Collateral, central bank repos, and systemic arbitrage [1]

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Abstract

Collateral, central bank repos, and systemic arbitrage

Liquidity is provided by central banks against collateral, often via repos. This paper contributes to the emerging literature on the effects of central bank collateral policy. Using a comprehensive dataset from the Bundesbank, we show that banks arbitrage the Eurosystem's collateral framework. Banks with lower-quality collateral and in worse financial health obtain disproportionally larger amounts of liquidity (central bank money) in Eurosystem repos. We refer to this as systemic arbitrage and it is present under different liquidity injecting policies before and after the financial crisis. Systemic arbitrage may impair market discipline and the central bank's balance sheet and may, therefore, contribute to financial fragility. In general, the paper sheds light on the role and potential impact of collateral with respect to the provisioning of liquidity in the financial system.

JEL classification: G12, G21, E42, E51, E52, E58

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1. Introduction

Central banks and their policies have come under increased scrutiny in the aftermath of the financial crisis. Different strands of the literature study the effects of unconventional monetary policies on interest rates and asset prices, financial market liquidity, bank behavior, and financial stability (see, among others, Krishnamurthy and Vissing-Jorgensen, 2011; Gagnon, Raskin, Remache, and Sack, 2011; Duygan-Bump, Parkinson, Rosengren, Suarez, and Willen, 2013; Chodorow-Reich, 2014; Eser and Schwaab, 2016; Krishnamurthy, Nagel, and Vissing-Jorgensen, 2017; Rodnyansky and Darmouni, 2017). Other work is concerned with the effectiveness of monetary policy in a low interest rate environment (see, e.g., Eggertsen and Woodford, 2003; Hamilton and Wu, 2012; Woodford, 2012; Di Maggio and Kacperczyk, 2017). In this paper, we focus on central bank collateral policy, as described and defined in a central bank's collateral framework (Nyborg, 2016a). This is an important, but, until recently, relatively underexplored feature of central banking. Its significance arises from the fact that central bank money, or liquidity, is issued against collateral, either through repos or outright purchases. This puts collateral policy at the core of the financial system, and gives it the potential to affect the financial system and markets in fundamental ways that are just starting to be appreciated (Koulischer and Struyven, 2014; Gorton and He, 2016; Nyborg, 2016a and 2017; Van Bekkum, Gabarro, and Irani, 2017). Our paper contributes by documenting how collateral policy may be arbitraged by banks, with potential adverse consequences for the interbank market, the central bank's balance sheet, and financial stability.

Our particular focus is on the collateral policy of the European Central Bank (ECB) under which liquidity has always been provided against a very broad set of eligible collateral. Traditionally, this has been done through reverse repos with collateral haircuts that are independent of the counterparty and rarely updated.[1] We provide evidence that this policy has led to a form of arbitrage, which we refer to as *systemic arbitrage*, whereby banks, *in aggregate*, funnel relatively high credit risk and lower-quality collateral on to the balance sheet of the central bank through the central bank's normal liquidity providing operations. Importantly, systemic arbitrage in the euro area is not a crisis phenomenon. It is present

[1] Details below. See Eberl and Weber (2014), Nyborg (2016a), or `https://www.ecb.europa.eu/paym/coll/html/index.en.html` for in-depth descriptions.

in the data before the onset of the financial crisis. It is also there after the start of the crisis. This is not surprising because the basic design of the ECB's collateral policy did not change with the crisis. However, we also raise the issue in this paper that systemic arbitrage may have been a contributing factor to the problem of financial fragmentation, which became an issue in the euro area as the crisis evolved (see, e.g., European Central Bank, 2012 or 2014, Van Rixtel and Gasperini, 2013, or Cline, 2014).

To explain more precisely what we mean by systemic arbitrage, it is useful to highlight how the ECB, or the Eurosystem, injects liquidity into the banking system.[2] Until October 8, 2008, this was done using what is commonly referred to as a liquidity-neutral policy (Nyborg, Bindseil, and Strebulaev, 2002). Under this policy, within each reserve maintenance period, the ECB aims to inject, through its main and longer-term refinancing operations (MROs and LTROs, respectively), the amount of central bank money banks need to fulfill reserve requirements and satisfy other liquidity needs *in aggregate*. These (reverse repo) injections are part and parcel of monetary policy implementation. The liquidity-neutral policy allowed the ECB to control the overnight rate close to its policy rate with great accuracy (Nautz and Offermanns, 2007; Linzert and Schmidt, 2011).[3] Banks could, and still can, also tap the marginal lending facility ("discount window") against the same set of eligible collateral as in the MROs and LTROs. In these Eurosystem repos, banks choose individually how much liquidity to ask for and what collateral to pledge. However, because reserve requirements are known prior to the start of each maintenance period, the liquidity-neutral policy implies that banks face a common aggregate constraint with respect to their liquidity uptakes. Banks may, therefore, be said to collectively arbitrage the central bank if banks in worse financial health and with worse collateral obtain an excess of liquidity in Eurosystem operations. The excess can then be passed on to more solid banks with lower Eurosystem liquidity uptakes that, because of the liquidity-neutral policy, are short liquidity. We refer to this as systemic arbitrage because it reflects banks collectively arbitraging the monetary operational system and collateral framework of the central bank.

The collective arbitrage we have described is tantamount to banks, in aggregate, economizing on credit risk and on the usage of higher-quality collateral. This does not require

[2] The Eurosystem is the system of central banks in the euro area, comprised of the European Central Bank and the individual national central banks.

[3] See also Bindseil, Nyborg, and Strebulaev (2009) and Bindseil (2014) for further details.

coordination among banks, but is what one would expect from banks individually and separately acting in their self-interest. On the downside, systemic arbitrage implies that more troubled banks avoid the discipline of the interbank market and that the central bank takes an overweight of relatively low-quality collateral and poor credit risk on to its balance sheet.

We would expect systemic arbitrage to be empirically relevant under a collateral policy where (i) there is a broad, heterogeneous set of eligible collateral, and (ii) collateral haircuts do not reflect market conditions or the credit-worthiness of banks. The ECB's collateral policy satisfies both conditions. The set of eligible collateral includes 30,000 to 40,000 different securities, ranging from government bonds to asset-backed securities (ABSs), as well as non-marketable assets such as credit claims. Historically, haircuts are updated every three to four years and are independent of the counterparty (Nyborg, 2016a). Furthermore, the ECB's operations and lending facility (discount window) are open to all banks in the euro area, including branches of foreign banks, on equal terms. This contrasts with the primary dealer system employed, for example, by the Federal Reserve System in the US. The wide range of eligible collateral, the non-market based haircuts, the independence of haircuts and credit risk, and the inclusivity of the operations make for an environment in which systemic arbitrage would be expected to emerge.

To test for systemic arbitrage, we employ a comprehensive dataset furnished by the Deutsche Bundesbank covering 1,588 German banks over the period 1/2006–10/2010. The data contains bank-level data on liquidity uptake in Eurosystem repos, pledged collateral, and financial health. Under the period when the liquidity-neutral policy was in place, we find that banks in worse financial health and banks with worse collateral have relatively large liquidity uptakes, controlling for size and reserve requirements. This is consistent with systemic arbitrage.

The preference for using lower-quality collateral in Eurosystem repos may reflect that such collateral have relatively low opportunity costs (Nyborg, Bindseil, and Strebulaev, 2002). For example, Eurosystem haircuts of lower-quality collateral, while relatively high, may not be sufficiently high to equilibrate opportunity costs. Divergence in opportunity costs can develop over time because haircuts are so rarely updated. Lower-quality collateral may also be difficult to use in other repo markets. For example, Eurex' popular, centrally cleared GC Pooling contract accepts only around 25% of the securities that can be used in Eurosystem repos.[4] Furthermore, in bilateral repos, two-way credit risk can give a preference among both counterparties for higher-quality collateral (Ewerhart and Tapking, 2008).

Our dataset also includes a two-year period of the unconventional full-allotment policy that replaced the liquidity-neutral policy in October 2008 (and is still in force). Under full allotment, banks receive the full quantity they ask for in the MROs and LTROs, subject to pledging sufficient collateral. All banks pay the same repo rate, regardless of how much they receive. We find that German banks, in aggregate, rely less on CGIIPS collateral under full allotment than before.[5] However, in the cross-section, banks in worse financial health and with worse collateral have relatively large liquidity uptakes under the full-allotment policy, just as they do under the liquidity-neutral policy. In this respect, there is not much contrast in bank behavior under the liquidity-neutral and full-allotment policies. We will come back to the aggregate finding below.

Several ECB officials and authors have interpreted full allotment as a form of lender of last resort policy (among others, Garcia-de-Andoain, Heider, Hoerova, Manganelli, 2016; Praet, 2016; Bindseil and Laeven, 2017). In work that may be contrasted with ours, Drechsler, Drechsel, Marquez-Ibanez, and Schnabl (2016) argue that while full allotment may be beneficial in that it provides liquidity support to needy banks, it may also allow for Jensen and Meckling (1976)-style gambling for resurrection by weaker banks. Drechsler et al's focus is on the liquidity policy of full allotment. Unlike what we do in this paper, they do not benchmark their analysis of full allotment with bank behavior under the liquidity-neutral policy. Our analysis also differs in that we focus on the potential for arbitrage admitted by the ECB's collateral policy rather than on liquidity policy and asset substitution as such.

Having said this, we also believe that there is a systemic arbitrage interpretation of Drechsler et al's results. Their conclusion on gambling for resurrection is based on the following central finding: Using a sample of 284 euro-area banks, they find that banks with relatively low ratings in 2007 increased their liquidity uptake relatively more than

[4]See `http://www.eurexrepo.com/repo-en/products/gcpooling/` (January 20, 2015). Eurex acts as a central counterparty (CCP) in these contracts. See also Mancini, Ranaldo, and Wrampelmeyer (2015).

[5]CGIIPS is an acronym, representing, in alphabetical order, Cyprus, Greece, Ireland, Italy, Portugal, and Spain. These countries are also often referred to as "the periphery," a usage we also adopt in this paper.

other banks after the maturity of the first one-year LTRO in June 2010.[6] These banks also pledged relatively more CGIIPS collateral after this date. An alternative and simpler interpretation of this finding is that banks in CGIIPS countries rolled over the maturing one-year loans in the three-month operation that was held when the one-year loans matured, while non-CGIIPS banks rolled over to a lesser extent because money was flowing from the periphery to the core, as evidenced by Target 2 imbalances (Sinn and Wollmershäuser, 2012; Sinn, 2014). Cline (2014) also documents large outflows from the periphery. The alternative interpretation is consistent with systemic arbitrage: under full allotment, the banking system continued to arbitrage the central bank (Eurosystem) as under the liquidity-neutral policy before. However, the scale may have been larger and cross-border flows more imbalanced. The arbitrage is made possible by an accommodative central bank collateral policy.

Clearly, lender of last resort, even on a large scale, does not require a full-allotment policy or the admittance of systemic arbitrage. There was always a lender of last resort functionality in the ECB's operational system, namely emergency liquidity assistance. This can be tailored to individual banks. Running a blanket, indiscriminate lender of last resort policy instead (full allotment against a very broad set of eligible collateral), runs the risk of aggravating the travails of a stressed banking sector because needed restructuring is put off and debt overhang problems perdure. From this perspective, the full-allotment policy, while probably intended as an emergency lender of last resort policy when it was introduced in 2008, may instead have morphed into a mechanism to keep failing banks from realizing losses. After all, the policy has now run for nine years. This may have been by design or as an unintended consequence of a broad and accommodative collateral policy.

Systemic arbitrage may contribute to financial fragmentation in the euro area because it may involve banks in less financially solid countries obtaining an overweight of liquidity from the Eurosystem, which then can be deposited in banks in more financially solid countries. As mentioned, in aggregate, German banks reduce the usage of CGIIPS collateral over time. Whereas before the onset of the crisis, German banks rely on CGIIPS collateral in

[6] Drechsler et al (2016) present their findings as a response to the emergence of the Greek debt crisis in May 2010. However, their Figure 4 shows that the effect they look at coincides with the maturity of the first one-year LTRO at the end of June, 2010. They point this out themselves in their footnote 28. Unlike the later, and equally large, three-year LTROs, banks could not repay this one-year LTRO early.

