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REGULATION, CDO EXPOSURES, AND DEBT GUARANTEES THROUGH THE FINANCIAL CRISIS

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ABSTRACT

Collateralized debt obligations with asset backed securities as collateral (ABS CDOs) often get overshadowed in debates over causes of large commercial bank holding company (BHC) distress during the 2007–2009 crisis. For BHCs, the Recourse Rule made holding the highest rated ABS CDO tranches more favorable by lowering required capital. The cost of repairing solvency to large BHCs that commented on preliminary Recourse Rule proposals reached a peak of $66 billion by Q1 2009, reflecting the costs of restoring solvency. From Q1 2008 to Q1 2009, among trading assets, only CDO holdings have a large positive association with higher estimated debt guarantees for BHCs.

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DISCLAIMER

Regulation, CDO Exposures, and Debt Guarantees through the Financial Crisis

1. Introduction

Studies have documented the extremely poor performance of collateralized debt obligations backed by asset-backed securities (ABS CDOs) during the 2007–2009 crisis (see Barnett-Hart 2009; Hull and White 2010; Cordell et al. 2012; Wojtowicz 2014; and Cordell et al. 2019). Yet, these instruments often get overshadowed in postcrisis policy debates (see Lo 2012). Changes to risk-based capital requirements, including the 2001 Recourse Rule, which favored holding parts of deals with the highest rating, also get overshadowed in debates about what went wrong. In what follows, I briefly review how ABS CDOs fit within the financial system, then show how the supply of ABS CDOs grew after the Recourse Rule and subsequent regulatory capital rule changes were finalized. I then show how large bank holding companies (BHCs) with subsidiaries that submitted comment letters during the Recourse Rule rulemaking process on average had higher estimated end-of-quarter debt guarantees once the crisis unfolded. The estimated debt guarantees reflect *ex ante* costs of returning a BHC to solvency (see Snethlage (2015), Grimaldi et al. (2016) and Miller (2024)), which may differ from *ex post* costs arising from failures or government assistance to distressed BHCs. Milne (2014) interprets the estimated debt guarantees as subsidies to shareholders and consistent with his findings the estimated debt guarantees are generally close to zero but spike when BHCs experience distress during the crisis. Lastly, given that BHCs reported holdings of CDOs as trading assets (assets used in trades to generate revenues for banks) only from Q1 2008 through Q1 2009 and that the estimated debt guarantees were only substantial in 2008 and 2009, I show that CDO holdings, more than other trading asset categories, had the largest association with estimated debt guarantees. These results point to regulatory capital requirements as a driver of the demand for securities that contributed to large BHC distress.

To understand factors driving the demand for CDO tranches (the French word for "slices") by BHCs, Erel et al. (2014) suggest that a "securitization byproduct" effect exists, whereby securitizing banks active in issuing deals also had reasons to hold parts of their own and other banks' deals. For instance, holding parts of a bank's own deal could signal confidence to potential investors, and familiarity with structuring such deals might also make parts of other banks' deals attractive. As a result, new issuance also created BHC demand, exposing BHCs to their own deal risks and to risks of similar deals issued by other banks. Moreover, the 2001 Recourse Rule for BHCs, among other things, lowered capital requirements for commercial bank holdings of highly rated, private-label tranches (see Acharya and Richardson 2009; Jabloecki and Machaj 2009; Friedman 2009; Kling 2009; FCIC 2011; Friedman and Kraus 2011; Kraus 2011; Erel et al. 2014; and Miller 2018). The reduction in required capital followed two notices of proposed rulemaking (NPRs). The 1997 NPR called for linking risk weights for private-label securitization tranches to ratings by Nationally Recognized Statistical Rating Organizations (NRSROs) to determine minimum capital requirements. The 2000 NPR repeated the call for linking risk weights to ratings. It also proposed adopting an early version of Basel II risk weights for determining securitization tranche capital charges that lowered capital charges for the highest rated tranches, even before Basel II guidelines were finalized by the Basel Committee on Banking Supervision in 2004. The final rule incorporated these proposed changes, which made the private-label AAA-rated securitization tranches more attractive to BHCs.

To examine the role of the Recourse Rule and ABS CDOs empirically, I first use daily deal data to create a daily series of total cumulative ABS CDO issuance and total cumulative ABS CDO issuance as of each deal's pricing date for the top five US investment banks and the four large US BHC issuers; almost all US issuance originated from these nine banks. I then estimate break points using the Bai and Perron (2003) method. For total (global) and US commercial bank issuance but not for investment bank issuance, the first break point appears close to the first public release date of the Recourse Rule, before it was published in the *Federal Register*, which makes sense because the investment banks were not subject to the rule. While not the focus here, one breakpoint for investment banks does occur around the time of the Securities and Exchange Commission's (SECs) 2004 Net Capital Rule amendment, which subjected investment banks to Basel II and its identical risk weights as the Recourse Rule's for highly rated, private label tranches.

As these findings are consistent with capital requirements being a possible driver of ABS CDO issuance, I also examine the role of the Recourse Rule on the ex ante, estimated cost of restoring BHC solvency using Merton's (1974, 1977) option-theoretic approach to valuing debt guarantees as in Miller (2024). Given the common treatment date, I estimate treatment effects using two-way fixed effects; I get nearly identical results if I use Mora and Reggio's (2019), Cerulli's (2019) or Callaway and Sant'Anna's 2021) ordinary least squares approaches. The dynamic treatment effects suggest no differences in the estimated debt guarantees until Q3 2008-Q3 2009, with the average treatment effect peaking at $65 billion for BHCs that commented on the Recourse Rule.

I use the available data on BHC-reported CDO holdings during Q1 2008–Q1 2009 from BHC call reports to estimate the sensitivity of the distribution of *ex ante* costs of restoring solvency to total asset shares of various trading assets, including CDOs. To do this, I estimate pooled 10th/25th/median/75th/90th quantile regressions with Parente and Silva's (2016) clustered standard errors. For instance, at the 10th/25th/median/75th/90th quantiles, BHCs with CDO holdings have a $3.75 million/$33.74 million/$16.4 billion/$64.99 billion/$108.30 billion higher debt guarantee, respectively. This asymmetry reveals the heterogeneity across the distribution of the estimated debt guarantees to CDO exposures, as the largest estimates arise with those holding CDO tranches. Trading assets, generally, have received much attention in the aftermath of the crisis, whereby legislators and regulators have sought to curb such activities through the Volcker Rule. I therefore include estimates of trading assets from BHC call report data under the 2013 and 2019 versions of the Volcker Rule. At the 10th/25th/median/75th/90th quantiles, respectively, I find that a 1 percentage point increase in the 2013 Volcker Rule trading asset share is associated with a $0.013 million/$0.152 million/$0.995 million/$12.9 million /$177.8 million higher estimated debt guarantee. At the 10th/25th/median/75th/90th quantiles, respectively, I find that a 1 percentage point increase in the 2019 Volcker Rule trading asset share is associated with a $0.77 million/$5.4 million/$98.3 million/$523.7 million/$1.482 billion higher debt guarantee. While estimated debt guarantees are more sensitive to the 2019 trading assets definition than to the 2013 trading asset definition, overall the findings are consistent with the observation that CDO holdings rather than trading assets generally were a key source of large BHC distress during the 2007–2009 crisis. Other categories of securities and explanatory variables have little association with the estimated costs of restoring solvency. I examine some of the financial innovations and regulatory changes that took place before the banking crisis; then I discuss the hypotheses and empirical results; and then I conclude.

2. On the Rise of CDOs and Commercial Bank Exposures

2.1 CDOs and Their Attributes

In general, CDOs, including ABS CDOs, have four attributes: (1) their purpose, (2) the assets held as collateral, (3) the liabilities issued, and (4) their credit structure (see Lucas et al. 2007). In terms of purpose, leading up to the banking crisis, asset managers might create CDOs for arbitrage purposes to generate assets under management. Managers can generate fees from these assets. Alternatively, as asset sellers, banks may create CDOs to reduce the size of their balance sheet, reduce the amount of required capital, or to lower funding costs. Lastly, BHCs might create them as a form of Tier 1 regulatory capital, as in the case of Trust Preferred Securities, which the Federal Reserve allowed for holding companies but which was prohibited by the Federal Deposit Insurance Corporation (FDIC) for banks (Cordell et al. 2011).

The assets used as collateral in CDO deals include risky debt, such as loans, bonds, or securitization tranches, which generate income streams. Cordell et al. (2012) report that about \$1.4 trillion in CDOs were issued between 1998 and 2007. They explain that a key subset of CDOs—which lay at the heart of the financial crisis—namely ABS CDOs, comprise Rule 144A unregistered securities that private companies may sell to qualified institutional buyers. They also show that of the \$641 billion of ABS CDOs issued between 1999 and 2007, about \$440 billion of the collateral came from securitization tranches, and \$201 billion in "synthetic" collateral included credit default swaps (CDSs). CDSs offer protection to the buyer against debt default and generate income streams to the seller in exchange for acquiring the debt in the event of default. If one breaks down the \$641 billion in ABS CDOs in terms of the quality of the assets, then \$322 billion was included in high grade deals, \$288 billion was included in lower rated "mezzanine" deals, and \$31 billion (\$20 billion in high grade and \$11 billion in low grade) was CDO-squareds, or CDOs backed with other CDO tranches.

The asset managers in arbitrage deals or asset sellers in balance sheet deals work with either investment banks or structurers to arrange the CDO deal by creating a corporate entity that houses the assets (see Lucas et al. 2007). The income streams from those underlying assets, in turn, get redistributed to various investors holding debt and equity tranches issued by the deal. The investors might be banks retaining a portion of the deal, or they might be other banks, insurance companies, hedge funds, or pension funds that seek to hold marketable debt. In terms of liabilities in CDO deals, the tranches sold to investors reflect the risk arising from reprioritizing incoming payment flows in a "waterfall" manner in the sense that the liabilities receive payments in order of their rating. The highest-rated tranches receive payment first and the lowest-rated debt tranche receives payment last.

