Fire Buys of Central Bank Collateral Assets*

Calebe de Roure
Frankfurt School of Finance & Management

Abstract

When central banks provide unlimited liquidity, banks raise their demand for collateral assets, and the short-term scarcity of collateral securities leads to higher prices, the Fire Buy premium. To avoid collateral scarcity, central banks increase the set of eligible collateral assets. However, if the risk-shifting channel is open for these newly eligible securities, banks prefer to pledge them and pay another premium, the Risk-Shifting premium. With the full fixed-income trading book of 26 German banks, I identify each trade of each bank and investigate how unlimited liquidity provision affects collateral prices. Also, I match banks' trades with their balance sheet and show how funding liquidity impacts premia payment. I quantify the Fire Buy premium to be 22.5 bps, which demonstrates that unlimited central bank liquidity provision imposes extra costs on banks exactly during stress periods; and the Risk-Shifting premium on BBB-rated assets to be 20.4 bps, which prices the severity of the risk-shifting channel in the Eurosystem. My results speak in favor of more differentiation among counterparties in the ECB haircut policy.

Keywords: Fire Buy, Risk-Shifting, Haircut Subsidy, ECB, Over-the-Counter Markets

JEL classification: E41, E44, E58, G11, G14, G15, G21

*Contact: calebederoure@gmail.com, https://sites.google.com/site/calebederoure/. I am deeply indebted to Falko Fecht for his advice and continuous willingness to help. Also, I am grateful for comments from Tobias Berg, Ben Craig, Darrell Duffie, Dimitris Georgarakos, Yalin Gündüz, Michael Kötter, Jochen Mankart, Margit Münzer, Martin Oehmke, Loriana Pelizzon, Larissa Schäfer, Sascha Steffens, participants in the Bundesbank Forschertreffen, Bundesbank Spring Conference (2016), 33^{rd} Meeting of the French Financial Association (AFFI), 2017 Annual Meeting of the American Finance Association and seminars at the Goethe University Frankfurt and Frankfurt School of Finance & Management. Financial support from the Bundesbank for my Ph.D. is gratefully acknowledged.

1 Introduction

In times of financial distress and malfunctioning of the interbank market, central banks often provide banks with unlimited liquidity. In order to access central bank liquidity, banks need to pledge eligible collateral assets. Thus, unlimited central bank liquidity provision may have an impact on the secondary market for these securities. Since the unrestricted provision of liquidity takes place precisely in periods of financial distress, adverse effects on this market may challenge financial stability when it matters most. The scope of the present study is to analyze how changes in central bank liquidity provision impact the secondary market for collateral assets, potentially affecting financial stability.

In 2008, after the Lehman Brothers collapse, many banks lost the access to the European interbank market. In order to provide funding liquidity for those banks and avoid fire sales spirals, the ECB decided to provide unlimited liquidity. Therefore, the ECB changed its usual form of liquidity provision based on variable-rate auctions to fixed-rate full allotment (FRFA) tenders. In this setup, banks can draw as much funds as they desire as long they have enough collateral to pledge. Hence, the demand for collateral assets increases and banks pay a premium to acquire these securities, the Fire Buy premium.[1] In order to mitigate this effect, the ECB enlarged its collateral framework to accept BBB-rated assets. However, the haircut the ECB applies to these assets does not reflect transactions' risk, i.e. these securities enjoy a haircut subsidy.[2,3] Since banks can exploit this subsidy from the ECB, they are willing to pay a further premium to acquire these assets, the Risk-Shifting premium. The objective of this paper is to present evidence for the existence of both premia and quantify them.

For this end, I match the fixed-income trading book of 26 German banks with their funding liquidity in ECB open market operations. My results show that after the introduction of FRFA tenders banks pay a Fire Buy premium of 22.5 basis points, and the 90^{th} percentile bank pays 20.4 bps more than the median to acquire BBB-rated collateral assets, the Risk-Shifting premium.[4] To the best of my knowledge, I am the first to link changes in the central bank collateral framework with prices of fixed-income instruments. My contribution is twofold. First, the existence of the Fire Buy premium demonstrates that the implementation of unlimited central bank liquidity provision imposes an extra cost on banks when they need liquidity most. Second, the Risk-Shifting premium prices how much banks value the risk-shifting mechanism in the Eurosystem. Moreover, it underscores the fact that haircut subsidy as a form of financial support for banks is not an efficient policy because the subsidy is passed on to other banks in form of premium

[1] Not only banks with limited access to the interbank market increased their demand for collateral assets but in general banks tend to hoard liquidity during financial crisis, s. e.g. Heider, Hoerova, and Holthausen (2015).

[2] In 2010, the ECB reviewed its haircut policy and concluded that haircuts applied to BBB-rated assets should be revised upwards. This revision was implemented on 1^{st} January 2011. See Appendix and ECB press release "ECB introduces graduated valuation haircuts for lower-rated assets in its collateral framework as of 1 January 2011" from April 4^{th} 2010.

[3] BBB-rated assets are investment grade and, by definition, good quality collateral. Thus, this study does not address the riskiness level of these assets but rather the haircut applied to them.

[4] As comparison, the 10 years German Bund, the safest assets in the ECB collateral pool, yielded on average ∼400 bps in 2008. In October 2008, the BBB-spread averaged ∼600 bps (measured by the Bank of America US Corporate BBB Option-Adjusted Spread).

payment.

My identification strategy offers a rare opportunity to match banks' trading behavior (at the bank-security level) with banks' funding liquidity. Therefore, I use several valuable data sets. First, I have the full fixed income trading book of 26 German banks. With this data set I can identify for each transaction the security being traded, the buyer, the seller, the size and the price of the trade (among other variables). Second, I am able to look into banks' balance sheet and recognize how much liabilities they have against the Eurosystem. In this way, I am able to identify how dependent a bank is on central bank funding and link it to its respective trading behavior. Third, I have the list of eligible collateral assets at the ECB as published on its website and the rating applied by the ECB to each security.[5] Thus, I can unambiguously identify how a bank's trading behavior changes with the FRFA announcement and conditional on its central bank funding liquidity.

My study relates to the literature on unlimited central bank liquidity provision. Bagehot (1873) proposes that, in times of financial distress, monetary authorities should lend in an early and unlimited manner to solvent banks, against appropriate collateral at high interest rates. Rochet and Vives (2004) provide a formal model for Bagehot's doctrine, in which even in modern interbank markets, central bank's liquidity intervention is desired. Drechsler, Drechsel, Marques-Ibanez, and Schnabl (2016) and Fecht, Nyborg, Rocholl, and Woschitz (2015) link unlimited central bank liquidity provision to the risk-shifting channel, when the haircut does not cover the collateral risk, liquidity provision is under-collateralized and the monetary authority bears a part of the risk. Both studies present evidence that relatively weaker banks, in the search for yield, use ECB facilities to access disproportionately high quantity of liquidity using lower-quality collateral.[6] My study expands the literature on unlimited central bank liquidity provision and the risk-shifting channel by investigating their effects on the secondary market for collateral assets and pricing how much banks value the risk-shifting channel when liquidity is unlimited.

My study also relates to the literature on OTC markets because price discrimination is a necessary condition for the Risk-Shifting premium. Securities eligible as collateral in central bank operations are debt instruments, which are mainly traded over-the-counter (OTC). In OTC markets, prices are a result of a bargaining process between counterparties, and price differentiation occurs; see e.g., Duffie, Gârleanu, and Pedersen (2005), Duffie, Gârleanu, and Pedersen (2007), and de Roure, Mönch, Pelizzon, and Schneider (2016). In Duffie et al. (2005), an agent's bargaining power is given by the outside option to trade, i.e. how quickly an agent can find another counterparty to liquidate the trade. Therefore, unlimited central bank liquidity provision may reduce banks' bargaining power in two ways. First, banks may want to execute the trade more quickly so they can pledge the asset as collateral. Second, banks needing central bank liquidity tend to hold their collateral assets, reducing the matching probability between buyers and sellers. Hence, my study complements the literature on OTC markets by linking monetary policy to prices of fixed-income instruments through the bargaining power channel.

In OTC markets, non-dealers participants normally pay a premium to trade with

[5]For a given security the binding rating for the ECB is the best one among the accepted agencies. In 2008, the ECB accepted only ratings from the big three agencies: Standard & Poor's, Moody's and Fitch. In 2009, the ECB started accepting ratings from DBRS.

[6]Specifically banks in need of liquidity prefer the ECB funds market to the interbank market because the ECB only applies a haircut based only on the security risk, whereas in the interbank market, haircuts also take into consideration the correlation between pledged collateral risk and counterparty risk.

dealers; see e.g. Li and Schürhoff (2014). Thus, a possible criticism of my findings is that the premia described in this study may be driven by the OTC market structure. In order to disentangle these the Fire Buy and the Risk-Shifting premia from the premium paid to trade with a dealer, I identify trades having dealers as counterparty and test if my findings are affected by that. I find no evidence that the dealer-non-dealer structure of OTC markets drive my results. Furthermore, I perform other falsification tests. My results are robust to anticipation effects and to interaction with Lehman Brothers bankruptcy.

My inferences are based on the almost simultaneous implementation of FRFA tenders (October 8^{th}) and the expansion of the ECB collateral framework to accept BBB-rated collateral assets (October 15^{th}). This feature poses no real concern for my identification strategy because both policies act in opposite directions. Whereas the FRFA increases the demand for collateral assets, the expansion of the collateral framework increases the supply of collateral assets. Hence, the inclusion of BBB-rated securities in the collateral framework act against the identification of the Fire Buy premium and allows the identification of two effects in the same period.

2 Theoretical Underpinning

2.1 Fire Buy Theory

In all open market operations, the monetary authority requests collateral and imposes a haircut on the collateral value to mitigate credit risk; see e.g., Chailloux, Gray, and McCaughrin (2008), Cheun, von Köppen-Mertes, and Weller (2009). Thus, when providing unlimited liquidity, central banks induce banks to acquire collateral assets.

The *Fire Buy* theory is based on the short-term scarcity of collateral assets. When central banks introduce unlimited liquidity provision, banks' demand for collateral assets increase. In the short term, these assets are in limited supply. Thus, the increased demand leads to higher prices, the Fire Buy premium.

The reason why central banks provide unlimited liquidity is to provide funding liquidity to banks in times of financial distress. The counterfactual of this policy is that some banks would have no other form to refinance themselves potentially starting fire sales spirals. Thus, trying to avoid fire sales the monetary authority creates fire buys of collateral assets, which represents one cost related to the provision of unlimited central bank liquidity. However, the Fire Buy premium cannot be interpreted as an argument against full allotment tenders because its welfare lost is probably smaller than the costs of no action.[7] In fact, the Fire Buy premium is an argument in favor of the expansion of the collateral framework when the provision of liquidity is unlimited, as indeed the ECB acted.