Eurosystem repos, by 2009/2010, they no longer need it to cover their aggregate liquidity uptake. A feature of the ECB's collateral policy that may contribute to fragmentation is that collateral haircuts are not adjusted for credit risk. Thus, a bank has an incentive to pledge collateral that is likely to default when the bank itself defaults. We refer to this as the "correlated default loophole." This means, for example, that banks domiciled in financially distressed countries have an incentive to hold and pledge same-country collateral (since a sovereign default is likely to lead to bank defaults as well). In other words, financial fragmentation and its consequences may be exacerbated by a collateral policy that does not adjust for credit risk and, especially, includes the correlated default loophole.[7]

A collateral policy that admits systemic arbitrage may increase financial fragility. This is partly because it allows less financially sound banks to circumvent the discipline of the market. Obscured market signals also impair the effectiveness of bank supervision. In addition, systemic arbitrage may reduce information production on the lower-quality collateral preferred by banks in central bank repos. These factors may cause inefficiencies to build up over time, leading to a more fragile financial system (Gorton and Ordoñez, 2014).

Compounding the problem, systemic arbitrage also weakens the balance sheet of the central bank. In the words of Thomas Jordan, the President of the Swiss National Bank: "In order to act appropriately, [central banks] need room to maneuver, which implies a sound central bank balance sheet..." (Jordan, 2012). In other words, a weak balance sheet may reduce the credibility of the central bank, for example with respect to policies to reduce financial instability. Our analysis in this paper serves as a counterpoint to the idea that full reserve banking or a large central bank helps financial stability (Kotlikoff, 2010; Benes and Kumhof, 2012; Cochrane, 2014; Greenwood, Hanson, and Stein, 2016). An expanding central bank balance sheet increases the footprint of its collateral policy and, therefore, runs the risk of enhancing the potential damage from systemic arbitrage.

The rest of the paper is organized as follows. Section 2 provides further institutional background relevant for this paper. It also describes the main data and reports on aggregate

[7]With respect to fragmentation, Uhlig (2013) also emphasizes banks' incentives to overweight domestic bonds in Eurosystem repos. However, unlike that of Uhlig, our argument does not require eligible collateral to vary across countries. In practice, the public list of eligible collateral is common to all euro area banks (see the references in footnote 1). Crosignani (2017) generates fragmentation in a stylized two-country model with asset substitution along the lines of Jensen and Meckling (1976).

time patterns in the data with respect to liquidity uptake and collateral usage by German banks. Section 3 sets up the panel analysis by describing the data and variables that will be used as well as providing descriptive statistics. Sections 4 and 5 then present the panel regressions. Section 6 provides discussion and Section 7 concludes.

2. Overview

This section provides an overview of key institutional features relating to Eurosystem liquidity injections, banks' collateral pools, collateral values, and haircuts. It also describes the main data in this paper and provides aggregate statistics on German banks' collateral pool holdings and liquidity uptake over time. Broad euro area statistics on liquidity uptake, or credit, are also provided. The aggregate statistics shed light on the increasing national fragmentation in the euro area as the crisis unfolded. It also serves as background to the more in-depth panel analysis, using additional bank-level data, in Sections 3, 4, and 5.

2.1 Central bank liquidity injections and banks' collateral pools

As touched on in the Introduction, the ECB injects liquidity into the banking sector primarily through its refinancing operations. There are two main types, namely the main refinancing operations (MROs) and the longer term refinancing operations (LTROs). Until September 19, 2007, the MROs were the main source of central bank money in the euro area. After that time, the LTROs have been more important (Nyborg, 2016a). Over the 1/2006–10/2010 sample period of this paper, the maturities of the LTROs range from one month to one year and those for the MROs always equal one week. Until October 7, 2008, the size of these operations were determined according to the ECB's liquidity-neutral policy (see the Introduction). Reserve maintenance periods are timed to coincide with every second Governing Council meeting and cover approximately one month. Within a maintenance period, banks need to hold a daily average level of reserves determined by their short term liabilities at the end of the calendar month ending before the start of the previous maintenance period. From October 8, 2008, the MROs and LTROs have been held under the full-allotment policy, where banks receive the quantity of liquidity they ask for at the policy rate. The only constraint is that banks need to post sufficient collateral to cover the quantity they receive.

There are two standing facilities. Banks can obtain liquidity from the marginal lending facility (discount window) and place liquidity in excess of reserve requirements at the deposit facility. Before the financial crisis, these rates were always at a spread of 100 basis points (bps) above or below, respectively, the ECB's policy rate. This spread was lowered to 50 bps after the Lehman bankruptcy and raised again to 75 bps in May 2009, where it remained for the duration of the sample period. Borrowings at the marginal lending facility are overnight, but can be rolled over indefinitely subject to having sufficient collateral.

When a bank obtains liquidity from the Eurosystem through the operations and standing facility described above, the actual repo is with its national central bank. However, the terms, including rates, eligible collateral, and haircuts, are set by the ECB.[8] In Germany, each bank has an eligible collateral inventory account, or collateral pool, with the Deutsche Bundesbank. Under the pooling system, collateral is not earmarked for particular transactions.[9] Banks can move eligible collateral in and out of their pool, with the only constraint being that at the end of each day, the total collateral value of a bank's pool needs to be at least equal to a bank's total gross Eurosystem liquidity uptake.[10] Banks therefore need to pay heed to the ECB's system for determining collateral values.

2.2 Collateral values and haircut policy

The *collateral value* of one unit of collateral i on day t is given by

$$V_{it} = (1 - h_{it})P_{it}, \tag{1}$$

[8] By "eligible collateral" we mean collateral that is accepted in the Eurosystem's refinancing operations and marginal lending facility. Until December 31, 2006, the Eurosystem operated with a Tier 1 and Tier 2 eligible collateral system. Whereas Tier 1 collateral were set by the ECB, Tier 2 assets were to some extent under the control of national central banks, though subject to approval by the ECB. European Central Bank (2003) is the last legal document that defines the rules under the two-tier system. With European Central Bank (2005) and European Central Bank (2006) the ECB introduced the single list framework in two steps.

[9] While national central banks in the Eurosystem are generally free to choose whether to pool or earmark collateral, only the Bank of Spain allows banks to earmark collateral for central bank operations (Bank for International Settlements, 2013).

[10] So usage of the deposit facility does not free up collateral.

where h_{it} is the Eurosystem haircut and P_{it} is the price of the collateral.[11] A bank can borrow a maximum of V_{it} on day t from the Eurosystem against one unit of collateral i.

Eurosystem haircuts are set by the ECB according to a rigid scheme that is rarely modified. Table 1 shows that over the five year sample period of this paper, the Eurosystem's haircut scheme for marketable collateral was updated only once, namely on October 24, 2008. Panel A covers the rules that applied up to October 24, 2008, and Panel B covers the period thereafter to the end of the sample period.[12] As seen, some haircut updates announced on October 23, 2008 came into force two days afterwards and others on February 1, 2009, implying that parts of Panel A applied until that later date.

Insert Table 1 here.

Table 1 reveals that a collateral's haircut is determined by four main factors. First, it depends on the collateral's type, e.g., central government bond, local government bond, covered bond, unsecured bond, or ABS. Each type is placed in a "liquidity category" by the ECB, with increasingly higher liquidity categories representing types of collateral that are viewed as intrinsically less liquid (and arguably also more risky) and thus receive higher haircuts, *ceteris paribus*. Among standard marketable collateral, government bonds have the lowest haircuts and ABSs the highest. The haircuts of non-marketable collateral (not shown in Table 1) are higher yet again.[13]

Second, haircuts are increasing in the collateral's residual maturity, *ceteris paribus*. Third, haircuts depend on the type of coupon; fixed, zero, or floating. Within each liquidity category and residual maturity bucket, the haircuts of fixed coupon collateral are less than or equal to zero coupon collateral. Both residual maturity and coupon type relate to the

[11] In practice, a theoretical price is often used instead of a market price. See Nyborg (2016a and 2016b) for further discussion and evidence.

[12] For part of the period covered by Panel A, the ECB operated with a two-tier system for eligible collateral (see footnote 8). This was replaced with a harmonized "single list" of eligible collateral on January 1, 2007. Under this system, collateral is divided into marketable and non-marketable collateral. Panel B: At the time they were introduced, many of the adjustments to eligibility criteria and haircuts in Panel B were labeled as being temporary. Nevertheless, most of these modifications are still in place today, though haircuts have in many cases changed further. Nyborg (2016a) provides a comprehensive overview of the development of these and other issues relating to the Eurosystem's collateral framework. Our Table 1 corresponds to the marketable collateral parts of his Tables 5.1 and 5.2.

[13] A comprehensive schedule of haircuts is provided in Nyborg (2016a).

concept of bond duration. Table 1 shows that haircuts are (weakly) increasing in duration. More generally, haircuts are increasing in risk and illiquidity (as assessed by the ECB). A collateral's Eurosystem haircut is therefore a good candidate for a simple measure of relative collateral quality at a given point in time. This will be explored further in Subsection 4.2.

In Panel A, the lowest haircut, 0.5%, is for collateral of Liquidity Category I (central government and central bank bonds) with residual maturity of less than one year. The largest, 25%, is for inverse floaters with more than 10 years to run.

Ratings are conspicuously absent from Panel A. Until October 2008, the haircuts of eligible collateral were not affected by ratings. However, a rating of A− (on the S&P scale) or higher was required for collateral eligibility.[14]

The main change introduced in Panel B is that the minimum ratings requirement is lowered to BBB−. A rating in the BBB− to BBB+ range adds 5% to the baseline haircut of paper rated A− or higher. Panel B also sees the introduction of a fifth liquidity category, with unsecured bank bonds (labeled credit institution debt instruments) being separated out from traditional pfandbriefen (covered bonds). The general point remains that illiquidity and risk increase Eurosystem haircuts and thereby also decrease collateral values.

2.3 Data: Collateral pools and liquidity uptake

Our main data consists of detailed information on individual German banks' collateral pools and their net Eurosystem liquidity uptake, or credit. The latter is defined as the total amount of borrowings a bank has outstanding on a given day from the Eurosystem, with these borrowings coming from three possible sources, namely (i) refinancing operations, (ii) the marginal lending facility, and (iii) emergency liquidity assistance, if any. The data has been made available by the Deutsche Bundesbank for the purpose of this research project and includes all banks in their system.

The collateral data consists of various collateral characteristics (to be described below) of individual banks' collateral pools on 667 irregularly spaced days over the period January 18, 2006 to December 31, 2010. The sampling frequency increases towards the end of the sample. There is at least one sample day in each of the 60 reserve maintenance periods

[14] Unless otherwise specified, all ratings in this paper are on the S&P scale.

covered by the sample period. Unique bank codes allow us to follow individual banks over time and merge the collateral data with other bank characteristic data (to be discussed in Section 3). Banks' liquidity uptake is part of the collateral data file as are their reserve holdings with the central bank.

The data comprises 1,588 banks that have collateral in their pool on at least one of the 667 sample days, for a total of 813,576 bank-day observations. For each bank-day, we have market and collateral values broken down by the collateral's type and country of origin.[15] In total we observe 4,323,775 bank, day, country of origin, and type of collateral combinations.

The collateral types relate to the liquidity categories in Table 1. In particular, the data breaks collateral into: debt instruments issued by central governments and central banks, local and regional governments, agencies and supranational institutions, non-financial corporations, and financial corporations. The latter is further partitioned into jumbo covered bank bonds, traditional covered bank bonds, unsecured credit institution instruments, and other financial corporation debt instruments. The last two categories are further broken down into asset-backed securities and non-marketable collateral.[16]

For each bank-day, we have the weighted (by collateral value) averages of the underlying collateral for the following variables: haircut, liquidity category, duration, default probability according to the Bundesbank's own model, own-use (of collateral), and the Herfindahl-Hirschman index (HHI) based on either the asset class or issuer group of the collateral.[17]

Own-use refers to collateral issued by an entity with which the bank that holds it in its

[15] The country of origin is the place of establishment of a collateral's issuer. This can either be a European Economic Area (EEA) or a Group-of-Ten (G-10) country.