The equity tranche, which does not get rated as the tranche that takes first losses, might ideally seem best suited for the originating bank. However, Gibson (2004) highlights the role of the default correlation for deal collateral and its effects on the value of the tranches. On the one hand, a higher default correlation increases the chance that the equity tranche will get wiped out and that the senior tranche will experience some losses. Therefore, the value of the senior tranche declines with default correlation. On the other hand, if the default correlation is higher, there's also a greater chance that there will be few defaults. Given that equity tranches gain more in a low-default scenario than they lose in a high-default scenario, the value of the equity tranche increases with default correlation. As a result, as Erel et al. (2014) observe, in cases when a bank arranges the deal, the bank could signal confidence in the deal to other investors by holding the highest-rated tranches rather than the equity tranches, which might instead get sold to hedge funds. I will discuss later how changes in regulatory capital requirements also made holding the higher-rated tranches more attractive to BHCs.

Lastly, CDO deals offer additional protection through their credit structure, either in the form of cash-flow or market-value protections (Lucas et al. 2007). Cash-flow protections rely on overcollateralization and interest coverage tests. Overcollateralization tests check the size of asset collateral against the size of a tranche as well as all other tranches above it; the larger the ratio the more protection for investors. Similarly, the interest coverage test checks the amount of interest due from the deal's assets relative to the interest due from a particular tranche as well as all other tranches above it; the larger the ratio the more protection for investors. Less common market-value protections work to limit the amount borrowed against assets in the deal as the assets' risk rises.

2.2 The Evolution of CDOs and CDO Market Crashes

The first CDO-like transactions began with collateralized bond obligations (CBOs) that Drexel Burnham Lambert created using high-yield bonds as collateral beginning in 1987 (Lucas et al. 2007, chap. 1). Das (2005) and Tavakoli (2008) observe that insurance companies also used CBOs to lower their assets' capital charges, which differ from bank capital charges; Merrill et al. (2019) show empirically how, leading up to the 2007–2009 crisis, capital-constrained insurance companies favored holding highly rated securitization tranches. Shortly thereafter, similar collateralized loan obligation deals emerged with a variety of loans used as collateral (Lucas et al. 2007, chap. 1). On the liabilities side, a key evolution occurred after the savings and loan (S&L) crisis.

In response to the S&L crisis, Congress established the Resolution Trust Corporation (RTC) in section 501 of the Financial Institutions Reform, Recovery, and Enforcement Act of 1989 (Pub. Law 101-73; 103 Stat. 183). The RTC had as its objective to assume mortgages, real estate, and failed S&Ls (FDIC 1998; Tavakoli 2008, 84; FCIC 2011, 69–71). Before the RTC, private-label securitizations had straightforward structures. For instance, early securitizations might have two tranches, one rated higher and the other rated lower. Because the RTC had difficulty selling S&L debt, they introduced more complex tranche structures to attract investors (FDIC 1998), and the private sector has adopted and adapted that practice since then.

An unexpected increase in the target federal funds rate in 1994 resulted in turmoil in a variety of fixed-income markets, and as a result, structured notes backed by a variety of bonds also experienced losses (Partnoy 2009; O'Malley 2015). Partnoy (2009) explains that leading up to the 1994–1995 "Tequila Crisis," investment banks created credit-linked structured notes backed by emerging market sovereign debt, denominated in the local currency. The structured notes paid investors in US dollars after converting the local currency bond returns at the current market exchange rate. The practice involved finding a suitable "speculative-grade" emerging market sovereign debt product, writing up the details of the contract, and trying to convince the NRSROs to rate the products as high investment grade. For example, with a Mexican structured note, once the rated product got sold to investors, as long as the Banco de México maintained the peso-dollar peg, the payoff was attractive to institutional investors; investors lost out, however, when the peso-dollar peg collapsed. The end result of the Tequila Crisis was similar to what occurred during the recent crisis, with investors suffering significant losses after purchasing highly rated structured products that had risky assets as collateral. The pattern continued shortly thereafter, and Kregel (1998), Das (2005), and Partnoy (2009, afterword) observe that similar products went bust during the Asian crisis in 1997–1999 and the Russian crisis in 1998.

The realized losses from deals with undiversified collateral between 1994–1998 resulted in a search for diversified deals through so-called multisector CDOs (Hu 2007; FCIC 2011). Hu (2007), FCIC (2011, 130) and Cordell et al. (2012) also mention the collapse of the multisector CDO around the time of the technology sector crash in 2000–2002, which occurred in spite of the more diversified collateral. Although multisector CDOs were designed to incorporate the benefits of a more diversified asset pool, the pools often included private equity fees, which declined with the technology sector crash, and airline leases, which declined following the events of September 11, 2001. These crash events prompted dealers to search for more stable collateral, which housing-related loans seemed to provide (FCIC 2011). Deng et al. (2011) use Granger causality tests to show that CDO issuance drove down the yields on mortgage-backed securities (MBSs) relative to Treasuries during the CDO market expansion, and not the other way around; they also point out that CDO pricing effects likely got passed down to the mortgage borrowers, which would have spurred growth in the mortgage market. In addition, financial innovations with credit risk management gave rise to new variants that also revealed their fragility during the 2007–2009 crisis.

Das (2005, 328–33) describes JP Morgan's deal to help rid itself of corporate credit risk with the first synthetic securitization of corporate credit risk in 1997. Das (2005, 369) also describes JP Morgan's deal to help the German Commerzbank get capital relief through the first synthetic securitization of mortgage debt toward the end of 1998. This product had tranches as liabilities as in a typical CDO, but here, CDSs, which represent claims to purchase the cash equivalent value of the referenced asset rather than the asset itself in the event that the referenced asset defaults, replaced the more traditional bonds of securitized assets. Therefore, they reflected bets on default rather than cashflows from mortgage and other consumer credit products and featured prominently among ABS CDO writedowns (Cordell et al. 2012).

If only a small fraction of households stopped making mortgage payments, the deals would lose considerable value. To understand how that might happen, Mian and Sufi (2009) find, among other things, that ZIP codes with relatively high levels of subprime borrowers (those with a FICO score less than 660) experienced a significant rise in mortgage defaults starting in 2006; those ZIP codes tended to have a higher proportion of securitized loans too. Griffin and Maturana (2016a) confirm the aforementioned finding in Mian and Sufi (2009) and also find that ZIP codes in which mortgage originators adopted dubious practices also experienced higher mortgage defaults. Also, Griffin and Maturana (2016b) find evidence of appraisal overstatements, owner occupancy misreporting, and unreported second liens in MBS loan data. Deng et al. (2011) also show that, as CDO issuance slowed, the yield-spread on MBSs and CDOs rose. However, this rise did not affect private-label MBS performance much, and Ospina and Uhlig (2018) show that overall, private-label MBSs issued by investment and commercial banks, rather than those issued by government-sponsored enterprises (GSEs), performed relatively well, even during the crisis. Moreover, most of the Alt-A and subprime losses were in securities rated less than AAA, especially those deemed noninvestment grade, which factors into CDO performance.

A reduction in the flow of mortgage payments could affect securitization tranches, which, in turn, would get a ratings downgrade. As CDOs often bundled assets together that had higher default correlation risk than arrangers and NRSROs had assumed, mortgage defaults or even a slowdown in home price appreciation could adversely affect private-label mortgage MBSs and wipe out an entire CDO deal (Cordell et al. 2012). This effect relates to the way deals were structured (Coval et al. 2009a), as they tended to price credit risk—especially since insurance company and pension fund investors have regulatory reasons to seek highly rated securities—but not the risk arising from the state of the economy. As a result, they were overpriced relative to similarly rated products, given the underlying risk. Coval et al. (2009b) also point out that some studies on CDO valuation find that imprecision in estimated default probabilities or default correlations, amounts recovered following defaults, or model specification errors get magnified by the CDO deal structures. The expected payoff for tranches declines as the diversification in deal collateral declines such that default correlations rise, and the effect is stronger with CDO-squareds (Coval et al. 2009b). Moreover, the collateral underlying private-label MBSs used in CDO deals tended to be geographically diversified because the ratings agencies gave better ratings in such cases (Cordell et al. 2012); as a result, collateral was more similar across deals and had higher default correlations. Deals also had similar vintages, given that the pooling and tranching got done at once (Cordell et al. 2012). Lastly, as Cordell et al. (2012) show, CDO deals often cross-referenced collateral from other deals, such that downgrades on collateral would affect multiple deals simultaneously.

2.3 Regulatory Changes Favoring CDOs

Table 1 provides a timeline of regulatory changes that have implications for the growth of the CDO market. More recent developments with bank capital regulation have tended to have a bias toward highly rated debt.

The origins of this bias arose in the aftermath of the Latin American debt crisis in 1982. Congress called for new bank capital guidelines (Kapstein 1994). To understand why, Congress at the time accepted the view that bank capital had aspects of a public good such that system-wide increases would raise confidence, and Congress did not want to be seen as forcing US taxpayers to bail out the banks, wanting instead to force shareholders to bear losses (Kapstein 1991, 13). In addition, Congress also accepted the position voiced by lobbyists that American banks could be at a disadvantage vis-à-vis their foreign competitors when it came to capital requirements if only US capital requirements increased, so Congress sought a multilateral rather than unilateral change.

To address these concerns, Congress passed the International Lending Supervision Act of 1983 (ILSA of 1983; Public Law No. 98-181; 97 Stat. 1278) to get American bank regulators to begin a multilateral push to address these concerns. US regulators began looking toward Europe for ideas about capital adequacy standards. After several years of deliberations between officials in the United States and the United Kingdom, Japanese officials then agreed to sign on, followed by officials in continental Europe (Kapstein 1991; Kapstein 1994). The end result was the 1988 Basel I accord on capital adequacy.

Capital requirement guidelines from the 1988 Basel Accords are known as "Basel I," and bank regulators in some countries began implementing them as a standard of good banking practices and large US banks had to implement them by 1993 (see Barth and Miller (2018)). A key change stipulated that banks had to fund with 8 percent capital to back their risky assets such as standard commercial loans. Basel I guidelines did lower capital charges for short-term Organisation for Economic Co-operation and Development country sovereign debt, which from the outset was treated as risk free. For mortgages/GSE or "agency" MBSs capital requirements now dropped to only 4.0/1.6 percent. Das (2005, 126) observes that because Basel I preceded many structured finance innovations, regulators approached the problem by establishing equivalence between the structured products and existing products covered by Basel guidelines. The trouble arises with the introduction of so-called "risk buckets" that assign assets a variety of arbitrary risk weightings that specify how much capital a bank must have to back their assets, which may not reflect the underlying market riskiness of the assets.