Banks prefer central bank liquidity over cash, the most liquid asset, because cash has a negative real return whereas central bank liquidity usually has positive returns, i.e. the yields on the collateral asset stay with the banks. In this sense, central bank liquidity is cheaper than cash. Thus, during financial crisis, when banks hoard liquidity, it is cheaper to hoard central bank collateral assets then cash.

[7] A welfare analysis between the costs and the gains from unlimited central bank liquidity provision goes beyond the scope of this study.

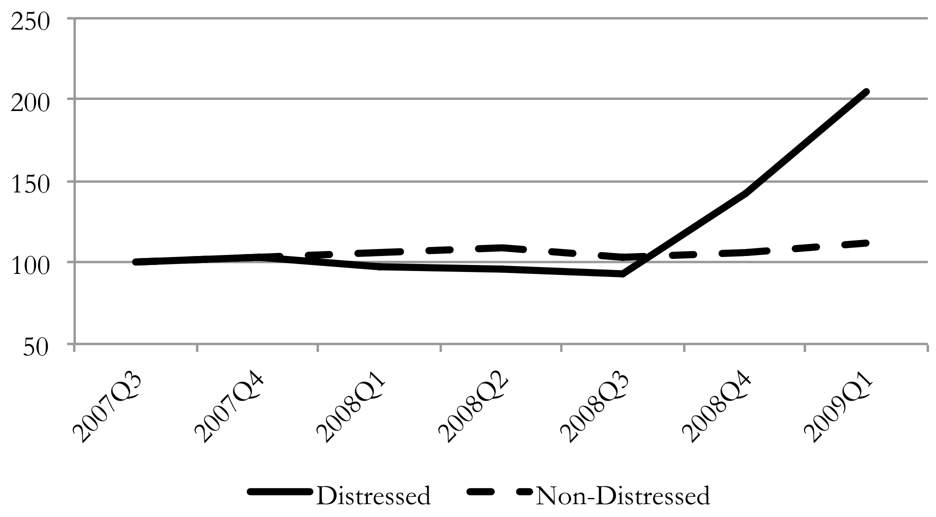

Figure 1: **Banks Holdings of ECB Eligible Collateral Assets.** Asset values adjusted for the respective haircut aggregated across banks in two groups. Values normalized to 100 in third quarter 2007 and correspond to the holdings on the last day of each quarter. Source: Security Holdings Statistics, Deutsche Bundesbank, Bade et al. (2016).

To illustrate how FRFA tenders increase banks' demand for assets eligible as collateral at the ECB, I present Figure 1 as anecdotal evidence. I use the Security Holdings Statistics of the Deutsche Bundesbank (Bade et al. (2016)), a quarterly data set that contains all asset holdings (security-by-security) of all 26 banks (bank-by-bank). I sum up the holdings (haircut-adjusted) of all eligible collateral assets at the ECB divided in two groups and normalize to 100 in 2007Q3. The first group, which I call *distressed*, represents ten banks in the sample that were rescued by the German government (central or regional) later in the crisis.[8] The second group I name *non-distressed*; it comprises the remaining 16 banks.

Figure 1 shows that before the implementation of fixed-rate full allotment tenders in 2008Q3 both lines move in parallel. In the following two quarters, distressed banks double their haircut-adjusted holdings of ECB collateral assets. This sharp increase suggests that specifically banks with liquidity needs adjusted their portfolio towards holding more ECB eligible collateral assets. The kink in 2008Q3 illustrates my identification strategy, the introduction of FRFA tenders change banks' demand curve for collateral assets. In the following sections I investigate the price impact of this increased demand.

A shortcoming of the graph is that it presents two simultaneous effects. First, the increased demand for collateral assets. Second, the change in the definition of eligible collateral assets to accept BBB-rated assets, which added more securities to the Single List.[9] Hence, the sharp increase is a mixture of increased demand for collateral assets

[8] The SoFFin, or *Sonderfonds Finanzmarktstabilisierung* and in English *Financial Market Stabilisation Fund*, provided liquidity through guaranteed debt issued by eligible financial institutions, also by direct investment in banks' equity and purchase of securities in open market operations. The program was designed by the German federal government. In addition, Figure 1 also includes banks that were rescued by state governments.

[9] The Single List is a list published every day on the ECB's website containing all securities accepted as collateral in its open market operations.

and the acceptance of new securities potentially already in banks' books.

2.2 The Risk-Shifting Theory

The *risk-shifting* theory says that some banks may use central bank liquidity lines to shift risks from their balance sheet to the monetary authority. This channel is open when the haircut applied by the central bank is below the market. In this case, transactions are undercollateralized, and the central bank bears part of the loss should issuer and counterparty default. In the Eurosystem, this haircut subsidy is higher for lower-rated collateral securities (Drechsler et al. (2016)). Hence, banks can pledge low-rated collateral to the ECB and leave better quality assets for other operations. In this way, banks are able to increase their yields by substituting collateral assets.

The reason why collateral arbitrage benefits banks differently is that in private repos they receive haircuts based on the collateral risk *and* on the correlation risk between collateral and their own counterparty risk, whereas in the ECB funds market haircuts adjust only to security risk. For instance, an Austrian and a Portuguese bank of similar rating might receive different haircuts in private repos when using a Portuguese sovereign bond as collateral. This differentiation happens because, in the scenario where Portugal is bankrupt, Portuguese banks are also likely to be bankrupt, whereas an Austrian bank would be less affected. This correlation risk is not taken into account in the Eurosystem (see Fecht et al. (2015) for further discussion).[10]

The *Risk-Shifting premium* is the premium banks in great need of central bank liquidity pay to acquire lower-rated collateral assets. They are willing to pay this extra premium because they can increase their yields through the risk-shifting channel by at least this amount. The Risk-Shifting premium enhances the *risk-shifting* theory by focusing on the effects of monetary policy design on the secondary market for collateral assets. Its existence demonstrates that the risk-shifting channel is so wide that banks are willing to pay a hefty premium to purchase lower-rated collateral assets.

The empirical identification of the Risk-Shifting premium is based on two components. First, the implementation of fixed-rate full allotment tenders, which increases the demand for collateral assets as described by the kink in Figure 1. Second, the expansion of the ECB collateral framework to accept BBB-rated assets. In this setup, one would expect that banks more dependent on ECB funds would pay more to acquire BBB rated collateral assets.

The use of two contemporaneous policies' implementation to identify the Risk-Shifting premium is possible because both policies act in different directions. On the one hand, the ECB has expanded its collateral framework to accept BBB-rated collateral assets in order to cover the scarcity of collateral assets by increasing the supply of these assets. On the other hand, when acquiring these newly eligible assets banks with lower bargaining

[10] The ECB explains: "*In contrast to commercial banking practice, where haircuts can be set at more stringent levels for counterparties with higher perceived credit risk, the Eurosystem, in line with its mandate to maintain a level playing field among market participants, cannot apply differentiated haircuts in its policy operations, i.e. haircuts that would depend on the creditworthiness of the counterparty. Furthermore, the Eurosystem calculates the haircut on an asset-by-asset basis, not adjusting the haircuts to the diversification or concentration features of the collateral pool. Additionally, the Eurosystem retains the ability to apply additional discretionary haircuts on an asset.*" Source: The Financial Risk Management of the Eurosystem's Monetary Policy Operations, ECB website.

power pay a premium. Hence the expansion of the collateral framework militates against the existence of the Fire Buy premium, whereas the identification of the Risk-Shifting premium is based on both policies simultaneously.[11]

The Risk-Shifting premium arises only because collateral assets are traded OTC, where prices are opaque and discrimination occurs. Duffie et al. (2005) and Duffie et al. (2007) demonstrate that prices in OTC markets are not unique but rather a result of a bargaining process, where the bargaining power is the outside option to trade and price discrimination occurs. The outside option to trade is given by how quickly an agent can find another counterparty to liquidate the trade. In the present context, changes in the collateral framework influence bargaining power in two ways. First, they impose timing pressure on the execution of the trade so that banks can use the asset as collateral. Second, they induce banks to hold more collateral assets, which reduces the number of sellers, increases the number of buyers, and affects the matching probability in OTC markets. Thus, monetary policy affects banks' trading behavior through the bargaining power channel.

The existence of the Risk-Shifting premium has twofold implications. First, on the presence of haircut subsidies the provision of central bank liquidity is also a financial support. If this subsidy was provided intentionally to support banks during the financial crisis, it was not an efficient policy because the financial support was passed on to other banks in the form of premium payments. Second, if banks are willing to incur a Risk-Shifting premium, it is because they can exploit the risk-shifting channel by at least this amount. Thus, the Risk-shifting premium prices how much a bank values the collateral arbitrage and serves as indicator of how severe the risk-shifting channel is.

3 Data

3.1 Data Sources

The innovation of the present study is to use a novel data set that allows me to identify trading behavior in the security-bank dimension and match it with banks' respective balance sheet. To this end, I merge several data sets. First, banks' fixed income trades provided by the German Federal Financial Supervisory Authority (BaFin). Second, the daily list of assets eligible as collateral at the ECB and their respective ratings made available by the Deutsche Bundesbank. Third, banks' balance sheet statistics, also furnished by the Deutsche Bundesbank.

Section 9 of the German Securities Trading Act states that all credit and financial services institutions must report to the German Federal Financial Supervisory Authority (BaFin) any transaction in securities or derivatives which are admitted to trading on a regulated market (including over-the-counter trades). From this data source, I obtained all fixed income transactions by 26 German banks between January 1^{st} and December 31^{st} 2008 including the buyer, seller, security, time, price and quantity.[12] Each trade is reported only once and can be a positive (buy order) or a negative value (sell order). In order to prevent small trades from driving my results I exclude all trades with a volume

[11]More precisely, for the identification of the Risk-Shifting premium only the expansion of the collateral framework is necessary. However, the unlimited central bank liquidity provision contributes to the identification by increasing the demand for newly eligible collateral assets.

[12]The time period and bank sample are chosen according to data availability.

smaller than €100,000.00 or the equivalent thereof. Trades are treated on a daily basis; in case a bank trades the same security more than once a day, I average prices weighted by their order size. The data set distinguishes between proprietary and client trade. Here I focus only on own-account trades. For the purpose of this paper, I am only interested in buy orders and abstract from short positions.

Every day the ECB publishes a list of all assets eligible as collateral, also called the Single List. This document is a list containing all securities (security-by-security) accepted by the ECB including information on their coupon, haircut, issuance and maturity dates, and other characteristics. By comparing the changes in the assets in the list, I am able to identify which assets have been added to and removed from the ECB collateral framework. Moreover, I received from the Bundesbank a list broken down by the asset rating applied by the ECB. From this data set, I am able to identify which securities in banks' trading book belong to the ECB Collateral Framework, and categorize them by ratings and haircut.

To avoid issues regarding the issuance and maturity of assets during the observation period, I focus only on assets that were in the list at the beginning and at the end of the year (except for BBB assets that were only added in October).