[16] Non-marketable collateral is either fixed-term deposits from eligible counterparties, credit claims (bank loans) or non-marketable retail mortgage-backed debt instruments. However, our data does not split up the non-marketables into these sub-categories.

[17] Asset class (for the purpose of the HHI) is one of the following: (1) bond, (2) medium-term note, (3) (treasury) bill, commercial paper, or certificate of deposit, (4) commercial bill (e.g. trade bill, bill of exchange), (5) other assets, (6) Jumbo Pfandbriefe-style, (7) Traditional Pfandbriefe-style, and (8) other securitized assets/ABS/MBS. Issuer group is one of the following: (1) central bank, (2) central government, (3) corporate and other issuers, (4) credit institution (excluding agencies), (5) regional/local government, (6) supranational issuer, (7) agency - non credit institution, and (8) agency - credit institution.

pool has close links, as defined in the official, legal documentation.[18]

Finally, banks are labeled by the Bundesbank as belonging to one of the following sectors, or bank types: Savings banks and their central banks, the Landesbanken; cooperatives and cooperative central banks; private banks ("regular" banks); branches of foreign banks; private loan banks; special purpose banks, and Bausparkassen (building societies). We refer the reader to Hackethal (2004) or Fecht, Nyborg, and Rocholl (2011) for a discussion of the roles different bank types play in the overall German banking system. The main types can be said to be savings banks, cooperatives, and the "regular" private banks.

2.4 Aggregate patterns over time: Collateral and liquidity uptake

For the purposes of this section, we prune the raw data of 813,576 bank-day observations as follows: First, we exclude 7,029 bank-days with missing country of collateral origin data. Second, we drop 2,544 bank-days with recorded negative reserve holdings or haircuts. Third, we also drop 5,028 bank-days without official bank type information or that relate to a change of bank type. In particular, we drop a bank from any of the five sub-periods we study (defined below) if it has changed its type within that period. The final sample comprises 798,975 bank-days (98.2% of the initial sample).

For each sample day, we work with the aggregate collateral pool and liquidity uptake (credit) over all banks. To gauge the liquidity uptake of German banks as compared to that of the rest of the euro area, we also have downloaded weekly data from the ECB's Statistical Data Warehouse on the aggregate outstanding credit to euro area banks.[19]

Besides aggregate collateral values and liquidity uptake, we also report on portfolio weights in the aggregate collateral pool for the following seven categories: (i) Government, central bank, agency, or supranational institution bonds; (ii) Covered bonds; (iii) Corporate bonds; (iv) Uncovered bonds, ABSs, and non-marketables ("Uncovered etc"); (v) German

[18] Entities A and B are said to have close links (i) if one of them directly or indirectly owns or controls 20% or more of the capital or voting rights of the other, or (ii) a third party directly or indirectly owns or controls the majority of the capital or voting rights of both A and B (European Parliament and Council, 2000). See European Central Bank (2005), footnote 50, and European Central Bank (2010) or, for further discussion, Nyborg (2016a).

[19] Downloaded from `http://sdw.ecb.europa.eu/browse.do?node=bbn129` (January 20, 2015).

origin; (vi) CGIIPS origin; and (vii) Own-use.

Finally, we report on a set of variables labeled "excess collateral." These are defined on a given day t as

$$Excess\ collateral_t = \frac{Collateral\ value_t - Excluded\ collateral_t - Credit_t}{Collateral\ value_t - Excluded\ collateral_t}, \tag{2}$$

where $Excluded\ collateral_t$ is the collateral value of an excluded collateral subset, if any. A large excess collateral without exclusions is indicative of low collateral opportunity costs, especially for the collateral types with large portfolio weights. Excess collateral also gauges to what extent German banks may be collateral constrained. By excluding certain subsets of what we may think of as lower-quality collateral, the excess collateral variables tell us what the excess collateral value would be if the collateral of the excluded subset were written down to zero or not eligible. We consider three "excluded subsets," namely: (i) Collateral of non-German origin; (ii) Uncovered, ABS, and non-marketables; (iii) the union of "Uncovered etc" and CGIIPS domiciled collateral. Excess collateral given these exclusions is informative with respect to the strength of the aggregate collateral pool and, by implication, German banks. Overall excess collateral (no subset excluded) is also calculated.

We report on average values of the variables discussed above over the following five sub-periods: (1) "2006." January 18, 2006 to January 16, 2007. (2) "Pre-Crisis." January 17, 2007 to August 7, 2007. (3) "Crisis-to-Lehman." August 8, 2007 to September 9, 2008. Lehman Brothers filed for bankruptcy on September 15, 2008.[20] (4) "Post-Lehman." September 16, 2008 to January 19, 2010. (5) "2010." January 20, 2010 to December 31, 2010. Thus, for periods (1)–(3) and the first month of period (4), the liquidity-neutral policy applies and haircuts are set according to Table 1, Panel A. For most of period (4) and the whole of period (5), the full-allotment policy applies, as do haircuts from Table 1, Panel B (full allotment is introduced about one month after Lehman's bankruptcy).

Because the sampling frequency carried out by the Deutsche Bundesbank varies over

[20] The start date (end date) for each sub-period is chosen to correspond to the beginning (end) of a maintenance period, except (i) sub-period (4), where we begin the period the day after Lehman's bankruptcy rather than the first day of the relevant maintenance period, September 10, 2008. One weekly Eurosystem aggregate credit data point drops out (but this has no noteworthy effect on the statistics we calculate). The Bundesbank data has no sample days in the period September 10-15, 2008. (ii) The end date in sub-period (5) corresponds to the end of our sample, rather than the end of a maintenance period.

time, we use the following procedure to average within each sub-period. First, we take the equally weighted average across all sample days within the same maintenance period. We do the same for the weekly aggregate Eurosystem credit figures. Second, we take the equally weighted average across all maintenance periods in each of the five sub-periods. We also do this for the whole sample period.

Insert Table 2 here.

Table 2 shows the patterns of the average values for our variables for the full sample period and the five sub periods. Panel A shows that from 2006 to 2010, German registered banks reduce the aggregate liquidity uptake (credit) from EUR 233.0 to 149.6 billion, or by 35.8%. Over the same time period, Eurosystem liquidity injections increase from EUR 424.1 to 653.1 billion. German banks' share of total Eurosystem credit thus drops from 54.94% in 2006 to 22.91% in 2010. Most of this decrease occurs in 2010, coinciding with the maturity of the first ever one-year LTRO (July 1, 2010), where EUR 440 billion fell due. The dramatic decrease is testament to the increasingly fragmented market for liquidity in the euro area. Under the view that German banks suffered less as the crisis progressed than banks in other parts of the euro area, this constitutes a first piece of evidence that worse banks have a relatively larger uptake of liquidity from the central bank.

Panel A also shows that German banks' aggregate collateral pool value exceeds their liquidity uptake. Even in 2006, the aggregate coverage ratio (collateral value to credit) is more than two to one. It has grown over time, reaching 4.47 as an average in 2010. This indicates that there has always been little use for much of the collateral held by German banks outside of Eurosystem operations. It supports the view that the ECB has an accommodative collateral policy. This gives rise to the possibility of systemic arbitrage.

The aggregate portfolio weights in Panel B show that collateral quality decreases over time from 2006 to Lehman's bankruptcy and the introduction of the full-allotment policy, but recovers thereafter. For example, from 2006 to "Lehman," there is a shift of approximately 10 percentage points (pps) from government and covered bonds to "Uncovered etc" collateral. The trend continues but at a much weaker pace into the post-Lehman, full-allotment period, but then reverses somewhat, especially for government bonds, whose weight increases by around 6 pps from "Lehman" to 2010. There are also large shifts taking place with respect to the origin of the collateral used by German banks in repos with the

Eurosystem. From 2006 to "Lehman," German domiciled collateral decreases by around 10 pps, while CGIIPS collateral increases by 6 pps. After Lehman's bankruptcy and the introduction of full allotment, there is a sharp reversal. German domiciled collateral increases by around 18 pps to 63.04%, while CGIIPS collateral falls around 14 pps to 13.54%. This is consistent with financial fragmentation in the euro area.

These numbers also show that German banks reduce risks vis-à-vis the central bank in the post-Lehman, full-allotment era. This is at odds with claims that there has been widespread increase in risk taking behavior across the euro area over this time period (e.g., Drechsler et al, 2016).

Panel C shows that, overall, collateral in excess of credit increases from 52.90% in 2006 to 77.95% in 2010. Thus, German banks are not collateral constrained. However, excluding all "Uncovered etc" and "CGIIPS" collateral, the excess collateral is actually negative from 2006 until the post-Lehman period. In the pre-crisis period it is −28.03%, suggesting that German banks may have been under some pressure up to Lehman's bankruptcy. This subsequently reversed. In 2010, the excess collateral excluding "Uncovered etc" and "CGIIPS" collateral is at its highest ever level at 45.95%. This supports our conclusion from Panel B that German banks reduced risks as the crisis progressed.

Overall, the aggregate statistics indicate large shifts in Eurosystem liquidity uptake and collateral holdings across banks in the euro area as the crisis unfolded. They are consistent with financial fragmentation along national lines and support the view that the full-allotment policy buttressed the weaker countries. In aggregate, German banks reduced their usage of relatively lower-quality collateral as well as their Eurosystem liquidity uptake.

3. Panel data, variables, and descriptive statistics

In the remainder of the paper, we utilize the panel structure of our data and examine the systemic arbitrage hypothesis by studying cross-sectional differences in liquidity uptake and pledged collateral among German banks. This section provides a basic description of the data.

3.1 Data

We clean the main data on collateral and liquidity uptake before combining it with additional data on financial health and deposit flows. This is done slightly differently than for the aggregate analysis, since now we are concerned with having complete data for each individual bank. Starting with the 813,576 bank-day observations in the raw data described in Subsection 2.3, we first remove 646 bank-day observations due to missing or zero collateral values. We also drop: 8,129 bank-day observations with negative or missing haircuts;[21] 5,954 additional bank-days with incomplete collateral data; 173 outliers (from five banks) where liquidity uptake exceeds daily reserve requirement by a multiple of more than 1,000; 2,455 observations with negative reserve holdings; 2,684 observations for which either bank type information is missing or the bank's official type changes within the sample period. We also exclude the two consecutive maintenance periods that include Lehman Brothers' bankruptcy and the start of the ECB's full-allotment policy. This covers the period September 10–November 11, 2008 and reduces the sample by 8,424 bank-day observations. Finally, we lose 74,049 bank-days because the reserve data ends in October 2010 and is also only available for banks that were required to hold reserves as of that month.

The final collateral and liquidity uptake data consists of 711,062 bank-day observations (87.4% of the raw data). Along the same lines as for the aggregate analysis, for each bank, we average all variables (described below) across sample days within each maintenance period. This leaves us with 55,334 bank-maintenance period observations.

This bank-maintenance period sample is combined with monthly balance sheet and yearly income statement data for all German registered banks. The balance sheet statistics provide us with the book values of equity and total assets (bank size) and end-of-month deposits from banks and non-banks (that we use to measure deposit flows). From the income statements, we obtain write-offs and provisions as well as return on assets (ROA).

We merge the three datasets by, for each bank-maintenance period, using the monthly balance sheet statistics (yearly income statement statistics) that apply at the end of the month (year) immediately preceding the start of the maintenance period. Deposit data are handled separately as described in the next subsection. In doing this, we drop 1,501 bank-

[21]These observations include the 7,029 bank-day observations without information on the country of origin in Subsection 2.4.

maintenance period observations without information on total assets, book value of equity, write-offs and provisions, ROA, or deposits. The final data on which we will carry out the panel analysis covers 56 maintenance periods and consists of 53,833 bank-maintenance periods involving 1,360 banks.

No banks in the Bausparkassen category survived the data filtering process. As noted by Fecht, Nyborg, and Rocholl (2011), these institutions have reserve requirements that are almost zero and therefore end up as extreme outliers in measures involving reserves. However, the final sample includes banks from all the other eight bank types.