TABLE 1. Regulatory and Statutory Changes to Capital Treatment of Securitizations

Date	Event	Summary of Change
July 15, 1988	Central bank officials from Group of 10 countries agree to Basel I	Implemented in United States between 1988 and 1991 and applied to all US banks in 1992, the framework introduced asset class–based risk weights equal to 0.0, 0.2, 0.5, and 1.0, which were used to adjust total assets used to compute the 8 percent minimum capital requirement relative to risk-weighted assets.
November 29, 2001 (appeared publicly in print on October 25, 2001)	Risk-Based Capital Guidelines; Capital Adequacy Guidelines; Capital Maintenance: Capital Treatment of Recourse, Direct Credit Substitutes and Residual Interests in Asset Securitizations (66 Fed. Reg. 59614), or "Recourse Rule"	Established risk weights for private-label MBSs and other similarly structured products such as CDOs on the basis of ratings. For AAA- and AA-rated securities, the risk weight was 0.2; for A-rated securities, the risk weight was 0.5; for BBB-rated securities, the risk weight was 1.0; for BB-and-lower-rated securities, the risk weight increased to 2.0. Before the rule, the risk weight was either 0.5 or 1.0.
October 1, 2003 (appeared publicy in print on September 4, 2003)	Risk-Based Capital Guidelines; Capital Adequacy Guidelines; Capital Maintenance: Interim Capital Treatment of Consolidated Asset-Backed Commercial Paper Program Assets (68 Fed. Reg. 56530)	Banks with ABCP programs were allowed to temporarily exclude assets in those programs from the computation of risk-weighted assets used to assess capital adequacy. The interim rule applied to the reporting periods of September 30, 2003; December 31, 2003; and March 31, 2004. It was set to expire on April 1, 2004.
April 26, 2004 (appeared publicly in print on April 9, 2004)	Risk-Based Capital Guidelines; Capital Adequacy Guidelines; Capital Maintenance: Interim Capital Treatment of Consolidated Asset-Backed Commercial Paper Program Assets; Extension (69 Fed. Reg. 22382)	Extended the interim rule on capital treatment of consolidated ABCP program assets through July 1, 2004.
July 28, 2004	Risk-Based Capital Guidelines; Capital Adequacy Guidelines; Capital Maintenance: Consolidation of Asset-Backed Commercial Paper Programs and Other Related Issues (69 Fed. Reg. 44908)	Made the interim rule on capital treatment of consolidated ABCP program assets permanent starting September 30, 2004.
Introduced in Senate February 1, 2005; passed in Senate March 10, 2005; passed in House April 14, 2005; enacted April 20, 2005	The Bankruptcy Abuse Prevention and Consumer Protection Act of 2005 (Pub. L. No. 109-8, 119 Stat. 23)	Gave counterparties in private-label MBS-collateralized repurchasing agreements the ability to take possession of collateral and terminate contracts during bankruptcy. Before the act, this was possible only in repurchasing agreements collateralized by agency MBSs and US Treasury securities.

Note: ABCP = asset-backed commercial paper; CDO = collateralized debt obligation; MBS = mortgage-backed security.

Source: Risk-Based Capital Guidelines; Capital Adequacy Guidelines; Capital Maintenance: Capital Treatment of Recourse, Direct Credit Substitutes and Residual Interests in Asset Securitizations, 66 Fed. Reg 59614 (November 29, 2001); Risk-Based Capital Guidelines; Capital Adequacy Guidelines; Capital Maintenance: Interim Capital Treatment of Consolidated Asset-Backed Commercial Paper Program Assets, 68 Fed. Reg. 56530 (October 1, 2003); Risk-Based Capital Guidelines; Capital Adequacy Guidelines; Capital Maintenance: Interim Capital Treatment of Consolidated Asset-Backed Commercial Paper Program Assets; Extension, 69 Fed. Reg. 22382 (April 26, 2004); Risk-Based Capital Guidelines; Capital Adequacy Guidelines; Capital Maintenance: Consolidation of Asset-Backed Commercial Paper Programs and Other Related Issues, 69 Fed. Reg. 44908 (July 28, 2004); Bankruptcy Abuse Prevention and Consumer Protection Act of 2005, Pub. L. No. 109-8, 119 Stat. 23 (2005).

As Jones (2000) points out, banks look to hold assets with lower capital charges and can do this by either lowering the amount of capital they have to back their assets by moving activities off their balance sheet or by shifting into assets that require less capital. Not only were commercial bank capital requirements for on-balance-sheet assets reduced by the Basel accord, those for off-balance-sheet activities were largely excluded from regulatory capital requirements. Jones (2000) describes how so-called risk buckets specified by Basel-type capital adequacy standards create incentives for bank asset managers to reduce regulatory capital. The adoption of the "Recourse Rule" on November 29, 2001 (66 Federal Register 59614, November 29, 2001, first made public on October 25, 2001) could foster similar arbitrage opportunities, as Acharya and Richardson (2009), Friedman (2009), Jabloecki and Machaj (2009), Kling (2009), Friedman and Kraus (2011), Kraus (2011), FCIC (2011, 99–100), Erel et al. (2014), and Miller (2018) discuss.

Regulators began working on the Recourse Rule not long after the implementation of Basel I guidelines with an initial NPR in 1994 (59 Federal Register 27116, May 25, 1994) that proposed using ratings to determine minimum capital for certain exposures but took no action. A 1997 NPR (62 Federal Register 59943, November 5, 1997) again proposed using ratings to determine minimum capital for certain exposures, this time including senior securitization tranches. A 2000 NPR (65 Federal Register 12320, March 8, 2000) also called for using ratings to determine capital charges for securitization tranches, as well as for adopting risk weights from an early draft of Basel II for securitization tranches. The 2001 final rulemaking incorporated these proposals.

Friedman and Kraus (2011) show in table 2.1 that the Recourse Rule specified that: (1) for AAA- or AA-rated private-label ABSs or MBSs, the capital charge would drop from 8.0 percent to 1.6 percent; (2) for A-rated ABSs, the capital charge would drop from 8.0 percent to 4.0 percent; (3) for BBB- or BB-rated ABSs, the capital charge would remain the same; (4) for ABSs rated lower than BB, the capital charge would increase from 8.0 percent to 16.0 percent; and (5) for the ABS equity tranches, the capital charge would increase from 8.0 percent to 100.0 percent, or dollar for dollar.[1] Friedman and Kraus (2011) claim the rule created incentives for bankers to prefer capital relief plus safety over yield by buying the AAA-rated ABS tranches while selling off the equity tranche; although as discussed earlier, Erel et al. (2014) discuss how banks could signal confidence in deals by holding the highest-rated tranches rather than the equity tranche. Miller (2018) shows that after the rule change, BHCs with subsidiaries that commented on the Recourse Rule NPRs in 1997 or 2000 increased their share of highly rated tranche holdings on average by up to 6 percentage points more than the control group by the time of the crisis; they also reduced holdings of the lowest-rated securities.

While the Recourse Rule was being finalized, the Enron scandal in late 2001 raised subsequent accounting and regulatory concerns about the corporate use of off-balance-sheet entities, including asset-backed commercial paper (ABCP) programs. Some large commercial banks had been using ABCP programs to finance certain securitization activities, including almost $50 billion in CDO deals (Covitz et al. 2013). While that amounts to just a fraction of the $641 billion in ABS CDOs or $1.4 trillion in total CDOs reported by Cordell et al. (2012), Citigroup issued a considerable amount of that (Mueller, Bharwani, and Araya 2006; FCIC 2011, 137–39, 195–200). Proposals to increase bank capital requirements for assets held in ABCP programs ultimately went nowhere. Such proposals began with an interim final rule that allowed

[1] They also observe on page 70 and show in their table 2.1 that the only differences between risk buckets under the Recourse Rule and in the 1999 consultative paper detailing a preliminary version of Basel II lay in the B-rated ABS tranches, which in the consultative paper specified a 100 percent, rather than a 16 percent, capital charge, and in A- and lower-rated sovereign debt.

banks to temporarily exclude assets held in ABCP programs from their calculations of risk-weighted assets used in regulatory capital requirements (68 Federal Register 56530, October 1, 2003, first made public on September 4, 2003), which banks could apply for Q3 2003, Q4 2003, and Q1 2004. A subsequent regulatory notice extended the rule to Q2 2004 (see 69 Federal Register 22382, April 26, 2004, first made public on April 9, 2004). The exclusion became permanent starting in Q3 2004 when regulators issued a final rulemaking (see 69 Federal Register 44908, July 28, 2004). Excluding these assets from bank risk-weighted assets would encourage asset securitization, especially of collateral that might be used in CDO deals, given that securitizing banks have incentives to hold highly rated tranches (Erel et al. 2014; Miller 2018). Indeed, Acharya et al. (2013) show in their paper's figure 1 that ABCP assets equaled roughly $600–$650 billion from 2001 to 2004 but began trending upward thereafter, reaching a peak of about $1.3 trillion before declining as the crisis began to unfold in mid-2007.

One last potential policy change that could have encouraged the growth of the collateral used in CDO deals arose with the passage of the Bankruptcy Abuse Prevention and Consumer Protection Act (BAPCPA) of 2005 (Pub. Law 109-8; 119 Stat. 23) on April 20, 2005, under a Republican-controlled Congress (Acharya and Öncü 2011; Srinivasan 2021). Before the act, any repurchasing agreement counterparty to a bank was exposed to the entire bank. Title IX financial contract provisions allowed private-label MBS repurchasing agreement counterparties to terminate any contract and keep the collateral in the event of a default. The act also extended a privilege to private-label MBSs that limited counterparty exposure to the repurchasing agreement, which was previously reserved for agency MBSs and US Treasury securities. As with the changes to ABCP program capital requirements, this change could also have encouraged the spread of exposures to securitized assets. I now summarize my hypotheses to examine how regulatory factors, especially the Recourse Rule, could have influenced commercial bank issuance and holdings of CDO tranches and how that could have contributed to the cost of restoring large securitizing BHC solvency.