The Balance Sheet Statistics of the Deutsche Bundesbank (BISTA) provide a monthly bank-by-bank overview of banks' activities. Among other variables, it contains the size of banks (total assets) and the total central bank funds in their balance sheet. With this information, I create the main explanatory variable central bank funding/TA$_{bw}$ among others. All variables are provided monthly and interpolated into weekly data.

	Mean	Std Error	10^{th} pcl	25^{th} pcl	50^{th} pcl	75^{th} pcl	90^{th} pcl	# Obs
C.B. Funding/TA	0.049	0.046	0.002	0.017	0.035	0.064	0.117	1,331
log(Total Assets)	18.54	0.862	17.32	17.76	18.71	19.28	19.55	1,331
Equity Ratio	0.030	0.014	0.013	0.021	0.028	0.037	0.050	1,331
Interbank Liabilities	0.290	0.137	0.121	0.157	0.302	0.396	0.491	1,331
Net Position Interbank	-0.013	0.091	-0.142	-0.076	-0.001	0.050	0.101	1,331
Security Portfolio	0.240	0.106	0.100	0.165	0.223	0.318	0.396	1,331

Table 1: **Distribution of Bank Variables.** C.B. Funding/TA is banks' liabilities to the ECB over total assets, Equity Ratio is equity over total assets, Interbank Liabilities are liabilities to other monetary financial institutions over total assets, Net Position Interbank are claims minus liabilities to other monetary financial institutions over total assets, Security Portfolio is the holding of stocks and fixed-income instruments over total assets. Weekly data for 2008. Source: Balance Sheet Statistics of the Deutsche Bundesbank.

3.2 Descriptive Statistics

Table 1 describes bank specific characteristics of the 26 banks in the sample in weekly frequency. The first covariate presents banks' reliance on central bank funding as a share of their size, the variable of our primary interest. In the sample, the ECB provides 3.5%

of a median bank's liabilities. This figure increases to 11.7% at the 90^{th} percentile. The other bank variables are used as control covariates. Bank size, log(Total Assets), is defined in €1,000 before taking logs, i.e. banks average total assets are €112 billion. Equity ratio is the amount of bank equity over total assets and averages 3% in the sample. Interbank liabilities represents the amount of funds raised in the interbank market and is defined as share of total assets. Similarly, Net Position Interbank represents banks reliance on the interbank market and is defined as the difference between loans provided and loans received in the interbank market over total assets. Its average value is -1.3%, which suggests that there are more banks lending in the interbank market than borrowing in the sample. Security Portfolio is the share of securities holding (stocks and fixed-income instruments) to total assets. On average, 24% of banks assets are securities.

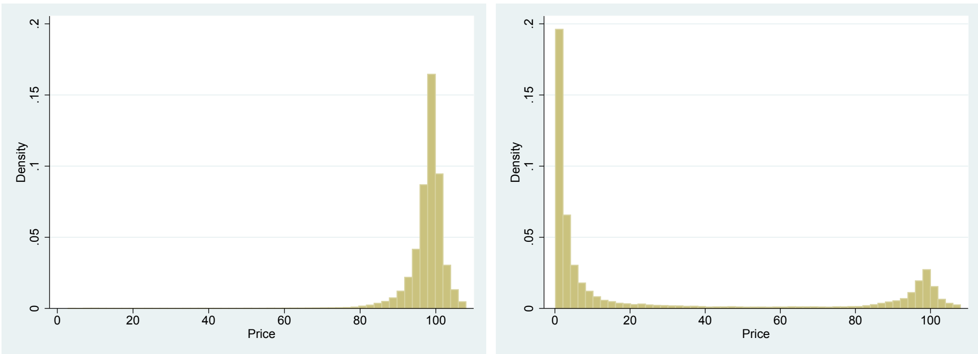

Figure 2: **Distribution of Asset Prices by Eligibility Status** (unrestricted sample). Left: Eligible Assets, mean 97.76, std error 4.71 and # obs 1,938,192. Right: Non-Eligible Assets, mean 21.37, std error 35.06 and # obs 1,001,792. Source: BaFin.

Figure 2 presents the distribution of the the price of fixed-income instruments in two categories: eligible (left) and non-eligible (right) as collateral in the ECB framework. The distribution of eligible assets is somewhat well behaved around 100, whereas the distribution non-eligible includes many assets with a very low nominal value. In order to avoid a very different control group, I exclude non-eligible collateral assets that their average price was below €30 in the first half year of 2008.

Table 2 describes variables relevant for the pricing of fixed-income securities used as control variables. Weekend and holiday values are interpolated so they can be matched with trade on those days. VIX is the implied volatility of the S&P 500 and used as a measure of market wide risk aversion. The average value, 32.64, represents the expected range of movement in the S&P 500 index over the next year. To represent the yield curve I use the one and three months as well as the one year Euribor. Their respective average values are 4.27, 4.63, and 4.81, which suggests an upward sloping yield curve. Market liquidity is measured by the number of trades in the last 5 trading days and its average value is 17.76. Order size represents the size of the trade and is defined in number of securities. Typically, fixed-income securities have a face values of 100. The average order size is 4,795,784, which is far more than the median 26,000 suggesting very large outliers.

Table 3 presents the mean and standard errors of securities characteristics of eligible assets.[13] Assets are divided into four categories according to Table 9 in the Appendix: (I)

[13]For the purpose of this study, I aggregate assets rated AAA and AAA- into AAA, securities rated

central government debt instruments and debt securities issued by central banks; (II) local and regional government debt instruments, Jumbo Pfandbrief, agency and supranational debt instruments; (III) covered bonds, traditional Pfandbrief, credit institution debt instruments, debt instruments issued by corporates; (IV) asset-backed securities (ABSs). In general terms, prices tend to be around 100 and with a standard deviation of around 3. This feature is common in fixed-income assets, where a par value is paid at maturity. Thus, the use of security fixed effects accounts for most of the variation in prices. Furthermore, the average haircut ranges mostly between 3% and 4% for assets rated AAA, AA, and A; and 7% to 10% for BBB assets. Although theoretically haircuts could go up to 20%, the mean is far lower. Lastly, assets of type (III) are the most populated.

	Mean	Std Error	10^{th} pcl	25^{th} pcl	50^{th} pcl	75^{th} pcl	90^{th} pcl	# Obs
VIX	32.64	16.29	19.6	21.98	25.1	41.63	59.98	365
Euribor 1M	4.27	0.482	3.52	4.19	4.37	4.48	4.59	365
Euribor 3M	4.63	0.515	3.97	4.38	4.85	4.96	4.96	365
Euribor 1Y	4.81	0.591	4.07	4.39	4.95	5.34	5.42	365
Liquidity	17.76	31.32	0	1	6	20	50	110,611
Order Size	4,795,784	3.23×10^8	2000	5000	26000	209,000	3,000,000	449,751

Table 2: Distribution of security control variables. VIX is the CBOE volatility index and represents risk-aversion, Euribor 1M is the European one month reference rate (3M three months and 1Y one year), Liquidity is the cumulative number of trades in the previous 5 trading days, Order Size is the size of the trade order in number of securities. Source: Bloomberg and BaFin

4 The Fire Buy Premium

4.1 Empirical Strategy

In this section, I investigate whether banks pay more to buy ECB collateral assets after the introduction of fixed-rate full allotment tenders. In my data set, for every transaction I have a bank identifier for buyer and seller. Given that I am interested in a purchase premium, I focus only on buy orders. In Section 6, I present results using sell orders as a falsification test. My estimation strategy is a differences-in-differences model (before/after FRFA, eligible/non-eligible as collateral assets), as:

$$p_{ibt} = \alpha_1 FRFA_t \times eligible_{iw} + \alpha_2 FRFA_t + \alpha_3 eligible_{iw} + \Gamma X_{it} + \theta p_{it-1} + \Delta_i + \Delta_{bw} + \Delta_w + u_{ibt} \quad (1)$$

AA+, AA, and AA- into AA and similarly for rates A and BBB.

	Category I				Category II				Category III				Category IV			
	AAA	AA	A	BBB	AAA	AA	A	BBB	AAA	AA	A	BBB	AAA	AA	A	BBB
Price	100.67	99.72	98.3	101.30	98.28	97.31	-	100.97	96.57	96.14	96.23	95.96	95.30	-	-	-
	(4.54)	(3.29)	(4.82)	(3.30)	(2.88)	(2.24)	-	(2.01)	(3.95)	(4.53)	(4.25)	(4.38)	(4.18)	-	-	-
Mean Coupon (%)	4.00	4.12	4.51	3.67	3.69	3.62	5.40	3.97	3.09	3.39	4.27	4.28	4.30	-	4.88	-
	(0.83)	(0.86)	(1.00)	(0.82)	(0.91)	(0.61)	(0.52)	(0.55)	(1.07)	(1.16)	(0.92)	(0.96)	(0.74)	-	(0.00)	-
Mean Haircut (%)	3.22	1.63	2.96	9.77	3.58	3.43	5.73	10.75	3.94	3.87	4.17	7.93	5.10	-	2.00	-
	(1.35)	(2.39)	(2.30)	(209)	(1.21)	(1.08)	(3.04)	(0.66)	(1.51)	(1.69)	(1.42)	(1.64)	(3.45)	-	(0.00)	-
Mean Days-to-Maturity	2,470	1,985	2,927	1,693	1,334	1,311	5,579	1,154	1,126	1,163	1,255	1,017	5,616	-	585	-
	(2,409)	(2,396)	(3,362)	(209)	(980)	(721)	(3,209)	(501)	(834)	(821)	(761)	(781)	(5,097)	-	(17)	-
Monthly # Trades	13,064	3,335	679	78	12,521	303	4	202	8,600	12,782	9,002	2,797	205	-	4	-
	(4,199)	(1,541)	(276)	(35)	(3,731)	(104)	(4)	(154)	(2,068)	(2,063)	(2,451)	(1,526)	(106)	-	(2)	-
Monthly Turnover	7,060	1,520	224	1.7	2,080	66.2	11.6	2.9	19,900	389	254	91.1	155	-	2.2	-
(in € billion)	(3,680)	(931)	(171)	(2)	(1,020)	(49.8)	(12.1)	(3.3)	(65,200)	(135)	(84.4)	(74.4)	(79.3)	-	(2.8)	-
# Assets	272	146	40	7	599	48	4	30	2,235	1,346	856	310	348	0	1	0

Table 3: Mean and standard errors of securities characteristics by rating and ECB categories. Monthly number of trades, mean over months. Maturity of perpetual bonds treated as 100 years. Category I: central government debt instruments, debt instruments issued by central banks; Category II: local and regional government debt instruments, Jumbo Pfandbrief, agency and supranational debt instruments; Category III: covered bonds, traditional Pfandbrief, credit institution debt instruments, debt instruments issued by corporates; Category IV: asset-backed securities. Note: with the expansion of the collateral framework, the ECB created a further category (uncovered debt) which is excluded from the analysis since I do not observe any trade with these assets. Missing prices omitted for confidentiality reasons. Source: BaFin and ECB.

where p_{ibt} is the price bank b pays for security i at day t,[14] $FRFA_t$ is a dummy variable that takes the value of 1 after the ECB announces fixed-rate full allotment tenders on October 8^{th} 2008,[15] $eligible_{iw}$ is a dummy that takes the value of 1 if the ECB accepts security i in week w as collateral and zero otherwise, X_{it} is a vector of security control variables, Δ_i, Δ_{bw} and Δ_w are security, bank-week and week fixed effects, respectively, and u_{ibt} is the error term. Further, in order to avoid autocorrelation I include the AR(1) process. The lagged price variable, p_{it-1}, is a constructed variable based on the interpolation of prices within the sample and does not necessarily mean that the asset was traded at this price on the previous day. Note that the standalone variable, $eligible_{iw}$, refers only to assets that a change in the eligibility status occurs, as the eligibility status for all other variables is captured by security fixed-effects.