3.2 Variables

The variables are divided into five categories; credit (liquidity uptake), collateral quality, financial health, deposit flow, and (collateral) concentration. All variables are per bank per maintenance period, as described above.

Credit (liquidity uptake) is equally weighted across sample days within each maintenance period and normalized by either total assets or daily average required reserves and expressed as a percentage of these. Credit normalized by total assets shows how much of a bank's balance sheet is financed by the ECB. In most of our regressions in Section 4, the variable on the left hand side is a bank's credit normalized by total assets.

The collateral variables are weighted by collateral value across a bank's collateral pool for each sample day and then averaged equally weighted across each maintenance period. Collateral quality variables are haircut, duration, probability of default (from the Bundesbank's proprietary model), liquidity category, and own-use. The latter is the collateral value of own-use collateral divided by total collateral value in a bank's pool. The concentration of a bank's collateral pool is measured by the Herfindahl-Hirschman index based on either asset class or issuer group.

We use the same three financial health variables as Fecht, Nyborg, and Rocholl (2011), namely (i) the equity ratio, defined as the book value of equity divided by total assets (balance sheet, monthly), (ii) write-offs and provisions (income statement, yearly) and (iii) ROA (income statement, yearly).

Deposit flows are based on monthly deposit data from banks' balance sheets and divided into bank and non-bank flows, both normalized by either assets or reserve requirements. Thus, there are four deposit flow variables in total. We are interested in deposit flows as a control to liquidity uptake and therefore wish to use it for the maintenance period that is contemporaneous to liquidity uptake. However, maintenance periods do not correspond to calendar months. We therefore proceed as follows, using the bank deposit flow normalized by assets as an example.

First, for each bank i and month t, define $\Delta Deposits_{i,t} = Deposits_{i,t} - Deposits_{i,t-1}$, where *Deposit* refers to bank deposits. Second, for maintenance period p, define

$$\Delta Deposits_{i,p} = \frac{d_{t-1} \times \Delta Deposits_{i,t-1} + d_t \times \Delta Deposits_{i,t}}{d_{t-1} + d_t},$$

where d_s is the number of days in month s that are in maintenance period p. This gives an estimate of the average daily bank deposit flow in maintenance period p. Finally, for bank i in maintenance period p we define the normalized deposit flow as

$$Normalized\ deposit\ flow_{i,p} = \frac{\Delta Deposits_{i,p}}{Total\ assets_{i,p}}, \tag{3}$$

where $Total\ assets_{i,p}$ is the total assets the last month before the start of maintenance period p. When we normalize by reserve requirements, we use the daily average reserve requirement for maintenance period p. Normalized non-bank deposit flows are defined analogously.

3.3 Descriptive statistics

We report descriptive statistics over the total sample period and three sub-periods. We use longer sub-periods than under the aggregate analysis in Subsection 2.4 in order to increase the power of our tests. The sub-periods are: (1) "Pre-crisis." January 18, 2006 to August 7, 2007. (2) "Early Crisis." August 8, 2007 to September 9, 2008. (3) "Full Allotment." November 12, 2008 to November 9, 2010. The start (end) date of each sub-period always coincides with the start (end) of a maintenance period. The number of maintenance periods in each period are 19, 13, and 24, respectively.

For each sub-period, we first take an equally weighted average across bank-maintenance periods for each bank, leaving us with a population of bank-subperiod observations for which we calculate means etc.[22] The reported statistics thus capture cross-sectional features of the data within each sub-period. For reasons of data confidentiality, we are not

[22]Note that our basic collateral and liquidity uptake data are provided for all banks with collateral in their respective pools. The averaging for each bank here is therefore across maintenance periods on which a bank has collateral in its pool (on at least one of the sample days).

allowed to report statistics that are taken from a single observation. Therefore, instead of minimums and maximums, we average the three smallest and three largest observations (for the relevant variable), which we refer to as Min3 and Max3, respectively. For the median we average three (four) observations around the median if the number of observations is odd (even). This variable is referred to as Median34. All references to a minimum, maximum, or median, below, refer to the Min3, Max3, or Median34 statistics, respectively.

Insert Table 3 here.

Table 3 provides descriptive statistics of normalized credit, collateral quality, financial health, normalized deposit flow, and collateral concentration for the three sub-periods (Panels A, B, and C) and the full sample period (Panel D). Note first that for normalized credit, the Min3 statistic is zero in all sub-periods. This means that many banks with collateral in their pools do not ask for Eurosystem credit. Focusing on credit normalized by total assets, we see that average liquidity uptake (credit) increases considerably under full allotment, going from 1.39% and 1.27% over the pre-crisis and early-crisis periods, respectively, to 2.60% under full allotment.

As we know from Subsection 2.4, the increase in average liquidity uptake is not due to an aggregate increase by German banks. Thus, it must reflect a large increase in the number of smaller banks that take Eurosystem credit. As seen in Table 3, the number of banks in our dataset increases from 879 and 833 in the pre-crisis and early-crisis periods, respectively, to 1,335 under full allotment. Recall that our dataset is comprised of all banks with collateral in their respective eligible collateral accounts with the Bundesbank. The largest increase is among cooperatives, from 363 in the early crisis to 774 under full allotment, suggesting that this sector was hit especially strongly by the crisis.

Average collateral quality measures are also somewhat different under full allotment. For example, the average liquidity category goes from 2.69 and 2.92 under the liquidity-neutral pre-crisis and early-crisis periods, respectively, to 3.35, under full allotment. This reflects the introduction of an additional liquidity category (Table 1). These numbers show that the average pledged collateral lies between a covered and uncovered bank bond. The corresponding figures for haircuts are 2.22%, 2.70%, and 5.89%. The increase after full allotment reflects the increase in haircuts to uncovered bank bonds. The average probability of default increases from 3.10 bps to 3.76 bps as we go from the liquidity-neutral early-crisis period to full allotment, but was a surprisingly large 6.66 bps over the pre-crisis period. Default probabilities are measured over the next twelve months by the Bundesbank's proprietary model. We do not have access to the details of this model, but our understanding is that it may have been updated from time to time. In the regression analysis, we use maintenance period fixed effects to control for potential changes over time and, for robustness, several measures of collateral quality.

The average bank's financial health is relatively stable over time. The average equity ratio is 5.56%, 5.58%, and 5.56% for the pre-crisis, early-crisis, and full-allotment periods, respectively, with the corresponding numbers for write-offs and provisions being 0.53%, 0.49%, and 0.45%. However, there is substantial variation across banks. For example, under full allotment, write-offs and provisions range from 0.00 to 2.76%. Not surprisingly, ROA falls as the crisis evolves, with the averages being 0.18%, 0.15%, and 0.05% over the three sub-periods in chronological order.

For deposit flows, it is arguably most interesting to focus on the variation across banks. This increased over time, especially for interbank flows. In the pre-crisis period, the standard deviation of this measure across banks is 0.47% (normalized by assets), increasing to 0.71% and 2.12% for the early-crisis and full-allotment periods, respectively. This is consistent with the idea that markets, even within Germany, became more segmented. The large increase in the number of banks in our dataset in the full-allotment period may also reflect such segmentation.

Mean values for the two Herfindahl-Hirschman indexes show that individual banks' holdings of collateral are fairly concentrated within specific asset classes. For either the asset class or issuer group measures, there are eight individual categories (see footnote 17). An even spread of collateral (by collateral value) across the eight categories would give an HHI value of 12.5%. Over the three sub-periods, mean values range from 63.73% to 65.77% (asset class) and 79.61% to 85.53% (issuer group). So the average bank essentially holds collateral within one to two categories. Over the whole sample period, the correlation between the two measures is 0.62.

Insert Table 4 here.

Table 4 complements Table 3 by providing average values, within each sub-period, for our variables for five size-sorted groups. The five groups comprise the four quartiles of the size distribution, with the last quartile being divided into banks in the 99th percentile (14 banks) and the rest. The size groups are constructed according banks' average sizes over the full sample period.

The table reveals that larger banks took more Eurosystem credit, relative to their total assets, than smaller banks before the introduction of full allotment. For example, for the 14 largest banks, the average liquidity uptake is 3.17% and 2.57% of total assets in the pre-crisis and early-crisis periods, respectively. For the smallest quartile of banks, the corresponding numbers are 0.59% and 0.48%. After the introduction of full allotment, however, this reverses. For the 14 largest banks, the average liquidity uptake is now 1.61% of total assets as compared with 2.42% for the smallest quartile. While this suggests a reversal of fortune for large and small banks, this is not so evident when looking at the collateral quality variables. For example, haircuts increase slightly more for the largest group than for the smallest. Next, we turn to examining the relation between liquidity uptake, size, collateral quality, and other variables more carefully using panel regressions.

4. Panel regressions: Liquidity uptake

This section studies the relation between liquidity uptake, collateral quality, financial health, deposit flows, and collateral concentration. We run panel regressions using the bank-maintenance period structure of the data described in Section 3. Our focus is especially on the determinants of liquidity uptake at the individual bank level.

In the first subsection, we use haircuts as a measure of collateral quality. Maintenance period fixed effects control for the inclusion of collateral rated in the BBB+ to BBB- range in October 2008, with associated larger haircuts. In the second subsection, we decompose haircuts into liquidity category, duration, and probability of default. In the third and last subsection, we then repeat the initial regression with the full set of collateral quality variables as well as the unexplained portion of haircuts from the exercise in the second subsection.

4.1 Regressions using haircuts to capture collateral quality

We regress liquidity uptake, or credit, normalized by total assets on size [ln(assets)], haircuts, the three financial health variables, bank and non-bank deposit flows normalized by total assets, and collateral concentration, with bank type and maintenance period fixed effects. A squared term is included for the equity ratio to account for nonlinear effects from this variable. Collateral concentration is captured by the HHI over issuer groups.[23] All financial health variables are lagged (as discussed in Section 3). Because credit is truncated at zero, we use the tobit procedure.[24] Separate regressions are run for the pre-crisis, early-crisis, and full-allotment periods as described in Section 3 as well as for the full sample period.

The results are in Table 5. Panel A reports the tobit coefficients, with t-statistics based on standard errors clustered at the individual bank level in parentheses underneath. Statistical significance (two-tailed) at the 1%, 5%, and 10% levels are indicated by a, b, and c, respectively. We have also calculated standard errors using the Huber-White correction for heteroskedasticity and report the level of significance of the tobit coefficients based on these standard errors in square brackets, using the same lettering scheme.

Tobit coefficients are difficult to interpret economically as they represent a combined measure of, in our case, (i) the change in the probability of taking credit (PoC), and (ii) the change in normalized credit conditional on taking credit (CCoC).[25] To help gauge the economic significance of the results, in Panel B of Table 5, we decompose the tobit coefficients into the effects of a one unit change in the independent variable on PoC and CCoC. For each independent variable, we report the average of each of these two marginal effects, keeping the other independent variables fixed at observed values. z-statistics with standard errors clustered at the individual bank level are in parentheses underneath the average marginal effects. Significance levels using clustered and Huber-White standard errors are indicated in the same way as in Panel A.

Insert Table 5 here.

With respect to the tobit coefficients in Panel A, we start by noting that normalized credit is increasing in bank size. The coefficients are statistically significantly different from

[23]The high correlation between HHI(issuer group) and HHI(collateral class) precludes us from including both measures. There are no noteworthy differences from using one or the other measure. Details are available from the authors upon request.

[24]We have also run the panel regressions without the tobit procedure and using credit normalized by reserve requirements, with similar results. Details are available from the authors upon request.

[25]See McDonald and Moffitt (1980).

zero at the 1% level for all sub-periods, using either type of standard error, except under full allotment with standard errors clustered at the bank level, where the coefficient is not statistically significant. This echoes the results from the size-sorted descriptive statistics in Table 4. However, the regression results show that the relatively small liquidity uptake by large banks under full allotment may reflect other characteristics of these banks.