3. Hypotheses

Given that BHC call reports included only details about CDO holdings from Q1 2008–Q1 2009, I examine the issue of how commercial bank CDO exposures were created, even if unintentionally, from three different angles. The first examines the supply of ABS CDOs using structural break analysis to determine whether any structural breaks in the series coincide with any of the regulatory changes discussed earlier. The second examines whether BHCs with subsidiaries that commented on the Recourse Rule had higher estimated *ex ante* costs of restoring solvency. To examine the link between BHC distress and CDO exposures, the third angle examines the association between CDO holdings, as well as other trading assets, and the estimated debt guarantees. To motivate the subsequent analysis, I propose three hypotheses.

Hypothesis 1: Did CDO Issuance Respond to Regulatory Changes?

If ABS CDO issuance, as a measure of the supply of ABS CDO tranches, increased after the policy changes summarized in the previous section, that could corroborate the view that BHC CDO exposures were spurred, even if unintentionally, by regulatory changes. The policy changes would facilitate the creation of the securities. At the same time, through the "securitization byproduct effect," commercial banks could be increasing their exposure through the deals they create or by purchasing parts of other banks' deals, as argued by Erel et al. (2014). So even though commercial banks have not made their ABS CDO tranche holdings before the crisis public, an increase in the supply by large BHC CDO dealers could in principle mean a greater ABS CDO exposure.

Hypothesis 2: Did BHCs with Subsidiaries That Commented on the 1997 and 2000 Recourse Rule NPRs Have Higher Estimated Debt Guarantees during the Crisis?

US banks can and do comment on rulemakings during notice-and-comment periods. However, the final 2001 rulemaking did not specify which banks commented. Given that the final Recourse Rule adopted the essence of the proposed changes in the 1997 and 2000 NPRs in using banks that submitted comments, I aim to identify banks that would make extensive use of the regulatory changes rather than to identify what banks were trying to achieve. This opens the way to examine just how commercial bank exposures could have arisen unintentionally from the rulemaking process. Because BHCs with commenting subsidiaries would have found the now lower capital charges on highly rated, private label securitization tranches, including CDO tranches, attractive subsequent distress from such securities could have resulted in higher estimated debt guarantees. Specifically, I test whether BHCs with subsidiaries that submitted comment letters during the notice-and-comment period for either the 1997 or 2000 Recourse Rule NPRs also had higher estimated *ex ante* debt guarantees. If they did, then such a finding could suggest how these regulatory changes exposed BHCs to subsequent ABS CDO writedowns. However, this hypothesis does not explicitly examine the mechanism on the demand side by which BHCs might be exposed, leading to the third hypothesis.

Hypothesis 3: Were CDO Tranche Holdings Associated with Higher Estimated Debt Guarantees?

BHCs did not report their CDO tranche holdings before the crisis, but they did briefly have to report holdings from Q1 2008 through Q1 2009. Using that information, if BHCs with greater CDO tranche holdings had higher estimated *ex ante* debt guarantees, that would show how bank demand reflected by their holdings of CDOs could have contributed to the crisis.

4. Empirical Tests of Hypotheses

4.1 ABS CDO Issuance and Structural Breaks

To test the first hypothesis relating rising ABS CDO issuance and implicit derived BHC demand to policy changes, I apply structural break analysis to daily series of cumulative ABS CDO issuance. I use the Green Street asset-backed securities database to construct the cumulative ABS CDO issuance series and select all CDOs that had structured product collateral to create series comparable to the structured finance ABS CDO series constructed by Cordell et al. (2012, 2019).[2] Beyond deal collateral classification, the database includes information such as the pricing date of the deals when most if not all deal tranches have terms established, which I use to estimate the break dates.[3] The database also includes information on book runners—the top book

[2] Green Street currently warehouses the data, available at https://www.greenstreet.com/, that were previously available at ABAAlert.com, which Deng et al. (2011) use.

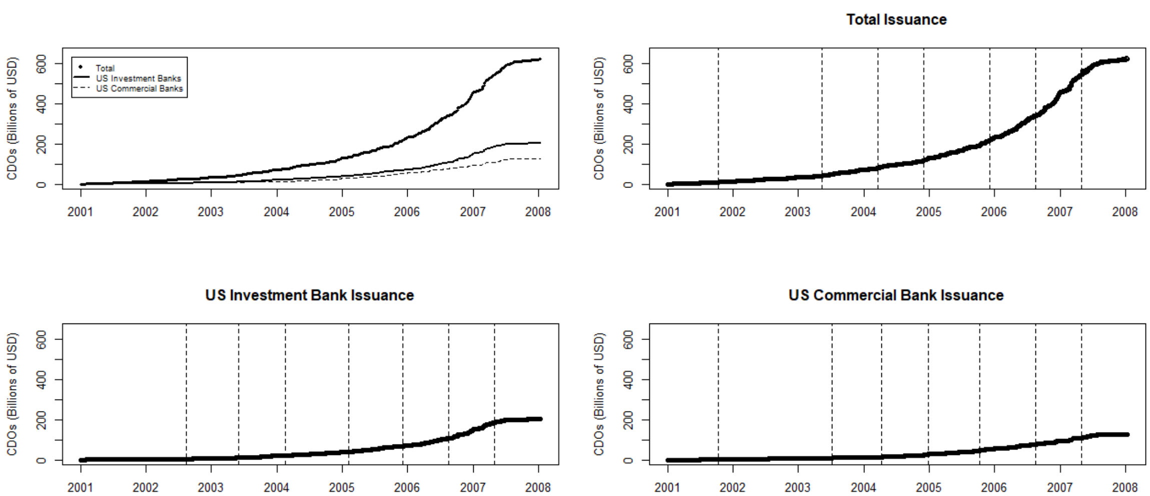
[3] ABS CDO underwriting took time to complete, as acquiring the underlying collateral during the "ramp-up" period typically took 6-9 months (see FCIC (2011)). Acquiring the remaining assets could also take time after the pricing date, the date when an investor can place an order for part of the deal, but for the purposes here, the pricing date reflects demand to purchase tranches, together with BHC derived demand arising from the "securitization byproduct" effect.

runner being the one I use to identify the bank issuing a deal. In terms of numbers, most of the top book runners for each deal are foreign banks; a small fraction of deals lists no book runner. Consistent with table 4 in Cordell et al. (2012), the largest US dealers include the top five investment banks (Bear Stearns, Goldman Sachs, Lehman Brothers, Merrill Lynch, and Morgan Stanley) and four large BHCs (Bank of America, Citigroup, JPMorgan Chase, and Wachovia).[4]

Between 2001, when Green Street first reports data for CDOs with structured product collateral, and 2007, the total volume issued equals \$619.7 billion, not far from the \$633.8 billion reported by Cordell et al. (2012, 2019) for 2001 to 2007.[5] Although the nine large US dealer banks listed earlier issued less than half of the total volume earlier in the sample, by the end of the sample, that proportion rose to about 53 percent.

Figure 1 depicts 1,771 daily observations for the aggregate cumulative series across all book runners, domestic and foreign, as well as for US investment banks and US commercial bank subsidiaries in the upper left panel. The other three panels depict one of each of the three series, with Bai and Perron (2003) method-estimated break points overlaid on the graph. To estimate the break points, I assume each segment has a linear form with a constant and trend. Table 2 reports the break dates and 99 percent confidence intervals for the break dates. Because I use daily data, I set the minimum segment size equal to one-tenth of the sample size, or 177 observations.

FIGURE 1. Cumulative Sum of ABS CDOs, January 2, 2001–December 31, 2007



Source: Author’s estimates.

[4] Salomon Brothers, which was acquired by Citigroup in 1999, appears as the top book runner on five deals in 2001 and 2002, whereas Citigroup does not appear as a book runner until 2003, when Salomon Brothers ceased operating (see numbered page 1 from Citigroup Global Markets Holdings Inc., Annual Report (Form 10-K) (Dec. 31, 2004)). I therefore, assign Salomon Brothers to Citigroup. Similarly, Banc One Capital appears in one deal in 2004, which I assign to the acquiring bank, JPMorgan Chase.

[5] The data series used here will not likely match the data used in Cordell et al. (2012, 2019), given the differences in classification. For instance, Cordell et al. (2012) report that they classify some additional deals on the basis of the underlying collateral as well as synthetic deals, which had credit default swaps on mortgage debt as collateral. Cordell et al. (2012) also report that they focus on securities classified as 144A, which were not publicly traded but instead traded on ABS trading desks. Selecting ABS CDOs backed by 144A collateral in the Green Street data lowers the total to \$556.3 billion issued between 2001 and 2007.

TABLE 2. Break Points

	0.5 Percent Confidence Interval	Break Point	99.5 Percent Confidence Interval
Total issuance	10/15/2001	10/16/2001	10/17/2001
	5/14/2003	5/15/2003	5/16/2003
	3/18/2004	3/22/2004	3/24/2004
	11/26/2004	11/29/2004	11/30/2004
	11/24/2005	11/25/2005	11/27/2005
	8/7/2006	8/8/2006	8/9/2006
	4/18/2007	4/19/2007	4/20/2007
US investment bank issuance	8/8/2002	8/15/2002	8/16/2002
	6/3/2003	6/4/2003	6/5/2003
	2/4/2004	2/20/2004	2/24/2004
	2/2/2005	2/3/2005	2/4/2005
	11/21/2005	11/25/2005	11/27/2005
	8/7/2006	8/8/2006	8/9/2006
	4/18/2007	4/19/2007	4/20/2007
US commercial bank issuance	10/16/2001	10/17/2001	10/18/2001
	7/10/2003	7/11/2003	7/16/2003
	4/13/2004	4/14/2004	4/15/2004
	12/20/2004	12/21/2004	12/27/2004
	10/3/2005	10/4/2005	10/6/2005
	8/3/2006	8/8/2006	8/9/2006
	4/11/2007	4/19/2007	4/20/2007

Source: Author's estimates.