The use of time-varying bank fixed-effects accounts for all variation in the bank-week dimension and dismisses the use of bank control variables. In the present context, the use of security-week fixed effect would also account for all variation in this dimension including the price effect of FRFA on eligible assets that goes beyond the week of implementation. Thus, the use of bank-week and security-week fixed effect is a very restrictive approach that only identifies the Fire Buy premium within the week of the policy implementation. As the cross section of securities in the sample is large enough to identify this effect, I also estimate Equation (1) with security-week fixed effects to test the short term impact of FRFA on eligible assets.

In summary, for the estimation of Equation (1), I use all buy positions of the fixed income trading book and compare whether assets eligible as collateral were purchased at a premium. Formally I test,

Hypothesis 1*: Given the scarcity of ECB collateral assets, banks pay a Fire Buy premium after the introduction of FRFA tenders by the ECB,* $\alpha_1 > 0$.

In order to match weekly with daily variables, I repeat the week value in all days of the week. I opted for this method because balance sheet statistics are reported on a monthly basis and interpolated into weekly data. Interpolating the data further into daily statistics would add no economic meaning.

To identify the Fire Buy and the Risk-Shifting premia I use one side of the trade: buy positions. I focus only on this side of the market because it is the side where the restrictions on bargaining power are binding. In other words, banks reliant on ECB funds have fewer outside options to trade when buying collateral assets, which is probably not the case when banks sell these assets.

The second part of my identification strategy for the Fire Buy investigates whether FRFA tenders encourage banks to buy more ECB collateral assets. In so doing, I estimate a linear probability model (OLS) using a differences-in-differences approach (before/after FRFA, eligible/non-eligible as collateral assets), as:

[14] I use prices instead of yields because the majority of the trades are widespread.

[15] In Equations (1) and (2) $FRFA_t$ is not suppressed because the fixed-effects are defined weekly whereas $FRFA_t$ daily.

$$fb_{ibt} = \beta_1 FRFA_t \times eligible_{iw} + \beta_2 FRFA_t + \beta_3 eligible_{iw} + \Pi X_{it} + \omega fb_{ibt-1} + \Delta_i + \Delta_{bw} + \Delta_w + e_{ibt} \quad (2)$$

where fb_{ibt} equals 1 if bank b buys security i at day t and zero otherwise. For estimation of Equation (2) I expand the data sample with zeros for all combinations of bank-security-time, where no trade takes place.

In Equation (2), the diff-in-diff interaction term tests whether the introduction of FRFA increases the probability that banks buy collateral assets in the secondary market. If the coefficients β_1 is significant and positive, banks are more likely to buy collateral assets. Formally,

Hypothesis 2*: After the introduction of FRFA, banks are likelier to buy ECB collateral assets,* $\beta_1 > 0$

4.2 Results

Before introducing the formal estimation of the Fire Buy premium, I present Figure 3, which illustrates the monthly average price paid by banks in the sample for fixed-income securities aggregated in two groups: eligible and non-eligible as collateral in the ECB. Figure 3 shows that the price of both groups deteriorate over the year, however in November and December the price of eligible collateral assets increase again, which illustrates my identification strategy.

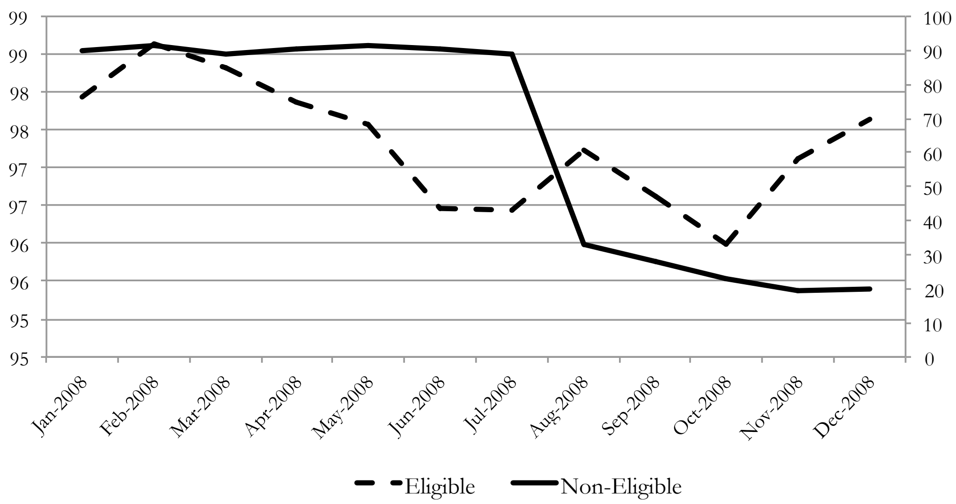

Figure 3: **Security Prices.** Monthly average price of securities aggregated by eligible (left axis) and non-eligible (right axis) at the ECB collateral framework. Sources: own calculation, BaFin, ECB.

In Table 4, Regressions (I) and (IV) present the estimations of Equations (1) and (2), the Fire Buy premium. Regressions (II) and (V) are similar but instead of using security control variables, they use security-week fixed effects. Regression (III) and (VI) expand (I) and (IV), respectively, with a third interaction term, the increase in ECB dependence.

Regression (I) shows that after the introduction of FRFA banks pay a Fire Buy premium of 22.5 bps. The result is significant at the 1% level and is in line with Hypothesis 1: banks pay a Fire Buy premium to buy ECB collateral assets after the introduction of FRFA tenders.

The significance of $FRFA_t$ shows that all assets in the sample became cheaper after the introduction of FRFA. This effect is clearly presented in Figure 3 and relates to the prices fall in the last quarter of 2008. Also, all other control variables are significant at the 5% level and with the expected coefficient. Higher market volatility, VIX_t, relates to lower prices; higher short-term interest rates, $euribor1M_t$ and $euribor3M_t$, relates to higher prices; higher medium term interest rates, $euribor1Y_t$, relates to lower prices; assets traded more often, $liquidity_{it}$, relate to lower prices; and larger trades, Order Size_{it}, have larger price impact.

Regression (II) uses security-week fixed effects instead of control variables. The main result holds: banks pay 15.6 bps premium to buy eligible collateral assets after the introduction of unlimited liquidity provision. The cost of using this approach is that demeaning prices in the security-week dimension also extract all possible price impact of FRFA that goes beyond the week of its implementation. Therefore, the effect captured by this coefficient is identified only within the week of the policy implementation and can be seen as the short-term impact of FRFA.

Regression (III) expands (I) with a third interaction term $ECBreliant_b$. This variable represents banks in the sample that substantially increased their liabilities against the Eurosystem after the introduction of unlimited liquidity provision.[16] Therefore, I define $ECBreliant_b = 1$ for all banks that have a larger increase in their liabilities against the ECB than the median bank (this represents a 25% increase or more). The two-way interaction term, $FRFA_t \times eligible_{iw}$, and the three-way interaction term are positive and significant. All banks pay a 9.8bps Fire Buy premium, and banks that had a significant increase in their liabilities against the ECB pay a further 15.2 bps. This result suggests that banks with higher liquidity need also pay a more severe Fire Buy premium.

Regression (IV) is in line with my second hypothesis: after the introduction of unlimited central bank liquidity provision banks buy 0.07 more collateral assets for every 100 trades. Introducing a third interaction term, $ECBreliant_b$, we find that specially banks that increased their liabilities against the ECB were the ones buying more collateral assets at a somewhat higher probability, 0.3%, which suggests that banks in great need of central bank liquidity are also likelier to buy collateral assets.

All estimations in Table 4 present a very high overall R^2, over 0.9. This number means that almost all data variation is explained by the model. The within R^2 shows that this value is also driven by the fixed-effects and not only by the regressors of interest. A further factor that increases these values is the use of lagged variables, which is needed to avoid autocorrelation issues.

A common concern regarding estimations with high R^2 is the serial correlation of the error term. I address this issue with the Wooldridge (2010) test for autocorrelation in panel data. In the last line of Table 5, the p-value of the test is presented. There, we find that the inclusion of the AR(1) process excludes the possibility of autocorrelation at the 5% confidence level.

[16]For a given bank, I compare its mean liability against the ECB before and after FRFA.