Importantly, with respect to the hypothesis of systemic arbitrage, we see first that higher haircuts, i.e., lower collateral quality, are associated with larger liquidity uptakes. The haircut coefficient is statistically significant at the 1% level in all sub-period regressions, regardless of how we calculate standard errors. With respect to economic significance, Panel B shows that in the pre-crisis period, a one percentage point increase in haircut increases the probability of taking credit by 2.5 percentage points and, conditional on a bank taking credit, increases normalized credit by 0.147 percentage points. The latter effect represents a 10.64% increase over the average normalized credit, which is 1.39% in the pre-crisis period. Both marginal effects are about twice as large in the pre-crisis period as compared to the early-crisis and full-allotment periods.

With respect to the effect of financial health, the results on the equity ratio show that firms with relatively more healthy equity positions have lower liquidity uptakes. In the specification with Huber-White standard errors, the coefficients are negative and statistically significant at the 1% level in every sub-period. Using clustered standard errors, the coefficients remain significant for the pre-crisis and full-allotment periods, at the 10% and 1% levels, respectively. Thus the results on the equity ratio are especially strong under full allotment. This supports the view that funding, and not only mere liquidity, is provided to banks through Eurosystem repos under the full-allotment policy.

To account for the possibility of a nonlinear relation between the equity ratio and liquidity uptake, we have also included a square term (of equity ratio). This is positive and statistically significant at least at the 5% level in all sub-periods, using either type of standard error. This indicates that the relation between the equity ratio and normalized credit is downward sloping and convex, which makes intuitive sense.

Economically (Panel B), the effects of the equity ratio on liquidity uptake are similar in the pre-crisis and the full-allotment period, but weaker in the early-crisis period. In the full-allotment period, for instance, a one percentage point decrease in equity ratio increases the probability of positive credit by 2.4 percentage points and, conditional on a bank taking credit, increases credit as of total assets by 0.147 percentage points. The latter represents a 5.65% increase over the average normalized credit in the full-allotment period.

The coefficients on write-offs and provisions are also statistically significant in all sub-periods. In the clustered standard errors specification, the p-value is at least 10% across all sub-periods. However, the coefficient changes from negative in the two pre-full allotment sub-periods to positive under full allotment. While the full-allotment result is consistent with systemic arbitrage taking place, the negative coefficients in the two earlier sub-periods are surprising. This may be a result of relatively weaker banks understating, or "hiding", losses before the worst onslaught of the crisis. Such behavior could explain why the results are weaker for the equity ratio in the early-crisis period as well. As the crisis progressed, hiding losses may have become increasingly difficult to do. An alternative explanation is that this relates to poorly performing cooperatives and savings banks that get the liquidity they need from their respective head institutions. Such banks may have put collateral on account with the central bank as a "back-up." As seen in Table 3, after full allotment, the number of cooperatives with collateral on account increased substantially.

Economically (Panel B), in the full-allotment period, a one percentage point increase in write-offs and provisions (as a percentage of total assets) increases the probability of positive credit by 6.8 percentage points and, conditional on a bank taking credit, increases normalized credit by 0.405 percentage points. The latter represents a 15.59% increase over the average normalized credit in the full-allotment period.

Table 5 also uses the two deposit flow variables as controls. Banks with large inflows from other sources may have less of a need to tap the central bank. As seen, over the early crisis period, prior to full allotment, an increase in non-bank deposits tends to decrease a bank's central bank liquidity uptake. However, after the introduction of full allotment, this relation disappears. Deposits from other banks do not have a statistically significant impact on normalized credit in any subperiod.

The coefficient on the Herfindahl-Hirschman index is negative and statistically significant at the 1% level, using either type of standard error, in all sub-periods. This shows that banks that take more credit from the Eurosystem have a broader set of collateral holdings. It may well be that taking more credit requires acquiring a broader set of eligible collateral. What is interesting here is that while one might expect this to be increasingly better collateral with higher opportunity costs, the positive coefficients on haircut suggests that banks are able to broaden their collateral holdings into worse, rather than better, collateral when they seek more liquidity from the Eurosystem. This is supportive of the systemic arbitrage hypothesis.

To summarize, the results point to the existence of systemic arbitrage whereby banks in worse financial health and with worse collateral have larger liquidity uptakes from the central bank. The results are slightly stronger under the full-allotment period, when alternative sources of liquidity may have been reduced for many banks. Controlling for an unobserved bank effect by clustering at the bank level weakens the results only slightly relative to using Huber-White standard errors; the main variables remain statistically significant at conventional levels. This provides an illustration of the strength of the results, especially given the low frequency occurrence of the financial health variables and their relative lack of variation. That there are only relatively small differences, in terms of inferred statistical significance, between using Huber-White and clustered standard errors also suggests that our regression model is reasonably well-specified (Petersen, 2009; King and Roberts, 2015).

4.2 Haircuts and other collateral quality measures

Our use of Eurosystem haircuts as a rough and ready measure for collateral quality is based on Table 1, which shows that haircuts are increasing in duration, default probabilities (as captured by the rating), and illiquidity (as captured by the Eurosystem's liquidity category classification). In this subsection, we take a closer look at the extent to which these variables explain haircuts by using our bank-maintenance period panel data to regress haircuts on these more specific collateral quality measures. The findings are in Table 6.

Insert Table 6 here.

Panel A provides correlations of the three collateral quality measures over the three sub-periods discussed above and over the full sample periods. The correlation coefficients range from -0.273 (duration and default probability, pre-crisis) to 0.527 (liquidity category and default probability, full allotment), showing that the three variables capture different properties of banks' collateral pools.

Panel B contains the regressions. Over the three sub-periods, the adjusted R^2 ranges from 0.236 (early-crisis) to 0.673 (full-allotment period), showing that haircuts are fairly well explained by the three specific collateral quality measures. The coefficients on all three measures are statistically significant at the 1% level in all four regressions. This is not surprising given how Eurosystem haircuts are set, as seen in Table 1. As expected, haircuts are seen to increase in duration, liquidity category, and default probabilities. This holds true in all sub-periods, with one exception, namely the coefficient on the probability of default is negative in the pre-crisis period. This is odd, especially because the probability of default is calculated from the Bundesbank's own model. Overall, the results in Table 6, Panel B support the view that haircuts capture collateral quality, but also that our three specific collateral quality measures do not explain haircuts completely. This may be a result of the haircuts being updated infrequently and the relatively coarse grid that is used to set them, as seen in Table 1. Thus, it is interesting to revisit the regressions in the previous subsection with haircuts broken out into its "components."

4.3 Regressions using all collateral quality measures

In this subsection, we run tobit regressions that are essentially the same as those in Table 5, except that haircuts are replaced by its components; duration, probability of default, liquidity category, and the residual from regressing haircuts on these specific collateral quality measures.[26] We also include collateral own-use, which measures the fraction of collateral issued by an entity with which the bank that holds the collateral has close links. This can be viewed as a fourth collateral quality measure in that it may represent collateral that banks were unable to place in the market.

Insert Table 7 here.

The results are in Table 7. The structure is the same as for Table 5. Panel A reports on the tobit coefficients and Panel B on the marginal effects. Our discussion concentrates on the collateral quality variables. The results are essentially the same as in Table 5 for the financial health, deposit flow, and HHI variables.

We see in Panel A that liquidity uptake is increasing in the liquidity category and the probability of default in all three sub-periods, with all coefficients being statistically significant at least at the 5% level when using clustered standard errors. This supports our conclusion in Subsection 4.1 that banks with lower-quality collateral take more Eurosystem

[26]The residuals are from cross-sectional regressions within each maintenance period.

credit.

The results on duration are in line with this conclusion for the pre-crisis and early-crisis periods, with the pre-crisis (early-crisis) coefficient being positive and statistically significant at the 1% level when using clustered (Huber-White) standard errors. However, under full allotment, the coefficient on duration changes sign, becoming significantly negative. This may reflect the composition of banks' collateral pools. Table 6 shows that duration is negatively correlated with both the liquidity category (except over the early-crisis period) and the probability of default. Thus, it is possible that the negative coefficient on duration in Table 7 under full allotment reflects a dominant usage of relatively short term, but risky and illiquid collateral among some German banks.

The coefficient on own-use is statistically significant (using either type of standard error) only in the full-allotment period, when it is positive. This is suggestive of a particularly active exploitation of the correlated default loophole in the collateral framework during the full-allotment period. Work not shown here indicates that this is especially driven by private loan banks and special purpose banks.

With respect to economic significance, Panel B shows that, in the pre-crisis period, a one-step increase in the liquidity category increases the probability of positive credit by 13.6 percentage points. Conditional on a bank taking credit, it also increases normalized credit by 0.809 percentage points, which is 58.35% larger than the average normalized credit in the pre-crisis period. PoC is approximately 55% and 90% larger in the pre-crisis period than the early-crisis and full-allotment periods, respectively. CCoC is around 70% and 85% larger, respectively. In contrast, for the probability of default, both marginal effects are much smaller for the pre-crisis period than the other two periods. Under full allotment, a one basis point increase in the probability of default increases the probability of positive credit by 1.1 percentage points and, conditional on a bank taking credit, increases normalized credit by 0.065 percentage points. The latter represents a 2.51% increase over the average normalized credit in the full-allotment period.

Panel B also shows that in the pre-crisis (full-allotment) period, a one year increase in duration increases (decreases) the probability of positive credit by 2.5 (1.6) percentage points and, conditional on positive credit, increases (decreases) normalized credit by 0.150 (0.096) percentage points. The latter represents a 10.81% (3.69%) increase (decrease) over the average normalized credit in the pre-crisis (full-allotment) period.

Finally, in the full-allotment period, a one percentage point increase in own-use as a percentage of total assets increases the probability of positive credit by 0.4 percentage points and, conditional on positive credit, increases credit as of total assets by 0.022 percentage points. The latter represents a 0.85% increase over the average normalized credit in the full-allotment period.

To summarize, the results in this section support the view that banks take advantage of the Eurosystem's collateral framework. In particular, banks in worse financial health and with worse collateral have larger liquidity uptakes relative to their assets than financially healthier banks with better quality collateral. In short, banks engage in systemic arbitrage. It is noteworthy that this describes the data over all three sub-periods, including the pre-crisis period. Thus, systemic arbitrage is not a crisis phenomenon, but reflects more fundamental issues with the Eurosystem's collateral framework.

5. Panel regressions: Collateral quality

We have seen that banks with worse collateral and in worse financial health have relatively large liquidity uptakes. In this section, we ask whether it is also the case that banks in worse financial health have worse collateral. This is an interesting question, in part, because it would imply an amplification of systemic arbitrage. It also relates to the idea, discussed in the Introduction, that banks have an incentive to pledge collateral that is relatively more likely to default when the bank itself defaults ("correlated collateral"). This is so because haircuts are not adjusted for "plain" counterparty risk or the risk of joint default of collateral and counterparty. While the granularity of the data does not allow us to test specifically whether weak banks have especially large usage of correlated collateral, we can test whether they have relatively larger usage of low quality collateral.

In this section, therefore, we regress measures of collateral quality on financial health. As before, collateral quality is captured by the haircut and its three "components," probability of default, liquidity category, and duration. We use the same bank-maintenance period data as described in Sections 3 and 4. As above, we run panel regressions with bank sector and maintenance period fixed effects. In our main specification, standard errors are clustered at the bank level, but we also report significance levels based on Huber-White corrected standard errors.

Because we are primarily interested in the relation between collateral quality and financial health for bank-maintenance period observations with positive liquidity uptake, we use the Heckman selection model.[27] This combines a selection mechanism for having a positive liquidity uptake with a panel regression of collateral quality on the three financial health variables (equity ratio, write-offs and provisions, ROA) and the fixed effects. Indexing banks by i and maintenance periods by j, the selection equation is

$$z_{ij}^* = \gamma' w_{ij} + \mu_{ij}. \tag{4}$$

The regression model is

$$y_{ij} = \beta' x_{ij} + \epsilon_{ij}, \tag{5}$$

where $(\mu_{ij}, \epsilon_{ij})$ are assumed to be bivariate normal $[0, 0, 1, \sigma_\epsilon, \rho]$.

z_{ij}^* is not observed; the variable is observed as $z_{ij} = 1$ if $z_{ij}^* > 0$ and 0 otherwise with probabilities Prob$(z_{ij} = 1) = \Phi(\gamma' w_{ij})$ and Prob$(z_{ij} = 0) =$ 1-$\Phi(\gamma' w_{ij})$. $z_i = 1$ indicates that the bank has positive liquidity uptake (takes credit) and Φ is the standardized normal cumulative distribution function.