In my discussion of figure 1 and the break points I focus primarily on the US commercial bank series as well as its similarity to the series for the total across all issuers. The first break point occurs on October 17, 2001, one day after the break point for the total CDO series. The Recourse Rule appeared in the *Federal Register* on November 29, 2001, the rule's effective date, but was made public on October 23, 2001, just six calendar days after the pricing date break point. While the date does not fall within the 99 percent confidence interval, its proximity to the final rule being made public could be consistent with the hypothesis that ABS CDO issuance increased after the rule change, given that said rule change lowered capital requirements on the highly rated, private-label securitization tranches. The second break date occurs on July 11, 2003, just less than two months before the earliest ABCP interim proposed rulemaking from the Office of the Comptroller of the Currency (OCC) was made public on September 4, 2003. The third break date occurs on April 14, 2004, just five days after the OCC made public the extension of the interim rule on April 9, 2004. No break appears close to the final rulemaking that made the exclusion of ABCP assets from capital requirements permanent. The fourth and fifth break dates on December 21, 2004, and October 4, 2005, occur about five weeks before BAPCPA was introduced on February 2, 2005, and six months after it was enacted on April 20, 2005. The sixth break date reflects the last boom, and the seventh one reflects the subsequent bust in issuance as the 2007–2009 crisis began to unfold. Overall, these break points offer suggestive evidence that could be consistent with the Recourse Rule and extension of the ABCP interim capital rules' influencing ABS CDO issuance for the four large commercial bank CDO dealers.

Before turning to the next hypothesis, the February 20th breakpoint for the investment bank series does merit a brief discussion. On October 24th, the SEC made public a proposed a revision to the Net Capital Rule, which subjected investment banks to Basel II, including identical risk weights as the Recourse Rule for highly rate, private label securitization tranches.[6] Comments were due by February 4th, 2004 and the final rule was made public on June 8, 2004.[7] Given that the proposed and final rules stated that investment banks would be subjected to Basel II, the breakpoint could also reflect a change in investment bank ABS CDO issuance in response to the incentives from Basel II.

4.2 Estimating the Effects of the Recourse Rule and CDO Exposures on the Estimated Debt Guarantees

I next examine if users of changes to regulatory capital requirements, which made holdings of highly rated securitization tranches, including CDO tranches, more attractive also had higher estimated debt guarantees reflecting *ex ante* costs of restoring solvency. To do this, I estimate dynamic treatment effects on the estimated debt guarantees for BHCs that had subsidiaries that commented on the Recourse Rule, relative to a control group of other large BHCs with at least $1 billion in Q1 2010 US dollars.

I use the approach in Miller (2024), which is similar to Milne's (2014), to estimate the debt guarantee reflecting the *ex ante* cost of restoring solvency. Milne's (2014) and Miller's (2024) approach applies Merton's (1977) model for estimating the size of debt guarantees. Merton begins by applying the Black and Scholes (1973) call option pricing formula to value the bank's equity as a call option on a bank's assets as in Merton (1974):

$$E = AN(d_1) - De^{-rT}N(d_2), \tag{1}$$

where $d_1 = \frac{ln\left(\frac{A}{D}\right)+\left(r+\frac{\sigma_A^2}{2}\right)(T-t)}{\sigma_A\sqrt{T-t}}$ and $d_2 = d_1 - \sigma_A\sqrt{T-t}$, E denotes the market value of equity, A denotes total assets, D denotes total debt, r denotes the risk-free rate of interest, $N(\cdot)$ denotes the cumulative normal distribution function, σ_A denotes the volatility input of the bank's assets, t denotes the current time period, and T denotes the terminal date of the option contract. The call option has value when the entity has positive net worth. The call option formula implies a leveraged asset position in which one borrows a risk-free amount De^{-rT} and purchases an amount of risky assets equal to A.

Equation (1) has two unobservable inputs, A and σ_A. To back them out of the model, the volatility of assets relates to equity return volatility as follows:

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[6] See Alternative Net Capital Requirements for Broker-Dealers That Are Part of Consolidated Supervised Entities, 68 Fed. Reg. 62872 (November 6, 2003).

[7] See Alternative Net Capital Requirements for Broker-Dealers That Are Part of Consolidated Supervised Entities, 69 Fed. Reg. 34428 (June 21, 2004).

$$\sigma_E = \sigma_A \frac{\partial E}{\partial A}\frac{A}{E}, \quad (2)$$

where $\frac{\partial E}{\partial A}\frac{A}{E}$ measures the elasticity of the market value of equity with respect to the market value of the bank's underlying assets. Black and Scholes (1973) show $\frac{\partial E}{\partial A} = N(d_1)$, which I substitute into equation (2), and after solving the expression for the volatility of assets, σ_A, that gives:

$$\sigma_A = \sigma_E \frac{E}{A} N(d_1). \quad (3)$$

Equations (1) and (3) provide a system of two nonlinear equations in two unknowns, which I solve numerically using the Newton-Raphson method, which also requires data for the observable inputs in equation (1), as summarized in table A1.[8]

For the BHC debt input, *D*, I use total deposits as in Miller (2024). For the market value of BHC equity, I use the product of total shares outstanding and the end-of-quarter stock price. For an estimate of the risk-free rate of interest, *r*, I use the end-of-quarter value of the daily three-month treasury rate. For an estimate of equity volatility, σ_E, I annualize the quarterly standard deviation of daily market value of equity returns. Lastly, I use the standard assumption that the maturity equals one year.

After solving for A and σ_A, as in Miller (2024), I can use those values together with the other inputs to reconstruct the put option values provided by the formula derived in Merton (1977), as follows:

$$\begin{aligned} P &= A[N(d_1) - 1] - De^{-rT}[N(d_2) - 1] \\ &= De^{-rT}N(-d_2) - AN(-d_1) \end{aligned} \quad (4)$$

Ceteris paribus, the put option value increases with as the BHC debt-equity funding mix moves toward more debt, or as asset volatility increases. The put option formula can be used to value debt guarantees in that it means selling the risky assets to the guarantor and receiving a risk-free amount in return equal to De^{-rT}.

To understand the treatment variable for BHCs with subsidiaries commenting on the Recourse Rule NPRs, highly rated CDO tranche holdings would become more favorable under the 2001 Recourse Rule final rulemaking. I assume BHCs with commenting subsidiaries had an interest in submitting comments, given that they stood to gain from the rule change. The final rulemaking mentioned the number of banks that commented on the 1997 and 2000 NPRs, but does not mention them by name. Therefore, Miller (2018) uses the electronic Freedom of Information Act (eFOIA) process to find comment letters for the 1997 and 2000 NPRs that resulted in the merged 2001 Recourse Rule final rulemaking.

Miller (2018) identifies 17 BHCs from the sample of BHCs that had subsidiaries that submitted comment letters. Because I use a narrower sample of large banks with at least $1 billion in Q1 2010 US dollars, I find that 11 BHCs in the sample, listed in table 3, had subsidiaries

[8] To estimate the unobservable market value of assets and volatility of those assets, I adapt the code available from "ifrogs," xKDR, last modified June 25, 2013, https://github.com/ifrogs/ifrogs/blob/master/R/dtd.R and described in the following vignette: Ajay Shah, Manish Singh, and Nidhi Aggarwal, *Distance to Default: Implementation in R* (n.p.: rdrr.io, n.d.), https://rdrr.io /rforge/ifrogs/f/inst/doc/dtd.pdf. As in Miller (2024), I replace R's optim function with R's nlminb function to solve the system of equations. I also use as starting values for the market value of assets, the sum of the debt input and the market value of equity, but replace the lower bound on the estimated market value of assets with the sum of 0.8*[book debt] + market equity. For asset volatility, I use the estimated sample average asset volatility of 0.39 from Miller (2024) as this value produces stable estimates irrespective of whether the units are in thousands, millions, or billions of US dollars.

commenting on the Recourse Rule NPRs. I also use the eFOIA process to collect comment letters to identify banks that commented on the ABCP program regulatory capital rulemaking. The table shows that a subset of the Recourse Rule commenting banks also commented on the ABCP program regulatory capital NPR, which could also reflect their interest in making use of the rule, but the reverse is not true, given that my eFOIA request reveals no new commenting banks.

I assume the posttreatment period begins in Q4 2001, when BHCs could first apply the Recourse Rule risk weights. I also assume the pretreatment begins in Q3 2000, after the 2000 Recourse Rule NPR comment period deadline on June 7, 2000. This would have given banks their last opportunity to influence the rule.

To examine how the regulatory changes could have contributed to large securitizing BHC distress, I estimate dynamic treatment effects using the two-way fixed effects regression estimator. The method provides nearly identical results as the ordinary least squares estimators in Mora and Reggio (2019), Cerulli (2019) and Callaway and Sant'Anna (2021). A key issue when applying difference-in-difference methods concerns whether the treatment group outcome in the absence of treatment behaves like the control group. Mora and Reggio's (2019) test for common pretreatment dynamics between control and treatment groups provides results consistent with Cerulli's (2019) and Callaway and Sant'Anna's (2021) tests for parallel trends.[9]

The linear two-way fixed effects regression equation takes the following form:

$$G_{it} = \beta_0 + \sum_{\tau=2}^{T} \delta_\tau d_{\tau,t} + \beta_1 Comment_{it} + \sum_{\tau=2}^{T} \beta_\tau d_{\tau,t} \times Comment_{it} + \varepsilon_{it}, \quad (5)$$

where the G_{it} is the *ex ante* cost of restoring solvency estimated as a debt guarantee in billions of USD net of BHC-specific, time-specific and overall average guarantee values; β_0 denotes the intercept, $d_{\tau,t}$ denotes a time dummy variable that equals one if the time period equals $t = 2, \ldots,$ T and zero otherwise; δ_τ denotes a time dummy variable that equals one in period t and zero otherwise; $Comment_{it}$ denotes the treatment dummy variable that equals one if the BHC had a subsidiary commenting on the 1997 or 2000 Recourse Rule NPRs that called for using ratings and early versions of Basel II risk weights, with β_1 being the treatment effect for the baseline period whereas β_τ is the treatment effect for the time dummy-treatment variable interaction terms; and ε_{it} denotes the error term.