	(I) p_{ibt}	(II) p_{ibt}	(III) p_{ibt}	(IV) fb_{ibt}	(V) fb_{ibt}	(VI) fb_{ibt}
FRFA_t	-0.269***	-0.329***	-0.073	1.55×10^4	-6.33×10^4*	4.67×10^4**
	(0.046)	(0.086)	(0.078)	(2.13×10^4)	(3.40×10^4)	(2.22×10^4)
Eligible_{iw}	-0.034		-0.014	-0.001*		0.012***
	(0.034)		(0.037)	(0.000)		(0.001)
FRFA_t*Eligible_{iw}	0.225***	0.156**	0.098*	7.24×10^4***	9.52×10^4	-5.83×10^4**
	(0.036)	(0.080)	(0.059)	(2.34×10^4)	(0.002)	(2.93×10^4)
FRFA_t*ECBreliant_b			-0.250***			6.74×10^4
			(0.093)			(4.74×10^4)
ECBreliant_b*Eligible_{iw}			-0.026			-0.028***
			(0.021)			(0.001)
FRFA_t*ECBreliant_b*Eligible_{iw}			0.152**			0.003***
			(0.066)			(5.97×10^4)
VIX_{t-1}	-0.005***		-0.005***	1.54×10^6		1.59×10^6
	(0.001)		(0.001)	(7.23×10^6)		(7.21×10^6)
euribor1M_{t-1}	0.217***		0.215***	9.98×10^4		0.001
	(0.076)		(0.076)	(9.56×10^4)		(0.001)
euribor3M_{t-1}	0.537***		0.537***	-0.003*		-0.003*
	(0.196)		(0.196)	(0.002)		(0.002)
euribor1Y_{t-1}	-1.840***		-1.841***	0.002		0.002
	(0.169)		(0.169)	(0.001)		(0.002)
liquidity_{it}	-2.123×10^4**		-2.09×10^4**	-1.46×10^5***		-1.47×10^5***
	(0.000)		(0.000)	(1.05×10^6)		(1.06×10^6)
log(Order Size_{it})	0.004***		0.004***	0.070***		0.070***
	(0.001)		(0.001)	(0.001)		(0.001)
AR(1)	Yes	Yes	Yes	Yes	Yes	Yes
Security	Yes	No	Yes	Yes	No	Yes
Week	Yes	No	Yes	Yes	No	Yes
Bank-Week FE	Yes	Yes	Yes	Yes	Yes	Yes
Security-Week FE	No	Yes	No	No	Yes	No
adj. R^2	0.996	0.998	0.998	0.936	0.719	0.937
adj. within R^2	0.946	0.289	0.946	0.916	0.629	0.917
# Obs	190,602	303,601	190,602	5,293,340	5,693,506	5,293,340
Autocorrelation	0.000	0.000	0.000	0.000	0.000	0.000

Table 4: **Fire Buy premium.** (I-III) Fire Buy premium estimation, (IV-VI) Fire Buy linear probability model (OLS), Equations (1) and (2), respectively. p_{ibt} is the nominal price paid by bank b for security i on day t; fb_{ibt} takes the value of 1 if bank b buys security i on day t and zero otherwise; FRFA_t takes the value of 1 after its announcement on October 8^{th}, 2008 and zero otherwise; $CBfunding/TA_{bw}$ is the ratio of ECB funds to total assets; $Eligible_{iw}$ takes the value of 1 if asset i is eligible at week w; $ECBreliant_b$ equals one if bank b increases its liabilities against the ECB more than the median bank after FRFA implementation and zero otherwise. Variables with subscript t are defined daily and w weekly. Standard errors in parentheses and clustered in the bank-security dimension. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Autocorrelation gives the p-value for the Wooldridge (2010) test for autocorrelation in panel data, where H_0 is autocorrelation.

In summary, this section concludes that, after the introduction of FRFA tenders, collateral assets became more expensive and banks were more likely to buy them. Moreover, the Fire Buy premium is higher and more likely to happen to banks that increased their liabilities against the ECB by more than 25% in the last quarter of 2008.

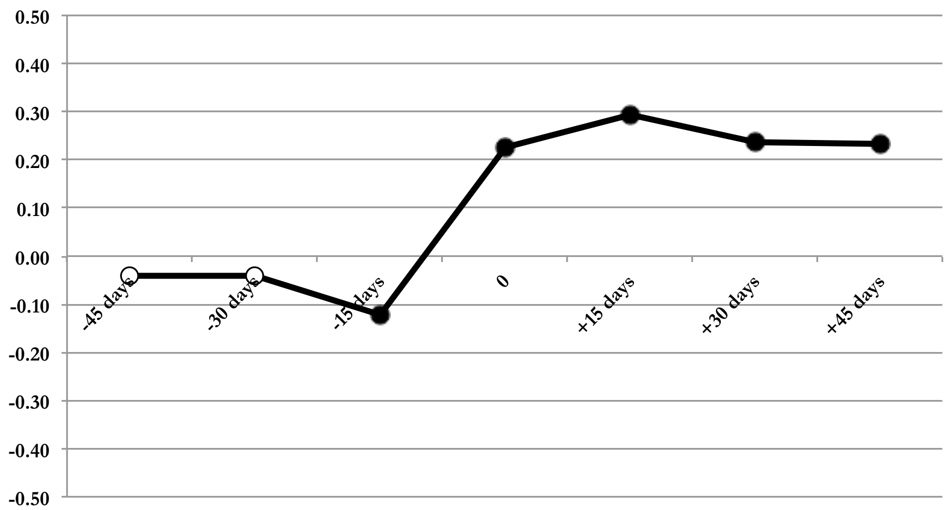

Figure 4: **Fire Buy Premium Anticipation Effect.** Coefficients of interaction term $\text{FRFA}_t \times eligible_{iw}$ using placebo dates for $FRFA_t$. Empty points represent statistical insignificance at the 5% level. Source: own calculation.

4.3 Anticipation Effect

The difference-in-differences empirical strategy is based on the idea that the causality is due to the treatment, the implementation of FRFA tenders. If agents anticipate the actions of the ECB before its introduction, they may react before the announcement and the coefficient of my estimations could be underestimated. Therefore, I estimate Equation 1 using placebo treatment dates: 45, 30, 15 days before the actual announcement of the policy. In this case, I restrict the sample until the day of the policy implementation (8^{th} of October). Similarly, to test whether the effect vanishes with time I estimate Equation 1 using placebo treatment dates: 45, 30, 15 days after the actual announcement of the policy.

Figure 4 presents the coefficient of the interaction term, α_1, for estimations described above. An empty dot means that the value is not statistically significant different from zero, whereas black dots are. The figure shows that up to 30 days before the actual policy implementation eligible assets were not significantly more expensive than non-eligible. 15 days before the relative price decreases before increasing with the policy and remaining at levels above 20 bps until 45 days after the policy.

Figure 4 presents no evidence for an anticipation of the Fire Buy premium.

5 The Risk-Shifting Premium

5.1 Empirical Strategy

In this section, I approach the question whether banks in great need of central bank money pay a premium for lower-rated collateral, the Risk-Shifting premium. Therefore, I look into the subset of eligible assets divided by rating category (AAA, AA, A, and BBB) and estimate a two-way interaction model using $CBfunding_{bw}$ and $FRFA_t$, as:

$$p_{ibt} = \lambda_1 FRFA_t * CBfunding/TA_{bw} + \lambda_2 FRFA_t + \lambda_3 CBfunding/TA_{bw} + \Phi W_{ibt} + \eta p_{it-1} + \Delta_i + \Delta_b + \Delta_w + \epsilon_{ibt} \quad (3)$$

$CBfunding/TA_{bw}$ is the ratio of central bank liabilities to total liabilities of bank b in week w. In the present context, the reliance on central bank liquidity is an indicator that banks have poor access to interbank markets and need to obtain funding from the central bank. Thus, central bank funding is an indicator of how distressed a bank is. The Risk-Shifting premium is identified using a level variable, $CBfunding/TA_{bw}$, because it accounts to what extent banks can explore the risk-shifting channel (total amount). This approach differs from the one used to identify the Fire Buy premium, in which I divided banks based on the change in ECB dependence. W_{ibt} is a vector of security and bank control variables.

In Equation (3) the coefficient of the interaction term, λ_1, represents how reliance on ECB funds influences the premium payment after the introduction of FRFA tenders. In this context, I test:

Hypothesis 3: *Banks in greater need of ECB funds pay a premium for lower-rated collateral assets,* $\lambda_1^{BBB} > 0$.

5.2 Results

In order to illustrate the Risk-Shifting premium, I present Figure 5. It shows the mean price of BBB-rated collateral paid by two group of banks: above and below the median of $CBfunding/TA_{bw}$. Until October 2008, the upper median pays continuous less than the lower median. After the introduction of FRFA this figure reverses and the upper median pays more in November and December. This movement illustrates my identification strategy for the Risk-Shifting premium: with unlimited central bank liquidity banks more reliant on ECB funds pay a premium to explore the risk-shifting channel.

In order to understand how severe the risk-shifting channel is I estimate Equation (3) for the full sample of collateral assets and for 4 rating subsamples (AAA, AA, A, and BBB). As before, all estimations use only the buy side of the market. Table 5 presents the result of the regressions.

Regression (I) presents the estimation for the full sample, i.e. including collateral of all ratings. The variable of our primary interest is the interaction between the ratio of central bank funds to total liabilities ($CBfunding/TA_{bw}$) and the dummy representing the introduction of fixed-rate full allotment tenders ($FRFA_t$). The coefficient of the

	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
	p_{ibt}	p_{ibt}	p_{ibt}^{AAA}	p_{ibt}^{AAA}	p_{ibt}^{AA}	p_{ibt}^{AA}	p_{ibt}^{A}	p_{ibt}^{A}	p_{ibt}^{BBB}	p_{ibt}^{BBB}
FRFA_t*CBfunding/TA_{bw}	4.90***	-1.28	2.95*	-0.358	0.844*	-0.196	0.794	-1.63	2.49***	8.001***
	(1.35)	(0.902)	(1.63)	(1.42)	(0.489)	(2.88)	(0.495)	(2.11)	(0.937)	(2.80)
FRFA_t	-0.893***	-0.074	-0.600***	0.063	-0.119**	-0.176	-0.389***	-0.451***	-0.332*	-0.629***
	(0.096)	(0.056)	(0.113)	(0.093)	(0.057)	(0.125)	(0.111)	(0.182)	(0.150)	(0.232)
CBfunding/TA_{bw}	-1.63		-0.727		-0.846**		0.517		0.060	
	(1.15)		(1.14)		(0.411)		(0.632)		(0.891)	
VIX_t	0.017***		0.023***		0.003**		0.006**		0.003	
	(0.002)		(0.002)		(0.001)		(0.002)		(0.002)	
euribor1M_t	0.632***		0.404		0.463***		0.336		-0.030	
	(0.233)		(0.283)		(0.178)		(0.235)		(0.368)	
euribor3M_t	1.41***		2.43***		0.369		0.014		-0.130	
	(0.368)		(0.385)		(0.377)		(0.337)		(0.458)	
euribor1Y_t	-3.84***		-4.31***		-0.901***		-0.820***		-0.453	
	(0.222)		(0.225)		(0.246)		(0.201)		(0.291)	
liquidity_{it}	0.003***		0.004***		-0.001**		-0.001***		0.001	
	(0.000)		(0.000)		(0.000)		(0.000)		(0.001)	
log(Order Size_{bw})	0.021***		0.014***		0.007***		0.004		0.007	
	(0.003)		(0.003)		(0.002)		(0.004)		(0.008)	
log(Total Assets_{bw})	-1.83***		-1.01*		-0.602***		0.072		0.316	
	(0.588)		(0.609)		(0.197)		(0.169)		(0.229)	
Equity Ratio_{bw}	-22.82***		-8.51**		-2.52		-0.855		-4.54**	
	(4.82)		(4.34)		(1.67)		(1.27)		(2.46)	
Interbank Liabilities_{bw}	-2.12		0.580		0.809		0.109		-2.67*	
	(1.71)		(1.58)		(0.650)		(0.799)		(1.48)	
Net Interbank_{bw}	0.525		-1.09		-0.652		0.396		1.20*	
	(1.51)		(1.73)		(0.461)		(0.542)		(0.617)	
Security Holdings_{bw}	4.75*		6.17***		0.808		0.255		2.74*	
	(2.81)		(2.67)		(0.802)		(1.36)		(1.58)	
AR(1)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Security FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Week FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Bank-Week FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Security-Week FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
adj. R^2	0.957	0.993	0.985	0.994	0.992	0.993	0.987	0.989	0.989	0.990
adj. within R^2	0.012	0.263	0.021	0.270	0.922	0.273	0.927	0.230	0.905	0.162
# Obs	108,355	87,960	56,668	47,191	22,225	15,996	15,286	12,342	8,298	6,416
Autocorrelation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5: **Risk-Shifting Premium**, Equation (3). (I-II) Sample includes all eligible collateral assets, (III-IV) only AAA-rated, (V-VI) only AA-rated, (VII-VIII) only A-rated, (IX-X) only BBB-rated. p_{ibt} is the nominal price paid by bank b for security i on day t; FRFA_t takes the value of 1 after its announcement on October 8^{th}, 2008 and zero otherwise; $CBfunding/TA_{bw}$ is the ratio of ECB funds to total assets; and lagged prices are based on the interpolation of transaction prices from all banks. Variables with subscript t are defined daily and w weekly. Standard errors in parentheses and clustered in the bank-security dimension. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Autocorrelation gives the p-value for the Wooldridge (2010) test for autocorrelation in panel data, where H_0 is autocorrelation.

