3	p-value	0.07	0.02	0.44	0.00	0.90	0.85	0.04
3	N	612	612	612	612	612	612	612
-								
2.5	Estimate	-7.73	-3.59	4.14	-10.30	1.78	0.99	-13.52
2.5	Standard Error	4.04	2.00	3.63	3.98	2.52	1.84	6.50
2.5	p-value	0.06	0.07	0.26	0.01	0.48	0.59	0.04
2.5	N	397	397	397	397	397	397	397
-								
2	Estimate	-10.70	-3.59	7.10	-12.15	2.08	0.41	-12.06
2	Standard Error	4.22	2.35	3.86	4.29	2.98	2.20	7.26
2	p-value	0.01	0.13	0.07	0.00	0.48	0.85	0.10
2	N	248	248	248	248	248	248	248
-								
1.5	Estimate	-8.50	-3.47	5.04	-16.91	2.19	1.61	-7.76
1.5	Standard Error	4.70	2.80	4.28	5.30	3.28	2.72	8.78
1.5	p-value	0.07	0.22	0.24	0.00	0.51	0.56	0.38
1.5	N	148	148	148	148	148	148	148
-								
1	Estimate	-3.06	-0.74	2.32	-13.88	5.08	1.76	5.83
1	Standard Error	8.00	4.10	6.94	8.52	4.69	4.23	14.44
1	p-value	0.70	0.86	0.74	0.11	0.28	0.68	0.69
1	N	82	82	82	82	82	82	82

Table 11: *RDD Sensitivity to Bandwidth Choice*