[9] In Mora and Reggio's (2019) approach, given a variable $y(t)$, the first time derivative measures growth, the second velocity, the third jerk, the fourth snap, the fifth crackle, and the sixth pop. With five pretreatment periods, I will test for the equivalence of parallel paths with parallel growth, parallel velocity, parallel snap and parallel crackle. Even if the paths are not parallel and diverge, the Mora and Reggio (2019) method still allows for the possibility of estimating higher order treatment effects. Cerulli's (2019) approach applies an F-test to test of equality of pre-treatment time dummy variables. Callaway and Sant'Anna's (2021) approach applies a Chi-square test of equal group-time average treatment effects.

TABLE 3. BHCs in Treatment Group

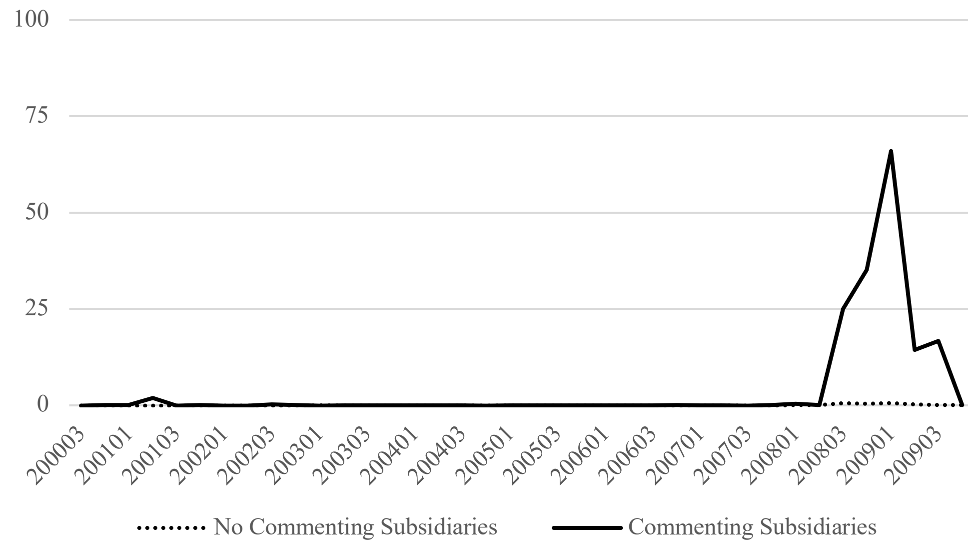
BHC	1997 Comment	2000 Comment	2003 Comment	ABS CDO Issuance	ABS CDO/Total Writedowns	TARP Disbursement
1. Bank of America	Yes	Yes	Yes	$23.4 billion	$9.10 billion/ $12.90 billion	$45.00 billion
2. Citigroup	Yes	Yes	Yes	$62.5 billion	$34.10 billion/ $55.40 billion	$45.00 billion
3. JPMorgan Chase	Yes	Yes	Yes	$10.5 billion	$1.30 billion/ $12.10 billion	$25.00 billion
4. Wachovia	Yes (through First Union merger	Yes	Yes	$29.6 billion	$1.86 billion/ $5.51 billion	(acquired by Wells Fargo)
5. Comerica	Yes	No	No			$2.25 billion
6. KeyCorp	No	Yes	No			$2.50 billion
7. PNC	Yes	Yes	No			$7.58 billion
8. State Street Bank and Trust Company	Yes	Yes	no		$6.60 billion/ $6.60 billion	$2.00 billion
9. SunTrust Banks	Yes	No	No			$4.85 billion
10. United States Bank National Association	Yes	No	No		$0.00 billion/ $0.25 billion	$6.60 billion
11. Wells Fargo	No	Yes	Yes			$25.00 billion

Note: TARP = Troubled Assets Relief Program.

Source: Write-down totals come from Creditflux Ltd. (2009).

I depict the group average values of the estimated debt guarantee for control and treatment groups in figure 2 from Q3 2000, after the 2000 Recourse Rule notice-and-comment period ended, until Q4 2009. For the control group, the average debt guarantee varies little throughout the sample, resembling those for BHCs with commenting subsidiaries, until the crisis. However, in Q3 2008, the group average debt guarantee for the treatment group (vs. the control group) rises to $25 billion (vs. $569 million), $35 billion (vs. $452 million), $66 billion (vs. $511 million), $14 billion million (vs. $323 million) and $17 billion (vs. $41 million), respectively, in Q3 2008, Q4 2008, Q1 2009, Q2 2009 and Q3 2009. That the estimated debt guarantees appear late is consistent with Milne's (2014) finding of small estimates of subsidies to shareholders until mid-2008.

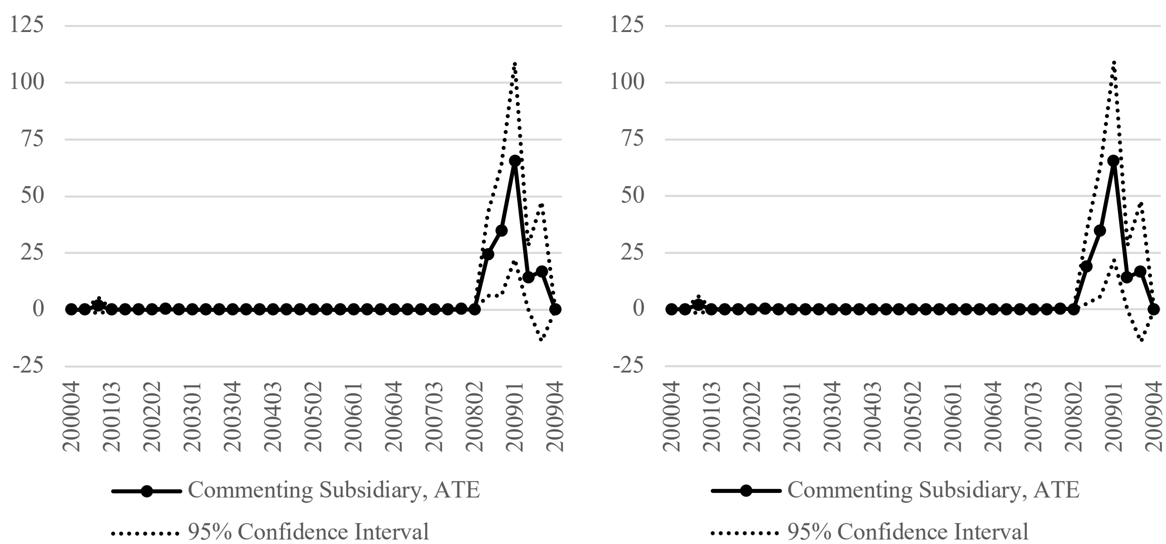
FIGURE 2. Group Average TBTF Subsidies across Control and Treatment Groups (billions of USD), Q3 2000–Q4 2009



Source: Author's estimates.

The left panel of figure 3 depicts the estimated dynamic average treatment effects (ATEs) from the unbalanced panel of 6,353 observations while the right panel depicts results for a smaller balance panel of 4,484 observations. The figures reveal no differences between the treatment and control groups during most quarters before the crisis. However, by 2008, the dynamic treatment effects for BHCs with commenting subsidiaries become larger, rising from $18.2 billion in Q3 2008 to a peak of $65 billion by Q1 2009 before falling.

FIGURE 3. Dynamic Treatment Effects, Q4 2001–Q4 2009



Source: Author's estimates.

In addition to the R-squareds for the two-way fixed effects regressions, table 4 summarizes the results of the confirmatory tests using the Mora and Reggio (2019) approach to determining the appropriateness of the parallel paths assumption based on whether common pretreatment dynamics exist. It also reports parallel trends tests based on the F-test of pretreatment dummy variables equaling zero in Cerulli (2019) and Callaway and Sant'Anna's (2021) test of equal group-time average treatment effects. The tests suggest one cannot reject the null hypothesis that common pretreatment dynamics between the treatment and control groups exist.

TABLE 4. Summary of Tests for Common Pre-Treatment Dynamics

	Unbalanced panel	Balanced panel
	Test Statistic (p-value)	Test Statistic (p-value)
Mora and Reggio (2019) common pretreatment dynamics, Wald test	7.632 (0.106)	5.361 (0.252)
Cerulli (2019) joint significance of pretreatment effects, F-test	2.000 (0.096)	1.91 (0.113)
Callaway and Sant'Anna (2021) Chi-Square test	7.760 (0.101)	5.499 (0.240)
Within R-Squared	0.378	0.375
Between R-Squared	0.429	0.418
Overall R-Squared	0.381	0.378
N	6,353	4,484

Source: Authors' estimates.

The results in this section suggest that BHCs that commented on the Recourse Rule NPRs, which would have lowered capital requirements on highly rated securitization tranches, including CDO tranches, making them more attractive to hold, had higher estimated debt guarantees during the crisis but not before. These findings offer some confirmatory evidence that supports hypothesis 2, as BHCs with Recourse Rule-commenting subsidiaries, on average had higher ex ante costs of restoring solvency, shows how regulatory changes could have exposed large securitization-active BHCs to distress.

4.3 Estimated Debt Guarantees and Trading Asset Holdings

The final exercise here shows how the estimated debt guarantees were more sensitive to CDO tranche holdings than any other trading assets. Regulators did not require BHCs to report CDO holdings before Q1 2008 or after Q1 2009, when the call report forms were revised. Therefore, I focus the analysis here on the period for which data are available; during this time, the estimated debt guarantees for the treatment group also happen to be substantial.