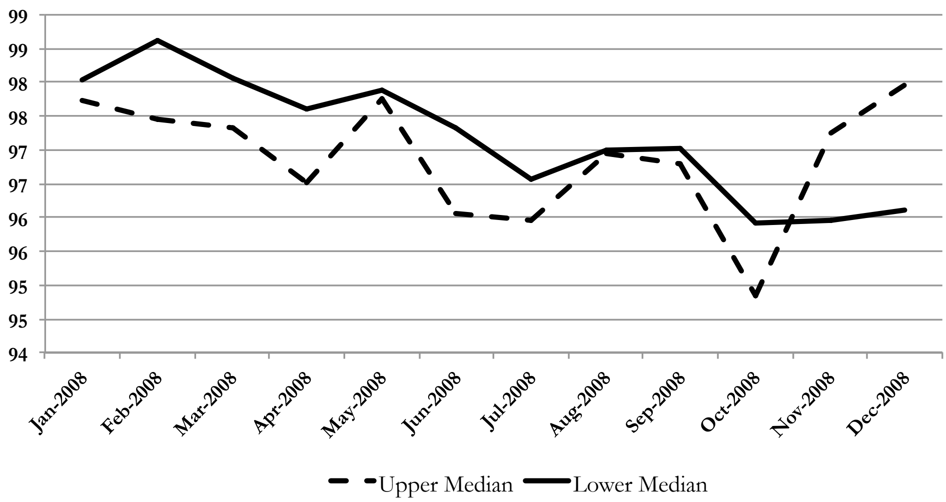

Figure 5: **Security Prices.** Average price of BBB-rated collateral assets aggregated by bank group. Upper and lower median refer to banks dependence of ECB funds. Source: own calculation.

interaction term is positive and significant. Suggesting that banks more reliant on ECB funds also pay more for collateral assets after the treatment. This estimation confirms the result from the previous section: banks more reliant on ECB funds also pay more for collateral assets after FRFA. Security control variables have similar signs as in Table 4 apart from VIX_t and $liquidity_{it}$. Here higher market volatility relates to higher prices and liquidity also. On the bank dimension, bank size, log(Total Assets$_{bw}$), and equity ratio are related to lower prices. The amount of credit a bank obtains from the interbank market, Interbank Liabilities$_{bw}$, and the net position in the interbank market (loans provided minus loans received), Net Interbank$_{bw}$, are not significantly related to prices; the amount of securities on bank balance sheets, Security Holdings$_{bw}$ is positively related.

Regressions (III), (V), (VII) and (IX) repeat the estimation of Equation 3 for the 4 rating subsamples. For AAA-rated and AA-rated collateral assets, the coefficient of the interaction term is positive and significant at the 10% level. This result relates to the fly-to-quality effect presented by Beber, Brandt, and Kavajecz (2009) among others, which suggests that during financial crisis banks adjust their security holdings towards higher quality assets. I do not investigate further this effect because it has been extensively discussed in the previous literature.

Regression (IX) shows that, for BBB-rated collateral assets, the coefficient is also positive and significant at the 1% level, which is in line with my third hypothesis: banks pay an extra premium to access the risk-shifting channel. Also, it suggests that the median bank pays 8.7 basis points (=0.035*2.49) to buy BBB-rated collateral assets, whereas banks in the 90^{th} percentile pays 29.1 bps (=0.117*2.49). The difference between these banks illustrates the Risk-Shifting premium, 20.4 basis points. In other words, banks more reliant on ECB funds are willing to pay on average 20.4 basis points to acquire BBB-rated collateral assets.

Regression (X) applies time-varying fixed effects and confirms this result. The latter approach accounts for all observable and non-observable effects on the security-week and bank-week dimensions and dismisses the use of control variables. However, it comes as the cost that the in this estimation the Risk-Shifting premium is only identified within the week of the treatment. Nevertheless, the result is statistically significant at the 1% level. A similar calculation for the Risk-Shifting premium suggests it could be up to 65.6 bps $(8.001 \times 0.117 - 8.001 \times 0.035)$.

The existence of the Fire Buy and the Risk-Shifting premia suggest two confounding effects. The possibility of raising unlimited liquidity from the central bank and the scarce provision of collateral assets lead banks to pay a premium to acquire these securities. In order to avoid a shortage of collateral assets and mitigate the Fire Buy premium, the ECB enlarged its collateral framework to accept BBB-rated assets. However, the haircut applied to these assets does not cover all risks related to the transaction. Banks exploiting the haircut subsidy pay a further premium to acquire BBB-rated collateral assets. If the haircut reflected all risks related to the operation, the risk-shifting channel would be closed, and yield seeking banks would not pay the Risk-Shifting premium. At the limit, we can interpret the Risk-Shifting premium as how much a bank can increase its yield by pledging the particular asset and shifting the extra risk to the ECB. Hence, the Risk-shifting premium prices gains from the risk-shifting mechanism.

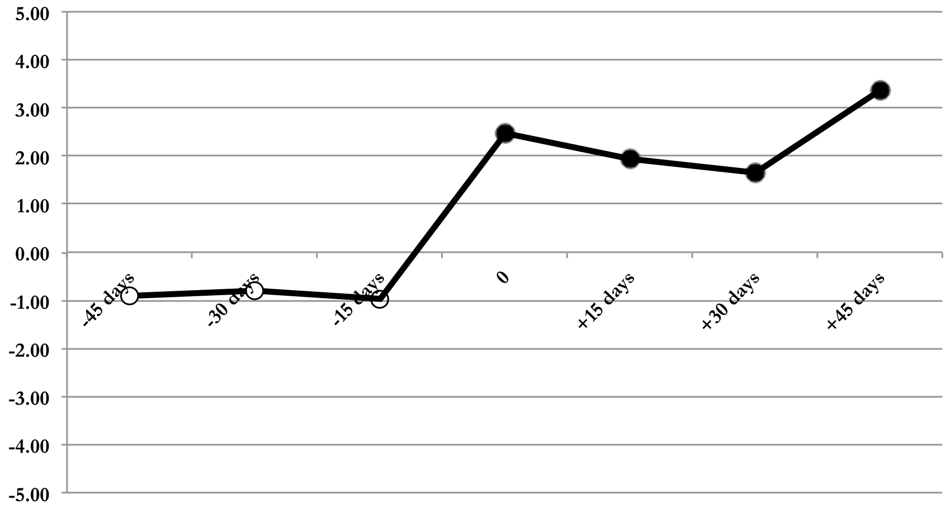

Figure 6: **Risk-Shifting Premium Anticipation Effect.** Coefficients of interaction term $\mathrm{FRFA}_t \times CBfunding/TA_{bw}$ using placebo dates for $FRFA_t$. Empty points represent statistical insignificance at the 5% level. Source: own calculation.

5.3 Anticipation Effect

In this section, I test whether banks could anticipate the Risk-Shifting premium and potentially start incurring it before the policy implementation. Therefore, I set a placebo treatment dates 45, 30, and 15 days before and after the actual policy announcement. The coefficient of the interaction term of these estimations are presented on Figure 6.

The coefficient of the placebo treatments before the actual implementation of FRFA are not significant at the 10% level, which suggests no anticipation effect. After the FRFA implementation, the Risk-Shifting premium decreases 15 and 30 days after the implementation and increases again 45 days after.

6 Falsification Tests

In this section, I present supporting evidence for the causal effect of the treatment, $FRFA_t$. I address three issues using falsification tests. First, is the network structure of OTC markets (dealers vs non-dealers) influencing my results? Second, are the results driven by the fact that I am looking only into buy orders? Third, are the results driven by the Lehman Brothers bankruptcy about a month before the ECB's actions?

6.1 Dealer-Non-Dealer Structure of OTC Markets

In over-the-counter markets, price differentiation occurs according to the network structure of the market. Periphery participants (non-dealers) pay a premium to trade with the core (dealers); see e.g. Li and Schürhoff (2014). In order to disentangle a premium payment attributed to the network structure from the proposed premia I identify trades in which dealers are the counterparty. For each trade I am able to identify both counterparties. Thus, I determine for each security the trader that has been the most frequent counterparty in my sample. I create a dummy variable called $Dealer_{i-b}$ that takes the value of 1 whenever the counterparty of the trade is the largest counterparty of the specific asset.[17] Further, I interact the variable $Dealer_{i-b}$ with the interaction terms in Equation (1) and (3).

Table 6 presents the results. Regression (I) shows the Fire Buy premium interacted with the dealer dummy, whereas Regressions (II)-(V) present the Risk-Shifting premium interacted with the dealer dummy. Overall, I find no evidence that the dealer-non-dealer structure of OTC markets drive my results because my main results hold: $\text{FRFA}_t\text{*Eligible}_{iw}$ and $\text{FRFA}_t\text{*CBfunding/TA}_{bw}$ are positive and significant in (I) and (V), respectively.

Also, we find that trading with a dealer leads to a premium payment, positive and significant coefficient of the variable $Dealer_{i-b}$ in Regressions (I), (II), (IV) and (V). An interesting side result is that the three-way interaction term of the Fire Buy premium is also positive and significant, meaning that buying collateral from dealers after the provision of unlimited central bank liquidity became more expensive. This result could be explained if the dealers were also hoarding liquidity and holding on to their collateral assets and imposed a premium to sell them.

In summary, I find no evidence that the dealer-non-dealer structure of OTC markets is responsible for the effects described in this study.

6.2 Sell Side of the Market

My identification strategy is based on the buy side of each trade with collateral assets. Thus, to confirm my results, I present evidence that banks incurring a premium payment in the buy side of the market also requested a premium to sell these assets. This behavior is consistent with banks willing to keep collateral assets in their balance sheet.