In the selected sample,

$$E[y_{ij}|z_{ij} = 1] = \beta' x_{ij} + \rho\sigma_\epsilon\lambda(\gamma' w_{ij}), \tag{6}$$

where λ is the inverse Mills ratio. The model is estimated by maximum likelihood, see Greene (2000), which provides consistent, asymptotically efficient parameter estimates.

The selection equation includes an additional variable, that is not in the regression model, namely Positive liquidity uptake$_{i,j-1}$.[28] This is an indicator variable that is 1 if bank i has positive credit from the Eurosystem in maintenance period $j-1$ and zero otherwise. As before, we run the model over the full sample period and over each of the three sub-periods; pre-crisis, early crisis, and full allotment. The results are in Table 8.[29]

Insert Table 8 here.

[27] In work not reported here, we have also run plain panel regressions. The results turn out to be very similar.

[28] We have also used the two deposit flow variables in the selection equation, without this making a noteworthy qualitative difference to the results.

[29] Because of the additional variable in the selection equation, we lose two maintenance periods in the main regressions (as seen by a comparison between Tables 5 and 8).

The findings in Table 8 are broadly consistent with the hypothesis that banks in worse financial health use worse collateral, but with a lower degree of statistical significance than in the previous section. Our discussion starts with the case that the haircut is the dependent variable (Panel A) and then moves on to the cases where probability of default (Panel B), liquidity category (Panel C), and duration (Panel D) are the dependent variables.

As seen in Panel A, the coefficient on the equity ratio is consistently negative across all sub-periods, indicating that banks with a lower equity ratio use collateral with higher haircuts. The coefficients are statistically significant at the 1% level in all sub-periods using Huber-White standard errors. Using clustered standard errors, only the pre-crisis period coefficient is statistically significant at conventional levels (5%). In terms of economic magnitude, a one standard deviation decrease in the equity ratio increases the haircut by 0.11, 0.04, and 0.04 standard deviations in the pre-crisis, early-crisis, and full-allotment periods, respectively.[30]

The coefficients on write-offs and provisions are positive for all sub-periods, which is consistent with banks in worse financial health employing worse collateral. Based on Huber-White standard errors, the coefficients are statistically significant at the 1% level in the pre-crisis and full-allotment periods. Using bank-clustered standard errors, we have statistical significance at conventional levels only in the pre-crisis period, but the p-value is 12.2% in the full-allotment period. In terms of economic magnitude, a one standard deviation increase in write-offs and provisions is associated with a 0.17 and 0.03 standard deviation increase in the haircut in the pre-crisis and full-allotment periods, respectively. The results on ROA are weaker, as they were in Section 4.

The results in Panel B, where collateral quality is captured by the probability of default, complement those in Panel A. Using bank-clustered standard errors, the coefficient on the equity ratio is negative and statistically significant at the 5% level or better in both the pre-crisis and early-crisis regressions. The coefficient on write-offs and provisions is statistically significantly positive at the 5% level in the full-allotment period. We also find that the coefficient on ROA is statistically significantly positive in the early-crisis period, which is somewhat surprising. This may reflect that banks with high ROA take more risk or generally use their assets more efficiently. In terms of economic significance, in the early-crisis (full-allotment) period, a one standard deviation increase in the equity ratio (write-offs

[30]Using the standard deviations in the pooled bank-maintenance period sample used in the regressions.

and provisions) is associated with a 0.06 (0.07) standard deviation decrease (increase) in the probability of default.

The results using liquidity category and duration (Panels C and D, respectively) also support the view that financially weaker banks use lower-quality collateral in central bank repos. Focusing on regressions with statistically significant coefficients based on bank-clustered standard errors, we see that a lower equity ratio is associated with less liquid collateral (pre-crisis and full allotment) and higher duration (early crisis). In addition, an increase in ROA is associated with more liquid collateral (pre-crisis) and lower duration (pre- and early- crisis).

Overall, these findings support the idea that weaker banks use worse collateral, as captured by either the probability of default, liquidity category, or duration. It is noteworthy that the results are strong over the pre-crisis period when the ECB operated with a liquidity-neutral policy. This supports the view that systemic arbitrage is not a crisis phenomenon. This also leaves us with the question as to whether systemic arbitrage contributed to the severity of the crisis in the first place.

6. Discussion: Market discipline impairment and financial fragmentation

In this section, we discuss more fully the potentially adverse consequences of systemic arbitrage that we touched on in the Introduction.

Systemic arbitrage channels an overweight of liquidity directly from the central bank to relatively weaker banks. This may affect markets in several ways. First, it reduces the market's disciplinary function with respect to weaker banks since they have less of need to access the secondary market for liquidity. Among other things, this would be expected to reduce information production on the quality of weaker banks' balance sheets. Second, the distribution of credit spreads may widen across banks. The reason is that weaker banks' balance sheets will be relatively highly encumbered, because of their relatively large collateralized liabilities in favor of the central bank; while the opposite is true for relatively strong banks. As a result, the range of expected losses given default on unsecured bank loans widens across banks. In turn, this may reduce the efficiency of the interbank market, for example for reasons articulated in Afonso, Kovner, and Schoar (2011). This is especially relevant if wider credit spreads are accompanied by a rise in information asymmetries, as seems plausible. Third, collateral information production may be impaired, thus increasing the likelihood of a financial crisis (Gorton and Ordoñez, 2014). Fourth, systemic arbitrage may be associated with an underlying incentive within the banking sector to make weak banks weaker and strong banks stronger. This derives from what we referred to in the Introduction as the correlated default loophole. In particular, since Eurosystem haircuts are neither adjusted for individual banks' credit risk, nor for the correlations between collateral and bank default risk, banks have an incentive to pledge collateral that is likely to default when they default themselves. The weaker are the banks that obtain the majority of the liquidity from the Eurosystem, and the worse their collateral is, the greater are the arbitrage gains vis-à-vis the central bank.[31] In short, systemic arbitrage weakens market discipline, reduces information aggregation, and fosters heterogeneity across banks with respect to credit risk and collateral quality. All these factors impair the workings of the market for liquidity and make it more vulnerable to shocks.

These issues may be relevant with respect to the well-documented and severe stress that emerged in the market for liquidity around the time of Lehman Brother's default in the fall of 2008 (see, e.g., Cassola, Holthausen, and Lo Duca, 2010, and Gabrieli and Georg, 2014). Several authors have suggested that information asymmetries about credit risk were at the heart of the problem and have developed theoretical models and/or empirical evidence along those lines (see, e.g., Heider, Hoerova, and Holthausen, 2015, and Bräuning and Fecht, 2017).[32] Our suggestion is that systemic arbitrage may have contributed to a growth in both information asymmetries and bank heterogeneity prior to Lehman's default, thereby making the market for liquidity ripe for turmoil. The financial system may have

[31] This effect is somewhat related to Diamond and Rajan (2011). These authors emphasize the incentives of highly leveraged banks to take correlated liquidity risks, i.e. invest in assets that are especially illiquid conditional on banks experiencing a (severe) liquidity shock. They go on to argue that a sufficient state-contingent liquidity provisioning by the central bank can eliminate, or reduce, the associated inefficiencies. In contrast, the correlated default loophole we emphasize in this paper involves banks seeking a strong correlation between their own default and that of the collateral they pledge in central bank repos. The central bank's liquidity support may foster this. Our emphasis is on the incentives created by the micro-design of the central bank's liquidity provisioning.

[32] Freixas and Jorge (2008) also study the effects of information asymmetries and opacity in interbank markets.

been especially vulnerable to a severe shock, such as the Lehman default in September 2008, coming as it did after more than a year of impairment in the market for liquidity.[33]

Because it increases the scope for systemic arbitrage, the full-allotment policy, introduced to alleviate the stress in the markets, may have contributed to worsening conditions over time instead. Our finding in Section 4 that bank and non-bank deposit flows no longer affect banks' liquidity uptakes under full allotment speaks to this, since it means that the role of markets have been greatly reduced under the full-allotment policy.

The full-allotment policy and the ability to use illiquid collateral in Eurosystem operations may also have reduced incentives for the private provisioning of liquidity for the simple reason that it reduces banks' need to hold liquid assets. Thus, this policy may have exacerbated the free-rider problem with respect to the private provisioning of liquidity (Bhattacharya and Gale, 1987). Indeed, Farhi and Tirole (2012) argue that an accommodative monetary policy and expectations of central bank interventions may lead banks to coordinate on excessive liquidity risk taking.

Systemic arbitrage and the correlated default loophole may also have contributed to financial fragmentation in the euro area. Acharya and Steffen (2015, Table 2) document that banks in non-GIIPS eurozone countries decreased their holdings of GIIPS sovereign bonds from March 2010 to June 2012, while banks in GIIPS countries increased theirs. Our findings in Subsection 2.4 show that fragmentation started even earlier (see also Abbassi, Bräuning, Fecht, and Peydró, 2014, for evidence on earlier fragmentation). The predicament of eurozone financial fragmentation is discussed in further detail in European Central Bank (2012 and 2014), Van Rixtel and Gasperini (2013), and Cline (2014). Our finding that German banks have decreased their reliance on periphery collateral over time also speaks to rising fragmentation in the euro area. The logic as to how the correlated default loophole in the Eurosystem's collateral framework contributes to a build-up in market fragmentation is straightforward. Under the view that a government default leads to same-country bank defaults, the correlated default loophole implies that banks prize domestic paper because they benefit from a premium paid in the market for a risk that is irrelevant to them. Thus,

[33]We also know that sovereign bond spreads (over German bonds) in the euro area started to increase in the second quarter of 2008 (see, e.g., Nyborg, 2016a), suggesting a shortage of riskfree collateral was developing in the euro area. This may have reduced the ability of the repo markets to pick up the slack from a stressed unsecured market (apply Ewerhart and Tapking's, 2008, logic).

as sovereigns get weaker, fragmentation is likely to increase.

Fragmentation is also visible in the liquidity uptake data. The evidence in this paper shows that German banks reduced their liquidity uptake, both in absolute and relative terms, under the full-allotment policy. We also know that it is especially banks in the periphery member states that have had large liquidity uptakes since the introduction of full allotment (see, e.g., Pisani-Ferry and Wolff, 2012, and Nyborg, 2016a). Thus, our evidence on systemic arbitrage from individual German banks may represent a microcosm of what appears to be a broad trend in the euro area under the period of this study, with weaker banks (from more financially fragile nations) taking increasingly more Eurosystem credit with increasingly lower quality and more correlated collateral. A lack of eurozone market integration hinders the flow of liquidity and capital and undermines the attractiveness of the single currency.

Our results raise the issue that ECB collateral policy has contributed to financial fragmentation in the euro area, strengthening the unfortunate nexus between sovereigns and banks. The full-allotment policy, under the current collateral framework, amplifies fragmentation because it increases the scope for taking advantage of the correlated default loophole. In turn, a larger exposure of banks in financially weaker member states to (risky) domestic sovereign debt would reduce other banks' willingness to lend to them, contributing further to market fragmentation.

Large-scale systemic arbitrage may reduce a central bank's room to maneuver, because it weakens the central bank's own balance sheet and impairs monetary policy transmission mechanisms that work through interbank markets. In turn, this may lead to a spiral of ever-stronger central bank policies. As systemic arbitrage and fragmentation increase in the euro area, potential losses from defaults in financially weaker countries may increase. As a result, the ECB may see it as necessary to administer increasingly more powerful medicine to keep weaker and highly indebted member states and their banks from defaulting. The introduction of quantitative easing in September 2014 (covered bonds and ABSs) and January 2015 (public sector debt) may be seen in this light.