I estimate the sensitivity of the quarterly estimated debt guarantees expressed in billions of Q1 2010 US dollars to CDO holdings, as well as against other trading asset classes relative to total assets and other control variables using a specification of the following form:

$$G_{it} = \beta_0 + \beta_1 CDO_{i,t} + \beta X_{i,t} + \varepsilon_{it}, \quad (6)$$

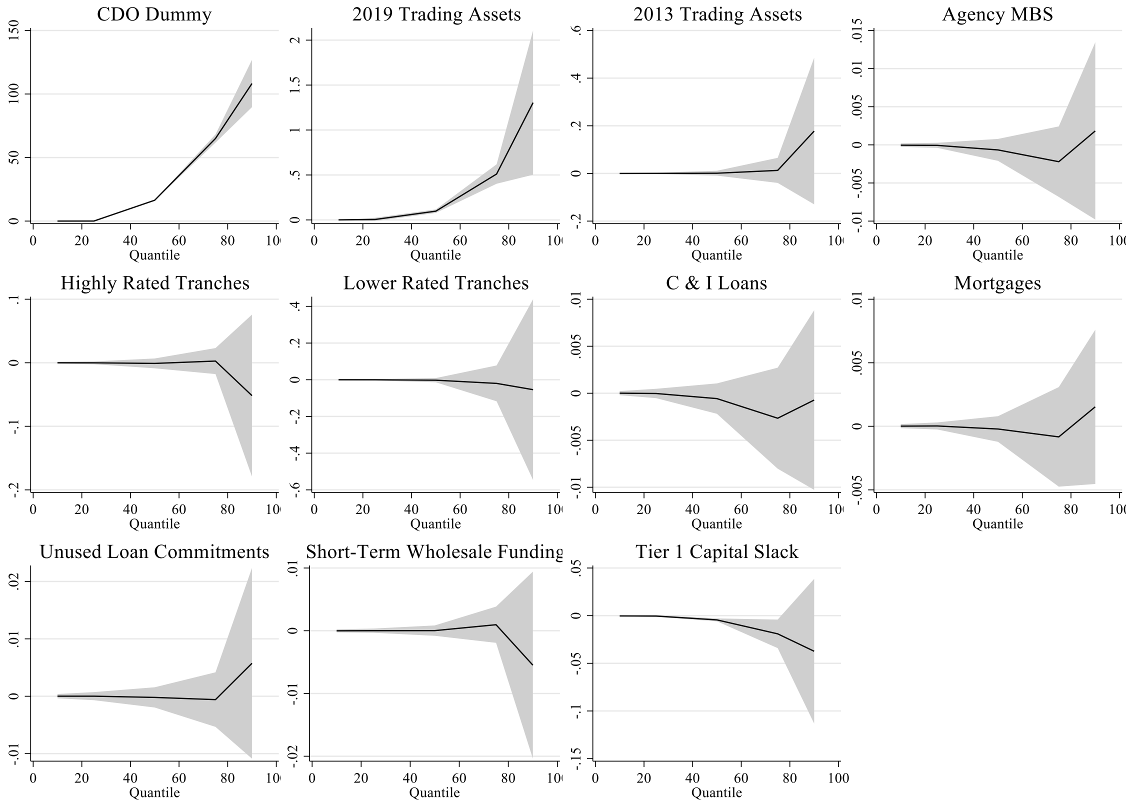
where, G_{it} is the estimated debt guarantee, $CDO_{i,t}$ is a variable that captures CDO holdings as a fraction of total assets, and $X_{i,t}$ is a matrix of other right hand side variables, the βs are the respective coefficients and ε_{it} denotes the error term. Given the limited range of values for CDO holdings, the key variable is a dummy that equals one if a BHC reports CDOs in trading accounts and zero otherwise. In the balanced sample, seven BHCs report CDO holdings: Bank of America, Citigroup, JPMorgan Chase, Keycorp, PNC, SunTrust, and Wells Fargo through its acquisition of Wachovia. In the appendix, I report results from similar regressions using the CDO share of total assets. As right hand side variables, I include (1) estimates of total assets held in trading accounts subject to the original 2013 Volcker Rule; (2) estimates of total assets held in trading accounts subject to the 2019 revision of the Volcker Rule, which reduced the various categories of assets covered by the rule; (3) agency MBSs; (4) highly rated, private-label tranches as proposed by Erel et al. (2014); and (5) lower-rated securities as in Miller (2018). In terms of other variables, I also include commercial and industrial loans as a fraction of total assets; total mortgages as a fraction of total assets; short-term wholesale funding as a fraction of total assets; unused loan commitments as a fraction of total assets; Tier 1 to risk-weighted assets minus 0.04 as in Erel et al. (2014); and dummy variables for Q2, Q3, and Q4. I summarize the construction of each variable used in the regression analysis in table A1. In table 5, I report the summary statistics for each of the variables used.

TABLE 5. Summary Statistics

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Estimated debt guarantee (billions of USD)	646	2.297	14.681	0.000	198.248
2019 trading asset share (%)	646	1.026	3.742	0.000	31.877
2013 trading asset share (%)	646	3.535	6.443	0.000	38.135
Agency MBS share (%)	646	8.973	6.287	0.000	43.518
Highly rated tranches (%)	646	1.371	3.143	-9.455	28.873
Lower-rated tranches (%)	646	1.857	4.508	-1.771	31.504
Trading CDO tranches (%)	646	0.006	0.035	0.000	0.451
Trading CDO tranche dummy	646	0.043	0.204	0.000	1.000
Commercial and industrial loan share (%)	646	12.172	7.507	0.029	48.125
Mortgage share (%)	646	47.086	15.341	0.000	85.165
Unused loan commitments (%)	646	8.134	4.624	0.000	38.099
Short-term wholesale funding (%)	646	21.942	7.873	0.912	62.047
Tier 1 to risk-weighted asset slack (%)	646	7.454	8.123	-4.324	103.771

Source: Author’s estimates.

FIGURE 4. Sensitivity of the Distribution of Quarterly Estimated Debt Guarantees (billions of USD) to Right Hand Side Variables, Unbalanced Panel Q1 2008–Q1 2009



Source: Author's estimates.

To summarize sensitivity of the distribution of debt guarantee estimates to the right hand side variables, I plot the the coefficients for each asset category at the 10th, 25th, median, 75th, and 90th percentiles in figure 4. For most variables, the solid lines in figure 4 show the coefficients change little across most of the distribution until the higher quantiles, and when they do change, the standard errors are large. The three key variables I focus on here are the CDO share of total assets, the 2013 Volcker Rule and 2019 Volcker Rule trading asset shares of total assets.

The pooled quantile regression estimates suggest that CDO holdings have a higher association with the largest rather than the smallest estimated debt guarantees. For instance, using the dummy variable for BHCs holding CDO tranches, the debt guarantees for CDO holding BHCs at the 10th/255th/median/75th/90th quantiles equal \$3.75 million/\$33.74 million/\$16.4 billion/\$64.99 billion/\$108.3 billion, respectively. The 2019 trading asset coefficients in figure 4 summarize how much more sensitive estimated debt guarantees are to 2019 trading assets relative to 2013 trading assets, due to the fact that 2019 trading assets were a subset of 2013 trading assets. For 2019 trading assets, I therefore add the coefficients to the 2013 trading asset coefficients. The results indicate that a one percentage point higher 2019 trading asset share at the 10th/25th/median/75th/90th quantile is associated with a \$0.77 million/\$5.4 million/\$98.3 million/\$523.7 million/\$1.482 billion higher debt guarantee. For the 2013 Volcker Rule trading asset classifications, the coefficients of the debt guarantees at the 10th/25th/median/

75th/90th quantiles equal $0.013 million/$0.152 million/$0.995 million/$12.9 million/$177.8 million. These results indicate that the sensitivity to CDOs (or the CDO share of total assets) is orders of magnitude greater than for trading assets, which is consistent with CDOs rather than proprietary trading assets, generally, being the source of large BHC distress during the 2008–2009. That the estimated debt guarantees have little association with agency MBSs could be consistent with the view that agency MBSs implicitly had US Treasury Department backing and did not contribute to a higher likelihood of default.[10] Also, that the estimated debt guarantees have little association with the highly rated residual could also be consistent with Ospina and Uhlig's (2018) finding that private-label MBS tranches overall exhibited good performance.

5. Conclusion

The policy response to the last crisis has tended to focus on what went wrong on the supply side of the financial system, such as mortgage origination, given that the policy response seeks to impose costs on those doing the apparent wrong. As discussed in section 2, the ABS CDO market crash was in fact the third structured product crash since the mid-1990s. Because the demand for such products continues to exist in spite of these crashes, ultimately, addressing the problem will entail understanding why that demand exists. Erel et al. (2014) and Miller (2018) have examined why BHCs held so many highly rated tranches and find that industry-specific incentives and regulatory capital can explain the increased holdings. Similarly, Merrill et al. (2019) find that risk-based capital requirements for insurance companies can explain increased holdings of highly rated tranches. Given the limited amount of data on bank holdings of CDO tranches, this study presents tests of three hypotheses to examine how regulatory factors, especially risk-based capital requirements, could have influenced issuers to supply and hold such tranches and contributed to large securitizing BHC distress.

The first empirical finding presented suggests that the increasing supply of ABS CDOs coincided with regulatory changes that lowered bank capital requirements for highly rated securitization tranches. Erel et al. (2014) find evidence of a "securitization byproduct" effect in which securitizing banks had reasons to hold highly rated securitization tranches, which is consistent with such banks responding to these regulatory changes. The second finding shows that US BHCs with subsidiaries that commented on those regulatory changes had higher estimated debt guarantees in Q1 2008–Q1 2009. Because the rise occurred suddenly, this could explain the drastic official measures taken in an effort to stabilize the banking system. The third finding shows that BHC holdings of CDO tranches are associated with significantly higher estimated debt guarantees, whereas other trading asset categories had a much lower sensitivity. Although conventional wisdom tends to attribute the distress experienced by large, securitizing BHCs arising from CDO exposures during the 2007–2009 crisis to market failure, the distress also reflects a regulatory failure, even if unintended. Bank regulation, especially for regulatory capital, has become increasingly complex and verbose in the 25 years between the unveiling of US Basel I in 1988 and the implementation of US Basel III in 2013 (Herring 2016; Herring 2018; Barth and Miller 2018).