Hence, I estimate Equations (1) and (3) using only sell orders. If the coefficients are positive and significant, it indicates that participants sell assets at even higher prices. Table 7 presents the results.

[17]The subscript $-b$ represents the counterparty of bank b in a given trade.

	(I) p_{ibt}	(II) p_{ibt}^{AAA}	(III) p_{ibt}^{AA}	(IV) p_{ibt}^{A}	(V) p_{ibt}^{BBB}
FRFA$_t$*Eligible$_{iw}$*Dealer$_{i-b}$	1.63**				
	(0.658)				
Dealer$_{i-b}$*Eligible$_{iw}$	-0.168				
	(0.156)				
FRFA$_t$*Eligible$_{iw}$	7.10***				
	(0.346)				
Eligible$_{iw}$	-1.66***				
	(0.299)				
Dealer$_{i-b}$*FRFA$_t$*CBfunding/TA$_{bw}$		7.99	0.309	-0.943	1.43
		(6.08)	(0.895)	(0.877)	(1.55)
Dealer$_{i-b}$*CBfunding/TA$_{bw}$		-1.94	-0.167	-0.507	-0.825
		(2.19)	(0.469)	(0.497)	(0.624)
FRFA$_t$*CBfunding/TA$_{bw}$		1.67	0.411	1.07**	1.99**
		(1.54)	(0.392)	(0.419)	(1.01)
Dealer$_{i-b}$*FRFA$_t$	-1.09	0.040	0.206*	0.199***	-0.161
	(0.493)	(0.045)	(0.118)	(0.072)	(0.126)
FRFA$_t$	-5.72***	-0.434***	-0.074	-0.574***	-0.288*
	(0.288)	(0.092)	(0.108)	(0.250)	(0.155)
CBfunding/TA$_{bw}$		-0.521	-0.656*	0.625	0.417
		(1.08)	(0.358)	(0.553)	(0.823)
Dealer$_{i-b}$	0.370***	0.148	0.045*	0.060**	0.097**
	(0.133)	(0.104)	(0.024)	(0.026)	(0.039)
Security Controls	Yes	Yes	Yes	Yes	Yes
Bank Controls	No	Yes	Yes	Yes	Yes
AR(1)	Yes	Yes	Yes	Yes	Yes
Security FE	Yes	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes	Yes
Bank-Week FE	Yes	No	No	No	No
adj. R^2	0.944	0.994	0.985	0.987	0.990
adj. within R^2	0.148	0.025	0.918	0.928	0.905
# Obs	236,157	56,668	28,247	19,517	8,298

Table 6: **Falsification Test – Dealer-Non-Dealer Structure of OTC Markets:** (I) Fire Buy premium with identification of dealers, (II-V) Risk-Shifting premium with identification of dealers. $Dealer_{i-b}$ takes the value of 1 when counterparty $-b$ is the largest counterparty of asset i in the sample; p_{ibt} is the nominal price paid by bank b for security i on day t; FRFA$_t$ takes the value of 1 after its announcement on October 8^{th}, 2008 and zero otherwise; $CBfunding/TA_{bw}$ is the ratio of ECB funds to total assets; $Eligible_{iw}$ takes the value of 1 if asset i is eligible at week w. Variables with subscript t are defined daily and w weekly. Standard errors in parentheses and clustered in the bank-security dimension. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	(I) p_{ibt}	(II) p^{AAA}_{ibt}	(III) p^{AA}_{ibt}	(IV) p^{A}_{ibt}	(V) p^{BBB}_{ibt}
FRFA_t*Eligible_{iw}	9.14***				
	(0.45)				
Eligible_{iw}	-2.18***				
	(0.35)				
FRFA_t*CBfunding/TA_{bw}		-0.051	1.37	-2.83**	-2.57
		(2.97)	(0.938)	(1.24)	(1.71)
CBfunding/TA_{bw}		0.054	-0.723*	-1.13*	0.657
		(0.186)	(0.378)	(0.602)	(0.879)
FRFA_t	-8.14***	0.241***	-0.129	-0.294	-0.166
	(0.41)	(0.069)	(0.131)	(0.188)	(0.283)
Security Controls	Yes	Yes	Yes	Yes	Yes
Bank Controls	No	Yes	Yes	Yes	Yes
AR(1)	Yes	Yes	Yes	Yes	Yes
Security FE	Yes	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes	Yes
Bank-Week FE	Yes	No	No	No	No
adj. R^2	0.998	0.995	0.994	0.985	0.992
adj. within R^2	0.846	0.856	0.920	0.909	0.909
# Obs	380,019	62,425	35,238	20,480	7,060

Table 7: **Falsification Test – Sell Positions:** (I) Estimation of Fire Buy premium using sell positions, (II-V) Risk-Shifting premium using sell positions by rating category. p_{ibt} is the nominal price paid by bank b for security i on day t; FRFA_t takes the value of 1 after its announcement on October 8^{th}, 2008 and zero otherwise; $CBfunding/TA_{bw}$ is the ratio of ECB funds to total assets; $Eligible_{iw}$ takes the value of 1 if asset i is eligible at week w. Variables with subscript t are defined daily and w weekly. Standard errors in parentheses and clustered in the bank-security dimension. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	(I) p_{ibt}	(II) p_{ibt}^{AAA}	(III) p_{ibt}^{AA}	(IV) p_{ibt}^{A}	(V) p_{ibt}^{BBB}
Lehman_t*Eligible_{iw}	2.49***				
	(0.176)				
FRFA_t*Eligible_{iw}	5.62***				
	(0.286)				
Eligible_{iw}	-2.18***				
	(0.310)				
Lehman_t*CBfunding/TA_{bw}		1.47	-0.618	0.208	-0.208
		(1.27)	(0.586)	(0.518)	(0.963)
FRFA_t*CBfunding/TA_{bw}		1.81	1.29*	0.634	2.62***
		(1.55)	(0.698)	(0.631)	(0.923)
CBfunding/TA_{bw}		-1.03	-0.697*	0.466	0.113
		(1.21)	(0.373)	(0.629)	(0.953)
Lehman_t	-2.60***	-0.029	0.126	-0.221	-0.025
	(0.242)	(0.103)	(0.080)	(0.158)	(0.090)
FRFA_t	-4.98***	-0.545***	-0.136**	-0.376***	-0.338**
	(0.237)	(0.111)	(0.061)	(0.116)	(0.157)
Security Controls	Yes	Yes	Yes	Yes	Yes
Bank Controls	No	Yes	Yes	Yes	Yes
AR(1)	Yes	Yes	Yes	Yes	Yes
Security FE	Yes	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes	Yes
Bank-Week FE	Yes	No	No	No	No
adj. R^2	0.944	0.985	0.987	0.988	0.989
adj. within R^2	0.151	0.021	0.922	0.927	0.905
# Obs	236,157	56,668	22,225	15,286	8,298

Table 8: **Falsification Test – Lehman Brothers Bankruptcy:** (I) Fire Buy premium estimation with Lehman treatment; (II-V) Risk-Shifting premium estimation by rating category with Lehman treatment. $Lehman_t$ takes the value of 1 after its bankruptcy on September 14^{th} and zero otherwise; p_{ibt} is the nominal price paid by bank b for security i on day t; $CBfunding/TA_{bw}$ is the ratio of ECB funds to total assets; FRFA_t takes the value of 1 after its announcement on October 8^{th}, 2008 and zero otherwise; $Eligible_{iw}$ takes the value of 1 if asset i is eligible at week w. Variables with subscript t are defined daily and w weekly. Standard errors in parentheses and clustered in the bank-security dimension. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In Regression (I), the coefficient of the interaction term $FRFA_t * Eligible_{iw}$ is positive and significant. This result suggests that banks in the sample sell ECB collateral assets at a premium after the implementation of FRFA. Regressions (II)-(V) point to no clear picture.

In summary, I find evidence that banks sell their collateral assets also at a premium suggesting that they would prefer to hold on to their collateral assets.

6.3 Lehman Brothers Bankruptcy

The Lehman Brothers bankruptcy was such an important event during the observation window that I test the possibility that some of my results may have been driven by this event. Hence, I propose an estimation including the bankruptcy as a further treatment in the interaction models described by Equations (1) and (3). Therefore, I define a dummy called $Lehman_t$ that takes the value of 1 after September 14^{th} and interact it with the previous variables. Note that there is no three-way interaction term because $FRFA_t * Lehman_t = FRFA_t$. The estimations are presented in Table 8.

In Estimation (I), the coefficients of the interaction terms $Lehman_t * Eligible_{iw}$ and $FRFA_t * Eligible_{iw}$ are positive and significant, suggesting that Lehman had indeed an impact on collateral prices, but this effect does not exclude the effect from FRFA. In fact, the economic significance increase in this setup. In Estimations (II)-(V), the interaction term $Lehman_t * CBfunding_{bw}$ are non-significant. Therefore, I find no evidence that the Lehman Brothers bankruptcy is the driver of my results.

7 Conclusion

In the present study, I describe the impact of unlimited central bank liquidity provision on the secondary market for collateral assets. In order to avoid fire sales the ECB provided unlimited liquidity leading to a scarcity of collateral assets and banks paid the Fire Buy premium. It demonstrates that banks pay more for collateral assets in times when central bank liquidity is most needed and underlines the necessity of an expansion of the collateral framework. In order to avoid a shortage of collateral securities, the ECB lowered the quality threshold to accept BBB-rated collateral. However, the haircut applied to these assets did not reflect the risk of the operation, encouraging banks to shift risks to the ECB balance sheet. This risk-shifting feature leads banks to pay the Risk-Shifting premium and represents how much banks can increase their yields using haircut subsidies. Moreover, it shows that haircut subsidies as form of financial support is not efficient because the financial support does not remain with the intended banks. Hence, my study links monetary policy to trading behavior and adds to the risk-shifting literature.

If eligible collateral assets were abundant, the Fire Buy premium would not arise. The ECB has sought to mitigate the problem by enlarging its collateral framework to accept BBB-rated collateral assets. Also, other forms of enlargement have been implemented, such as the inclusion of foreign currency-denominated bonds, and unsecured bank bonds. The analysis of these policies goes beyond the scope of this study.

When haircuts perfectly reflect securities' risk and the correlation risk between collateral and counterparty, banks are indifferent about which asset to pledge. In this way, an enlargement of the collateral framework merely means an enhancement of liquidity provision, and no Risk-Shifting premium would exist. Hence, this study takes the view that more differentiation between counterparties could take into account the correlation risk between collateral and counterparties. However, a haircut policy that takes discretionary decisions on a transaction-by-transaction basis is not feasible because the estimation of the correlation risk between counterparties and collateral is nontrivial since there are over 30.000 eligible collateral assets and 1.000 counterparties in the Eurozone. Nevertheless, this study takes the view that more differentiation rules among counterparties could help avoid the risk-shifting channel.