7. Concluding remarks

In this paper, we contribute to the emerging literature on collateral policy by showing that a broad collateral framework, such as that employed by the ECB, can be collectively arbitraged by banks. In particular, using a unique and comprehensive dataset of German banks, we document that banks in worse financial health and with worse collateral have relatively large liquidity uptakes in Eurosystem repos. This holds true both under the original liquidity-neutral policy that was in place until October 2008 and under the emergency full-allotment policy that replaced it. We refer to this phenomenon as systemic arbitrage because it represents the banking system arbitraging the monetary system. Under the liquidity-neutral policy, banks obtain the aggregate liquidity they need in a relatively inexpensive way through the usage of lower-quality collateral and worse credit risk. Under the full-allotment policy, this can be expanded.

A collateral policy that admits systemic arbitrage may be viewed as providing support to weaker banks. While there may be some merit to such a policy, it has the disadvantage of reducing the effectiveness of market discipline. In the long run, this may make weak banks weaker and require further and stronger support. The ECB's full-allotment policy and quantitative easing may be seen in that light.

The opportunity costs of high-quality collateral is a key driver of systemic arbitrage. In recent years, interbank repo transactions using high-quality collateral have increased in importance relative to unsecured transactions (European Central Bank, 2015). This is due to several factors; for example, technological advancements in collateral management, increased concern about counterparty credit risk as a result of the financial crisis, and preferable regulatory treatment of secured interbank lending, for instance, under Basel III. These developments are likely to aggravate systemic arbitrage and the associated impairments to efficiency and stability of the financial system.

In the euro area, disparity in the financial health of the different member states and their respective banking systems has been a growing concern since the onset of the financial crisis. We document that, in aggregate, German banks reduced their borrowings from the Eurosystem after the Lehman failure and the introduction of the full-allotment policy, both in absolute terms and relative to other euro area banks. They also reduced their reliance on CGIIPS collateral. So, in aggregate, German banks reduced risk vis-à-vis the central bank.

However, we know that this has been accompanied by large cross-border inflows through the Target system (Sinn, 2014), which is a potential risk to the Bundesbank should member states with Target deficits leave the euro. Thus, the costs to systemic arbitrage under the full-allotment policy are, in a sense, pushed up to a more aggregate level. An important direction for future research is to deepen our understanding of the consequences of broad collateral policies that admit systemic arbitrage and, in the context of the euro area, the implications with respect to financial fragmentation.

Systemic arbitrage may be reduced by designing a system where market forces play a stronger role, for example with respect to haircuts (Nyborg, 2016a). A challenge with respect to this is to have haircuts accurately reflect not only the risk of the collateral, but also credit risk. This may be difficult under today's system, with thousands of eligible counterparties in Eurosystem operations and a very wide range of eligible collateral. Thus, it may be worthwhile to consider implementing a primary dealer system, where only prime banks can borrow directly from the Eurosystem, or confining the list of eligible collateral.

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Table 1
Eurosystem haircuts.

Eurosystem haircuts (in %) for marketable collateral by liquidity category, residual maturity, and coupon (zero, fixed, or floating). Panel A: Applies from March 8, 2004 to December 31, 2006 for tier one marketable assets and, after the introduction of the "single list," for all marketable assets from January 1, 2007 to October 24, 2008. See Guideline of the European Central Bank (2003) for initial documentation of these haircuts and Guideline of the European Central Bank (2006) for the introduction of the single list. Panel B: Incorporates updates announced on October 23, 2008. Updates in blue slanted type and with a dagger (†) apply from October 25, 2008 (European Central Bank, 2008a). Those in red italic and starred (*) apply from February 1, 2009 (European Central Bank, 2008b). Nyborg (2017a) provides a further list of references showing the validity of the haircuts in both panels over the full periods listed here. Note that some marketable asset special cases as well as non-marketable assets are not covered by the table. See Nyborg (2017a) for details.

Panel A: Haircuts applied to marketable tier one assets (from March 8, 2004 to December 31, 2006) or all marketable assets (January 1, 2007 to October 24, 2008)

	Liquidity categories							
	Category I Central government debt instruments, Debt instruments issued by central banks		***Category II*** Local and regional government debt instruments, Jumbo Pfandbrief-style debt instruments, Agency debt instruments, Supranational debt instruments		***Category III*** Traditional Pfandbrief-style debt instruments, Credit institution debt instruments, Debt instruments issued by corporate and other issuers		***Category IV*** Asset-backed securities	
Residual maturity (years)	fixed coupon	zero coupon	fixed coupon	zero coupon	fixed coupon	zero coupon	fixed coupon	zero coupon
0-1	0.5	0.5	1.0	1.0	1.5	1.5	2.0	2.0
1-3	1.5	1.5	2.5	2.5	3.0	3.0	3.5	3.5
3-5	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
5-7	3.0	3.5	4.5	5.0	5.5	6.0	6.5	7.0
7-10	4.0	4.5	5.5	6.5	6.5	8.0	8.0	10.0
>10	5.5	8.5	7.5	12	9.0	15.0	12.0	18.0

Tier one floating rate debt instruments: Same as zero-to-one-year maturity bucket of fixed coupon instruments given the liquidity category.

Tier one inverse floating rate debt instruments: Haircuts are the same for all liquidity classes, but differ with respect to residual maturity as follows (residual maturity, haircut): 0-1, 2.0; 1-3, 7.0; 3-5, 10.0; 5-7, 12.0; 7-10, 17.0; >10, 25.0.

Table 1 – *continued*

Panel B: Haircuts applied to eligible marketable assets (from October 25, 2008 to December 31, 2010)

		Liquidity categories for marketable assets								
		Category I Central government debt instruments, Debt instruments issued by central banks		***Category II*** Local and regional government debt instruments, Jumbo covered bank bonds, Agency debt instruments, Supranational debt instruments		***Category III*** Traditional covered bank bonds, Debt instruments issued by corporate and other issuers		***Category IV**** *Credit institution debt instruments (unsecured)**		***Category V**** *Asset-backed securities**
Credit quality†	Residual maturity (years)	fixed coupon	zero coupon	fixed coupon	zero coupon	fixed coupon	zero coupon	fixed coupon	zero coupon	
AAA to A-†	0-1	0.5	0.5	1.0	1.0	1.5	1.5	*6.5**	*6.5**	*12**
	1-3	1.5	1.5	2.5	2.5	3.0	3.0	*8.0**	*8.0**	
	3-5	2.5	3.0	3.5	4.0	4.5	5.0	*9.5**	*10.0**	
	5-7	3.0	3.5	4.5	5.0	5.5	6.0	*10.5**	*11.0**	
	7-10	4.0	4.5	5.5	6.5	6.5	8.0	*11.5**	*13.0**	
	>10	5.5	8.5	7.5	12.0	9.0	15.0	*14.0**	*20.0**	

Floating rate debt instruments: *For liquidity categories I to IV*, same as in Panel A.*

Inverse floating rate debt instruments: *For liquidity categories I to IV* same as in Panel A.*

BBB+ to BBB-†:
Add 5% to AAA to A- according to residual maturity, coupon structure and liquidity category except for ABS for which BBB- to BBB+ is not eligible.†

Table 2

Aggregate collateral amount and liquidity uptake patterns from January 2006 to December 2010.

This table reports on various features of the aggregate collateral pool (of German banks) over time. Statistics are provided for the whole sample period (January 18, 2006 to December 31, 2010) as well as for five sub-periods: "2006", "Pre-Crisis", "Crisis to Lehman", "Post-Lehman", and "2010", with dates as shown below. The whole sample period covers 60 maintenance periods. We observe at least one day in each maintenance period. Values of each variable are first averaged within each maintenance period. The reported numbers are averages of these maintenance period mean values (there are two exceptions to this procedure–both in Panel A).

Panel A: Collateral and credit are the aggregated collateral values and liquidity uptakes, respectively. The Euroystem liquidity uptake is taken from the ECB's webpage, `http://sdw.ecb.europa.eu/browse.do?node=bbn129`). "Coverage ratio, Germany" is collateral divided by credit in Germany, calculated from the numbers in the table, except for the total sample period where the ratio is a quantity weighted average of the sub-period values in the table (weights: number of maintenance periods). "Credit ratio Germany/Eurosystem" is German liquidity uptake as a fraction of the total Eurosystem uptake, calculated from the numbers in the table (the total sample period ratio is calculated as for the coverage ratio).

Panel B shows collateral pool weights of (1) different collateral types, (2) the issuers' country of residence, and (3) of own-use collateral. Types are Government, Covered, Corporates, and "Uncovered etc.". Country of residence is either Germany or CGIIPS (Cyprus, Greece, Ireland, Italy, Portugal, and Spain). Own-use refers to collateral issued by an entity with which the bank that holds it in the pool has "close links" (European Central Bank, 2005, and European Central Bank, 2010).

Panel C shows excess collateral ratios calculated as (*collateral value* − *excluded collateral* − *credit*)/(*collateral value* − *excluded collateral*). First, we take all collateral into account (no subset is excluded). Second, we exclude "non-German" collateral, third, "Uncovered etc.", and fourth, the latter together with collateral of CGIIPS issuers.

		Total	**2006**	**Pre-Crisis**	**Crisis to Lehman**	**Post-Lehman**	**2010**
		18.01.06	18.01.06	17.01.07	08.08.07	16.09.08	20.01.10
		31.12.10	16.01.07	07.08.07	09.09.08	19.01.10	31.12.10
Number of banks (min – max)		45 – 1,387	864 – 981	202 – 859	203 – 862	801 – 1,387	45 – 1,383
Number of maintenance periods		60	12	7	13	16	12
Number of observed days		667	21	14	113	278	241
Panel A: Collateral and liquidity uptake							
Collateral, Germany	mEUR	616,517	494,536	516,887	596,291	728,599	669,086
Credit, Germany	mEUR	206,483	233,027	233,775	199,499	222,966	149,606
Credit, Eurosystem	mEUR	555,567	424,141	434,663	461,690	710,135	653,133
Coverage ratio, Germany	%	3.10	2.12	2.21	2.99	3.27	4.47
Credit ratio Germany/Eurosystem	%	39.58	54.94	53.78	43.21	31.40	22.91
Panel B: Collateral pool weights							
Government*	%	16.60	20.13	15.46	14.39	13.54	20.21
Covered**	%	22.60	28.03	24.62	22.13	20.88	18.81
Corporates	%	6.50	5.75	6.76	7.04	6.80	6.09
Uncovered etc.	%	54.29	46.09	53.16	56.44	58.75	54.87
Germany	%	54.49	55.21	46.98	45.03	58.51	63.04
CGIIPS	%	20.92	21.28	25.39	27.25	19.08	13.54
Own-use	%	6.47	1.71	1.40	1.38	11.12	13.51
Panel C: Excess collateral given different exclude subsets							
Nothing excluded	%	65.47	52.90	54.67	66.59	69.34	77.95
Excl. Non-German	%	34.27	14.44	3.04	25.66	46.82	64.91
Excl. Uncovered etc.	%	24.64	12.49	3.09	23.28	25.64	49.50
Excl. Uncovered etc. + CGIIPS	%	3.84	-11.65	-28.03	-3.33	3.66	45.95

* By central, regional or local governments, or central banks, agencies, or supranationally issued debt instruments

** Traditional and jumbo covered bank bonds

Table 3

Descriptive statistics: per sub-period and for the full sample period.

Descriptive statistics for normalized credit, collateral quality, financial health, normalized deposit flows, and concentration measures. The population is equally weighted averages across maintenance periods for each bank and sub-period (or the total sample period). Panel A covers the "Pre-Crisis", Panel B the "Early Crisis", Panel C the "Full Allotment", and Panel D the full period. "SE" is standard errors. "SD" is standard deviation. "Med34" is either the average of the *four* observations around the median if the number of observed banks is even or, else, of the *three* observations around the median. "Min3" is the average of the smallest three observations. "Max3" is the equivalent for the largest three observations. "Number of banks" shows counts in total and by bank sectors. "Head" institutions are Landesbanks and Cooperative central banks.