Those complex regulatory standards, by lowering bank capital requirements on highly rated, private-label securitization tranches, in turn exposed a handful of large US BHCs to ABS CDO risks. The rule changes meant banks were encouraged to take on even more risk under conditions

[10] For discussions of the government-sponsored enterprise subsidies, see Cook and Spellman (1992) and Lucas and McDonald (2006).

whereby they were less prepared to absorb risk. Although securitization has benefits, it does not mean such tranches merit other regulatory privileges through, for instance, lower capital requirements, especially given the frequency of structured product crashes. Simpler, higher-equity capital requirements (Admati and Hellwig 2013; Admati et al. 2014; Black 1975; Cochrane 2014) offer one solution to the recurring problem of banks reducing regulatory capital by holding assets with low risk weights.

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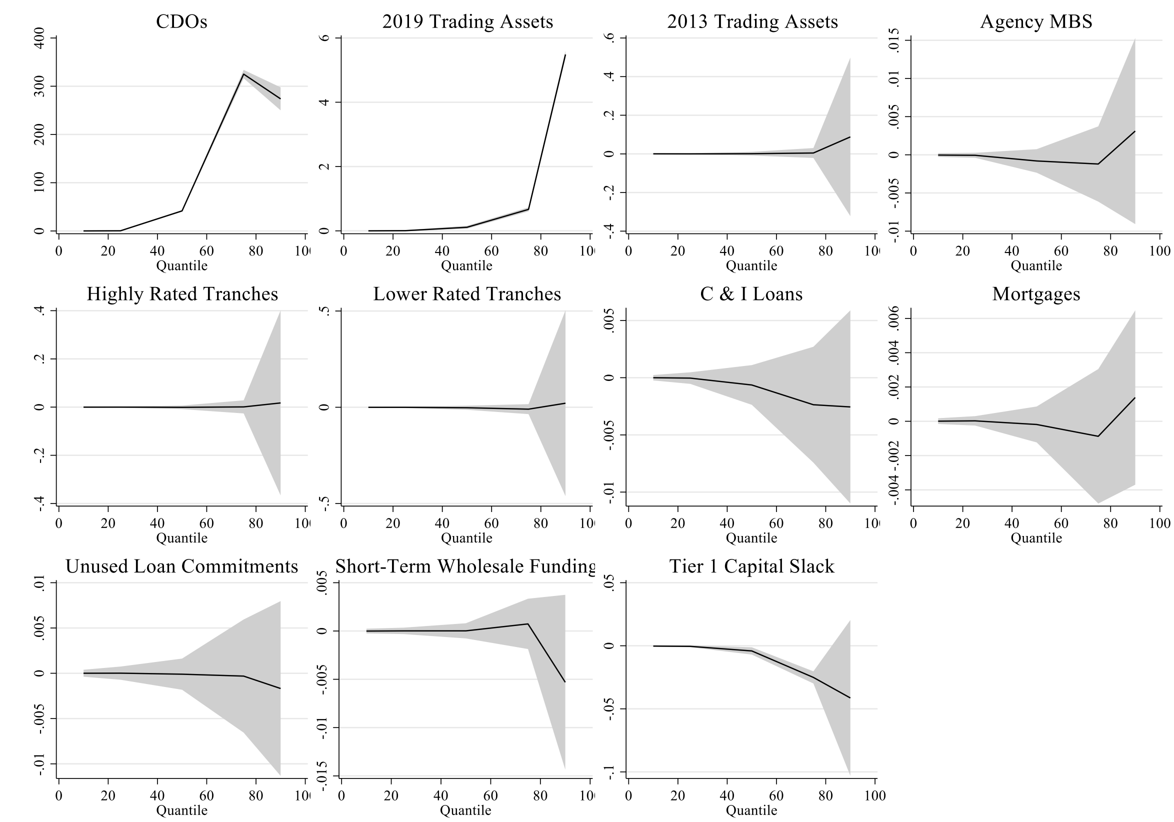
Appendix

TABLE A1. Variable Construction for Regression Analysis

Variable Name	Transformation Applied to Raw Series
End-of-quarter Merton (1977) put option prices	Using equations (1) and (3), solve for the unobservable market value of assets and their (1977) put option prices volatility after substituting values for the observable variables to get the numerical solutions. For the market value of equity, multiply the end-of-quarter shares by the market price for each bank using data from the Center for Research in Security Prices (CRSP) database available from https://wrds-web.wharton.upenn.edu/wrds/. Then merge the CRSP data with the call report data using the Federal Reserve Bank of New York's dataset "2023-3," available from https://www.newyorkfed.org/research/banking_research/datasets.html. As an estimate of bank debt, use total bank deposits from Compustat. For the interest rate, use the use the quarterly rate of return on the 90-day US Treasuries from CRSP. For the annualized historical equity return volatility input, multiply the quarterly standard deviation of daily stock return by the square root of four. The time-to-maturity equals 1. Lastly, as the option price inputs get reported as thousands of USD, divide the values by one million to get put option values expressed in billions of USD.
BHC with Recourse Rule commenting subsidiary	Dummy variable that equals one if the BHC has a subsidiary that commented on the Recourse Rule as reported in table 3; and equals zero otherwise.
CDO holdings	The sum of "trading assets: collateralized debt obligations: synthetic" (bhckf649), and "trading assets: collateralized debt obligations: other" (bhckf650) divided by total assets (bhck2170) for results in table A2; if missing, the variable equals zero. Alternatively, a dummy variable that equals one if the share of CDO to total assets is positive; or equals zero otherwise for results in table 6.
2019 Volcker Rule trading asset share	The sum of "all other mortgage-backed securities" (bhcm3536), "other debt securities" (bhcm3537), "other trading assets" (bhcm3541), "derivatives with a positive fair value" (bhcm3543), and "total trading liabilities" (bhct3548) divided by total assets (bhck2170).
2013 Volcker Rule trading asset share	The sum of the 2019 Volcker Rule trading asset share and the quantity of the sum of "other pass-through securities" (bhck1713), "all other mortgage-backed securities" (bhck1736), "asset backed securities" (bhckc027), "other domestic debt securities" (bhck1741), "foreign debt securities" (bhck1746), "investments in mutual funds and other equity securities with readily determinable fair values" (bhcka511), "gross positive fair value: interest rate contracts" (bhck8741), "foreign exchange contracts" (bhck8742), "equity derivative contracts" (bhck8743), "commodity and other contracts" (bhck8744), "gross negative fair value: interest rate contracts" (bhck8745), "foreign exchange contracts" (bhck8746), "equity derivative contracts" (bhck8747), and "commodity and other contracts" (bhck8748) divided by total assets (bhck2170).
Highly rated residual	Estimate by Erel et al. (2014) of the highly rated residual equals the sum of securities with risk weights of 0.2 held to maturity (bhc21754) and available for sale (bhc21773), securities with risk weights of 0.5 held to maturity (bhc51754) and available for sale (bhc51773), and all other MBSs in trading accounts (bhck3536) minus the quantity of the sum of GSE-issued US government agency obligations held to maturity (bhck1294) and available-for-sale (bhck1297), MBSs issued by Freddie Mac and Fannie Mae held to maturity (bhck1703) and available for sale (bhck1706), other MBSs issued by Freddie Mac, Fannie Mae, and Ginnie Mae held to maturity (bhck1714) and available for sale (bhck1716), other collateralized MBSs issued by Freddie Mac, Fannie Mae, and Ginnie Mae held to maturity (bhck1718) and available for sale (bhck1731), and municipal securities held to maturity (bhck8496) and available for sale (bhck8498) divided by total assets (bhck2170).

Lower-rated residual as a fraction of total assets	The quantity of the sum of total securities held to maturity (bhck1754) and available for sale (bhck1773) and total trading assets (bhck3545) minus the quantity of the sum of total securities with risk weights of 0.0 held to maturity (bhc01754) and available for sale (bhc01773), trading assets with risk weights of 0.0 (bhc03545), the quantity of total securities with risk weights of 0.2 held to maturity (bhc21754) and available for sale (bhc21773), and trading assets with risk weights of 0.2 (bhc23545) and the quantity of total securities with risk weights of 0.5 held to maturity (bhc51754) and available for sale (bhc51773) and trading assets with risk weights of 0.5 (bhc53545) divided by total assets (bhck2170).
Agency MBSs as a fraction of total assets	This variable only includes the quantity of the sum of Fannie Mae and Freddie Mac passthroughs held to maturity amortized cost (bhck1703) and available for sale amortized cost (bhck1706), other MBSs issued by Ginnie Mae, Fannie Mae, and Freddie Mac held to maturity amortized cost (bhck1714) and available for sale amortized cost (bhck1716), other MBSs collateralized by MBSs issued by Ginnie Mae, Fannie Mae, and Freddie Mac held to maturity amortized cost (bhck1718) and available for sale amortized cost (bhck1731), and other Ginnie Mae, Fannie Mae, and Freddie Mac MBSs in domestic offices, trading accounts (bhck3535) divided by total assets (bhck2170).
Commercial and industrial loans as a fraction of total assets	The sum of commercial and industrial loans to US addressees (bhck1763) and foreign addressees (bhck1764) divided by total assets (bhck2170).
Total mortgages as a fraction of total assets	Total loans secured by real estate (bhck1410) divided by total assets (bhck2170).
Short-term wholesale funding as a fraction of total assets	The quantity of the sum of time deposits of $100,000 or more (bhcb2604), commercial paper (bhck2309), other borrowed money with a remaining maturity of one year or less (bhck2332), federal funds purchased in domestic offices (bhdmb993), securities sold under agreements to repurchase (bhckb995), and trading liabilities (bhck3548) divided by total assets (bhck2170).
Unused loan commitments as a fraction of total assets	The quantity of the sum of revolving, open-end loans secured by one- to four-family residential properties, such as home equity lines (bhck3814) and credit card lines (bhck3816) divided by total assets (bhck2170).
Tier 1 to risk-weighted assets minus 0.04	The slack in the quantity of Tier 1 capital (bhck8274) divided by risk-weighted assets (bhcka223) minus 0.04.

FIGURE A1. Sensitivity of the Distribution of Quarterly Estimated Debt Guarantees (billions of USD) to Right Hand Side Variables, Unbalanced Panel Q1 2008–Q1 2009



Source: Author's estimates.