My results are drawn from a sample of 26 German banks and thus relate only to a small subsample of European banks. However, the ECB Collateral Framework applies to all banks in the Eurosystem, and the risk-shifting channel is open to all of them. Hence, the phenomenon described in this study may occur with other banks as well. I leave this issue to be determined by future research.

I make use of one specific identifying shock, the implementation of full allotment tenders. However, scarcity of collateral assets and a disputable haircut setting could occur in other situations. For instance, the asset purchase program in early 2011 may have induced banks to acquire collateral assets because they knew the ECB would buy them. I leave the investigation of this period to further research as well.

Appendix

The ECB Collateral Framework

The *ECB Collateral Framework* is a guideline for the implementation of monetary policy in the euro zone. The framework is relatively broad in all its dimensions; see Eberl and Weber (2014), Nyborg (2015), ECB (2003), ECB (2005), ECB (2006), ECB (2008a), ECB (2008b). First, it permits several categories of debt instruments: corporate bonds, government bonds, covered bonds, uncovered bank bonds and ABSs. Second, the quality threshold is relatively loose; until October 2008 bonds had to be rated A- or better, and thereafter BBB- or better. Third, the number of counterparties is relatively large; as of January 2011, 3,211 financial institutions had access to the ECB funds market.

To mitigate security risks, the ECB applies a haircut to the asset value according to Table 9. Haircuts increase with maturity, non-coupon payment, and category. In contrast to the private markets, the ECB does not take into account the correlation between collateral risk and counterparty. For instance, an Austrian and a Portuguese bank of similar rating might receive different haircuts in private repos when using a Portuguese sovereign bond as collateral. This differentiation happens because, in the scenario where Portugal is bankrupt, Portuguese banks are also likely to be bankrupt, whereas an Austrian bank would be less affected.

The ECB conducts open market operations predominantly via repos (repurchase agreements), but banks can also access central bank funds through the marginal lending facility. In both cases, banks need to pledge high-quality collateral. Unlike the Fed, where the primary dealer system is used, in the Eurosystem, a large number of banks can engage in transactions with the ECB.

Also in contrast to the US, where only Treasuries are accepted as collateral, the ECB allows a wider range of assets as collateral in four categories as described above. The definition of which securities are accepted as collateral depends on many factors including asset quality, type of asset, credit standard, place of issue, type of issuer, currency, asset marketability etc. The most notable characteristic is asset quality, which until October 2008 had to be a rating of A- or better, and BBB- or better thereafter.

Until October 2008, the ECB conducted variable-rate auctions, where participants had to submit bids for loan quantities at different interest rates. According to the aggregated demand for credit, the ECB determined the interest rate given the amount of liquidity it was prepared to supply. All bids above the clearing interest rate would be satisfied. Since October 2008, the ECB moved to a fixed-rate full allotment procedure in all its refinancing operations (Main Refinancing Operations or MROs; and Longer-Term Refinancing Operations or LTROs). This policy meant that banks can borrow any amount as long they have eligible collateral assets. In practical terms, the ECB became the lender of last resort.

AAA to A-

	Category I		Category II		Category III		Category IV	
Maturity	Fixed	Zero	Fixed	Zero	Fixed	Zero	Fixed	Zero
0-1	0.5	0.5	1	1	1.5	1.5	2	2
1-3	1.5	1.5	2.5	2.5	3	3	3.5	3.5
3-5	2.5	3	3.5	4	4.5	5	5.5	6
5-7	3	3.5	4.5	5	5.5	6	6.5	7
7-10	4	4.5	5.5	6.5	6.5	8	8	10
> 10	5.5	8.5	7.5	12	9	15	12	18

BBB+ to BBB-

	Category I		Category II		Category III		Category IV	
Maturity	Fixed	Zero	Fixed	Zero	Fixed	Zero	Fixed	Zero
0-1	5.5	5.5	6	6	6.5	6.5		
1-3	6.5	6.5	7.5	7.5	8	8		
3-5	7.5	8	8.5	9	9.5	10	Not	
5-7	8	8.5	9.5	10	10.5	11	Accepted	
7-10	9	9.5	10.5	11.5	11.5	13		
> 10	10.5	13.5	12.5	17	14	20		

Table 9: **Eurosystem haircuts** (in %) by liquidity category, residual maturity, and coupon (zero or fixed) in 2008. Category I: central government debt instruments, debt instruments issued by central banks; Category II: local and regional government debt instruments, Jumbo Pfandbrief, agency and supranational debt instruments; Category III: covered bonds, traditional Pfandbrief, credit institution debt instruments, debt instruments issued by corporates; Category IV: asset-backed securities. Note: with the expansion of the collateral framework, the ECB created a further category (uncovered debt) which is excluded from the analysis since I do not observe any trade with these assets. Source: Fecht et al. (2015).

ECB Haircut Adjustment of 2011

In 2008, when the ECB expanded its Collateral Framework to accept BBB rated assets, it imposed a flat 5% haircut add-on compared to assets with similar maturity and category, see Table 9. However, as my study shows, this flat haircut add-on does not cover all risks related to this type of collateral. In its press released of 8^{th} of April 2010, the ECB reviews its haircut policy and announces the introduction of a graduated haircut schedule. Table 10 presents the haircut increase in % points compared to Table 9.

In this adjustment, all revisions were related to BBB-rated collateral assets, and upwards (up to 19%), which evidences that previous haircuts were downwards biased.

AAA to A-

	Category I		Category II		Category III		Category IV	
Maturity	Fixed	Zero	Fixed	Zero	Fixed	Zero	Fixed	Zero
0-1	0	0	0	0	0	0	0	0
1-3	0	0	0	0	0	0	0	0
3-5	0	0	0	0	0	0	0	0
5-7	0	0	0	0	0	0	0	0
7-10	0	0	0	0	0	0	0	0
> 10	0	0	0	0	0	0	0	0

BBB+ to BBB-

	Category I		Category II		Category III		Category IV	
Maturity	Fixed	Zero	Fixed	Zero	Fixed	Zero	Fixed	Zero
0-1	0	0	0	0	+1.5	+1.5		
1-3	0	0	+3	+4	+10	+11.5		
3-5	0	0	+7	+8	+15.5	+17.5	Not	
5-7	0	0	+8.5	+10.5	+16.5	+19	Accepted	
7-10	0	0	+9	+11	+15.5	+19		
> 10	0	0	+7.5	+12	+13.5	+16.5		

Table 10: **Haircut Change of 1^{st} 2011 in %** Category I: central government debt instruments, debt instruments issued by central banks; Category II: local and regional government debt instruments, Jumbo Pfandbrief, agency and Supranational debt instruments; Category III: covered Bonds, traditional Pfandbrief, credit institution debt instruments, debt instruments issued by corporates; Category IV: asset-backed securities. Note: with the expansion of the collateral framework, the ECB created a further category (uncovered debt) which is excluded from this table for simplicity. Source: ECB

References

Bade, M., J. Flory, and T. Schoenberg (2016). SHS-Base. *Deutsche Bundesbank Data Report 2016-02*, Research Data and Service Centre.

Bagehot, W. (1873). Lombard Street: A Description of the Money Market. *Richard D. Irwin, Inc., Homewood, Illinois, 1962, reprinted from the Scribner, Armstrong & Co., edition, New York.*

Beber, A., M. W. Brandt, and K. A. Kavajecz (2009). Flight-to-quality or flight-to-liquidity? evidence from the euro-area bond market. *Review of Financial Studies 22*(3), 925–957.

Chailloux, A., S. Gray, and R. McCaughrin (2008). Central Bank Collateral Frameworks: Principles and Policies. *International Monetary Fund Washington, DC*.

Cheun, S., I. von Köppen-Mertes, and B. Weller (2009). The Collateral Frameworks of the Eurosystem, the Federal Reserve System and the Bank of England and the Financial Market Turmoil. *ECB Occasional Paper Series No 107*.

de Roure, C., E. Mönch, L. Pelizzon, and M. Schneider (2016). Why do Banks Trade Over-the-Counter in the Most Liquid Market of the Euro Area? *Mimeo*.

Drechsler, I., T. Drechsel, D. Marques-Ibanez, and P. Schnabl (2016). Who Borrows from the Lender of Last Resort? *Journal of Finance 71*(5), 1933–1974.

Duffie, D., N. Gârleanu, and L. H. Pedersen (2005). Over-the-Counter Markets. *Econometrica 73*(6), 1815–1847.

Duffie, D., N. Gârleanu, and L. H. Pedersen (2007). Valuation in Over-the-Counter markets. *Review of Financial Studies 20*(6), 1865–1900.

Eberl, J. and C. Weber (2014). ECB Collateral Criteria: A Narrative Database 2001–2013. *Ifo Working Paper No. 174*.

ECB (2003). Guideline of the European Central Bank of 1 December 2003 Amending Guideline ECB/2000/7 on Monetary Policy Instruments and Procedures of the Eurosystem (ECB/2003/16). *Official Journal of the European Union L.69*(08.03.2004), 31–47.

ECB (2005). Guideline of the European Central Bank of 3 February 2005 Amending Guideline ECB/2000/7 on Monetary Policy Instruments and Procedures of the Eurosystem (ECB/2005/2). *Official Journal of the European Union L.111*(02.05.2005), 32–46.

ECB (2006). Guideline of the European Central Bank of 31 August 2006 Amending Guideline ECB/2000/7 on Monetary Policy Instruments and Procedures of the Eurosystem (ECB/2006/12). *Official Journal of the European Union L.352*(13.12.2006), 35–36.

ECB (2008a). Guideline of the European Central Bank of 23 October 2008 Amending Guideline ECB/2000/7 on Monetary Policy Instruments and Procedures of the Eurosystem (ECB/2008/13). *Official Journal of the European Union L.36*(5.2.2009), 31–45.

ECB (2008b). Regulation (EC) No 1053/2008 of the European Central Bank of 23 October 2008 on Temporary Changes to the Rules Relating to Eligibility of Collateral (ECB/2008/11). *Official Journal of the European Union L.282*(25.10.2008), 17–18.

Fecht, F., K. G. Nyborg, J. Rocholl, and J. Woschitz (2015). Collateral, Central Bank Repos, and Systemic Arbitrage. *Working Paper University of Zurich.*

Heider, F., M. Hoerova, and C. Holthausen (2015). Liquidity hoarding and interbank market rates: The role of counterparty risk. *Journal of Financial Economics 118*(2), 336–354.

Li, D. and N. Schürhoff (2014). Dealer Networks. *CEPR Discussion Paper No. 10237.*

Nyborg, K. G. (2015). Central Bank Collateral Frameworks. *CEPR Discussion Paper No. 10663.*

Rochet, J.-C. and X. Vives (2004). Coordination Failures and the Lender of Last Resort: Was Bagehot Right After All? *Journal of the European Economic Association 2*(6), 1116–1147.

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data.* MIT press.