The logarithm of total book assets measures bank size. Credit is normalized either by total assets, with assets taken from the end-of-month preceding each maintenance period, or by average daily reserve requirements in each maintenance period. Collateral quality measures are collateral haircut, duration, probability of default, liquidity category, and the fraction of own-use collateral. Financial health measures are equity ratio, write-offs & provisions, and ROA. Equity ratio is equity divided by total assets, both taken from the end-of-month preceding each maintenance period. Write-offs and provisions (ROA) are given as preceding year's write-offs and provisions (income) divided by total assets, where assets are taken from the beginning of the preceding year. Deposit flows are contemporaneous and normalized in the same manner as credit is normalized. Deposit flows are separated into flows of banks and flows of non-banks. Concentration measures are the Herfindahl-Indices for collateral classes and issuer groups.

		Panel A: Pre-Crisis						*Panel B: Early Crisis*					
		January 1, 2006 – August 7, 2007						August 8, 2007 – September 9, 2008					
	Units	Mean	SE	SD	Med34	Min3	Max3	Mean	SE	SD	Med34	Min3	Max3
ln(assets)	Ln(Eur)	20.78	0.05	1.54	20.70	16.32	26.52	20.90	0.05	1.53	20.80	16.53	26.63
Credit, normalized													
By assets	%	1.39	0.11	3.25	0.04	0.00	32.86	1.27	0.09	2.72	0.10	0.00	21.23
By res. req.	%	335.99	96.27	2,854.31	4.30	0.00	44,600.07	319.60	89.71	2,589.06	8.25	0.00	41,312.02
Collateral quality													
Haircut	%	2.22	0.04	1.08	1.96	0.50	11.56	2.70	0.06	1.79	2.40	0.53	16.90
Duration	year	2.49	0.06	1.84	2.15	0.02	16.72	2.57	0.07	1.92	2.17	0.03	17.17
Prob. of default	bps	6.66	0.28	8.37	4.17	1.00	46.00	3.10	0.14	4.07	2.40	1.00	46.00
Liquidity category	1-6	2.69	0.02	0.55	2.76	1.00	4.35	2.92	0.02	0.67	3.00	1.00	5.33
Own-use	%	0.36	0.15	4.56	0.00	0.00	73.59	0.29	0.13	3.89	0.00	0.00	58.91
Financial health													
Equity ratio	%	5.56	0.14	4.05	5.12	0.52	60.33	5.58	0.13	3.68	5.21	0.48	54.87
Write-offs & prov.	%	0.53	0.02	0.54	0.49	0.00	6.65	0.49	0.01	0.31	0.48	0.00	2.63
ROA	%	0.18	0.05	1.46	0.17	-19.23	11.58	0.15	0.05	1.52	0.16	-20.88	10.28
Deposit flow, normalized													
Banks, by assets	%	0.03	0.02	0.47	-0.01	-1.96	5.01	0.17	0.02	0.71	0.07	-2.93	8.09
Non-banks, by assets	%	0.17	0.03	0.75	0.07	-0.99	9.54	0.36	0.07	2.13	0.16	-3.07	27.76
Banks, by res. req.	%	235.80	196.59	5,828.36	-0.99	-10,763.14	78,889.24	790.42	737.32	21,280.22	5.10	-18,517.94	230,243.68
Non-banks, by res. req.	%	35.02	17.23	510.96	6.20	-2,290.89	5,792.27	103.17	55.95	1,614.89	13.65	-858.48	18,609.47
Concentration													
HHI collateral class	%	65.71	0.82	24.34	60.84	20.42	100.00	65.77	0.83	23.95	60.80	17.95	100.00
HHI issuer group	%	85.53	0.63	18.73	97.71	28.44	100.00	84.34	0.67	19.48	94.44	25.25	100.00
Number of banks		Total:		879	Foreign:		11	Total:		833	Foreign:		11
		Private:		88	Head:		12	Private:		89	Head:		12
		Savings:		354	Private loan:		13	Savings:		334	Private loan:		13
		Cooperatives:		390	Special purpose:		11	Cooperatives:		363	Special purpose:		11

Table 3 – *continued*

		Panel C: Full Allotment November 12, 2008 – November 9, 2010						*Panel D: Full Period* January 1, 2006 – November 9, 2010*					
	Units	Mean	SE	SD	Med34	Min3	Max3	Mean	SE	SD	Med34	Min3	Max3
ln(assets)	Ln(Eur)	20.51	0.04	1.46	20.37	16.60	26.71	20.45	0.04	1.45	20.32	16.52	26.62
Credit, normalized													
By assets	%	2.60	0.08	2.88	1.82	0.00	23.32	2.16	0.07	2.59	1.41	0.00	22.30
By res. req.	%	409.52	79.54	2,906.12	145.15	0.00	50,974.22	366.15	75.70	2,791.59	116.76	0.00	47,301.43
Collateral quality													
Haircut	%	5.89	0.06	2.12	5.96	0.71	18.06	4.78	0.06	2.07	4.30	0.78	15.26
Duration	year	2.79	0.05	1.96	2.42	0.07	25.92	2.68	0.05	1.68	2.33	0.05	17.91
Prob. of default	bps	3.76	0.06	2.09	3.60	1.00	19.39	4.34	0.09	3.27	3.86	1.00	39.24
Liquidity category	1-6	3.35	0.02	0.60	3.45	1.01	5.29	3.18	0.02	0.59	3.21	1.00	5.01
Own-use	%	0.83	0.20	7.28	0.00	0.00	99.41	0.61	0.16	5.84	0.00	0.00	99.41
Financial health													
Equity ratio	%	5.56	0.07	2.69	5.25	0.45	41.80	5.63	0.09	3.21	5.27	0.48	56.79
Write-offs & prov.	%	0.45	0.01	0.30	0.41	0.00	2.76	0.47	0.01	0.29	0.45	0.00	3.35
ROA	%	0.05	0.06	2.24	0.15	-41.28	8.74	0.08	0.06	2.23	0.16	-38.41	12.49
Deposit flow, normalized													
Banks, by assets	%	0.15	0.06	2.12	0.04	-6.29	34.66	0.10	0.02	0.60	0.04	-2.22	9.68
Non-banks, by assets	%	0.30	0.02	0.58	0.23	-2.81	5.96	0.29	0.02	0.61	0.18	-1.32	8.11
Banks, by res. req.	%	113.58	149.57	5,465.08	2.42	-39,193.02	80,169.25	224.82	187.84	6,927.13	2.42	-8,057.08	103,577.58
Non-banks, by res. req.	%	9.07	8.45	308.56	18.78	-6,060.81	1,037.90	26.95	6.77	249.57	15.48	-2,547.89	3,462.38
Concentration													
HHI collateral class	%	63.73	0.62	22.60	60.68	20.70	100.00	66.13	0.56	20.59	64.09	21.46	100.00
HHI issuer group	%	79.61	0.53	19.25	83.08	30.02	100.00	82.46	0.46	16.94	86.20	32.05	100.00
Number of banks		Total:		1,335	Foreign:		11	Total:		1,360	Foreign:		12
		Private:		106	Head:		12	Private:		107	Head:		12
		Savings:		408	Private loan:		13	Savings:		416	Private loan:		13
		Cooperatives:		774	Special purpose:		11	Cooperatives:		789	Special purpose:		11

*not covering September 10 – November 11, 2008

Table 4

Averages by bank size groups: per sub-period and the full sample period.

Averages of normalized credit, collateral quality, financial health, normalized deposit flows, and concentration measures by bank size groups. The population is equally weighted averages across maintenance periods for each bank and sub-period (or the total sample period). Panel A covers the "Pre-Crisis", Panel B the "Early Crisis", Panel C the "Full Allotment", and Panel D the full period. We build five size groups according to the 25, 50, 75, and 99 percentiles by averaging each bank's total assets across all 56 maintenance periods: <25%, 25-50%, 50-75%, 75-99%, and >99%. A bank does therefore not change its size group from one sub-period to another. A bank in size group 25-50%, for instance, has average size larger than the 25^{th} and smaller than or equal to the 50^{th} percentile.

The logarithm of total book assets measures bank size. Credit is normalized either by total assets, taken from the end-of-month preceding each maintenance period, or by average daily reserve requirements in each maintenance period. Collateral quality measures are haircut, duration, probability of default, liquidity category, and the fraction of own-use collateral. Financial health is measured by equity ratio, write-offs & provisions, and ROA. Equity ratio is equity divided by total assets, both taken from the end-of-month preceding each maintenance period. Write-offs and provisions (ROA) are given as preceding year's write-offs and provisions (income) divided by total assets, where assets are taken from the beginning of the preceding year. Deposit flows are contemporaneous and normalized in the same manner as credit is normalized. Deposit flows are separated into flows of banks and flows of non-banks. Concentration measures are the Herfindahl-Indices for collateral classes and issuer groups. "n.a." indicates that data is not available.

		Panel A: Pre-Crisis January 1, 2006 – August 7, 2007					*Panel B: Early Crisis* August 8, 2007 – September 9, 2008				
		Size groups					**Size groups**				
	Units	<25%	25-50%	50-75%	75-99%	>99%	<25%	25-50%	50-75%	75-99%	>99%
ln(assets)	Ln(Eur)	18.67	19.84	20.68	22.15	26.01	18.77	19.88	20.73	22.21	26.11
Credit, normalized											
By assets	%	0.59	0.93	1.37	1.96	3.17	0.48	1.07	1.33	1.59	2.57
By res. req.	%	53.20	366.15	128.51	598.85	977.21	42.02	300.82	126.66	583.85	597.44
Collateral quality											
Haircut	%	2.12	2.14	2.13	2.38	2.58	2.57	2.64	2.45	2.96	3.44
Duration	year	2.08	2.17	2.24	2.99	4.48	2.23	2.37	2.20	2.99	5.01
Prob. of default	bps	6.97	7.95	7.05	5.61	3.59	3.48	3.77	3.05	2.61	3.31
Liquidity category	1-6	2.70	2.61	2.61	2.79	2.94	2.96	2.90	2.81	2.99	3.35
Own-use	%	n.a.	n.a.	0.09	0.40	5.49	n.a.	n.a.	0.12	0.46	5.83
Financial health											
Equity ratio	%	7.07	6.03	5.29	4.85	4.34	7.20	5.92	5.43	4.91	4.24
Write-offs & prov.	%	0.51	0.55	0.59	0.50	0.17	0.47	0.55	0.52	0.46	0.29
ROA	%	-0.04	0.24	0.20	0.22	0.13	-0.14	0.23	0.19	0.19	0.19
Deposit flow, normalized											
Banks, by assets	%	0.02	-0.02	0.03	0.05	0.24	0.07	0.19	0.20	0.16	0.40
Non-banks, by assets	%	0.23	0.10	0.09	0.25	0.09	0.23	0.22	0.59	0.30	0.37
Banks, by res. req.	%	-10.74	-135.80	321.03	500.27	110.36	5.07	16.38	-204.28	2335.96	532.08
Non-banks, by res. req.	%	116.12	5.54	-12.12	53.47	21.00	18.82	18.41	40.35	223.41	322.68
Concentration											
HHI collateral class	%	79.33	71.41	64.27	58.28	41.58	78.65	71.75	66.43	57.93	39.80
HHI issuer group	%	92.58	88.60	84.92	82.10	60.02	93.47	86.78	85.46	79.81	53.73
Number of banks		143	171	252	299	14	122	162	237	298	14

Table 4 – *continued*

		Panel C: Full Allotment					*Panel D: Full Period*				
		November 12, 2008 – November 9, 2010					January 1, 2006 – November 9, 2010*				
		Size groups					**Size groups**				
	Units	<25%	25-50%	50-75%	75-99%	>99%	<25%	25-50%	50-75%	75-99%	>99%
ln(assets)	Ln(Eur)	18.84	19.95	20.80	22.21	26.17	18.81	19.91	20.75	22.16	26.10
Credit, normalized											
By assets	%	2.42	2.82	2.69	2.50	1.61	2.03	2.33	2.14	2.11	2.36
By res. req.	%	204.68	262.60	526.43	646.17	423.06	171.49	275.66	474.89	537.97	649.33
Collateral quality											
Haircut	%	6.33	6.21	5.53	5.38	8.51	5.50	5.27	4.26	4.06	5.24
Duration	year	2.72	2.59	2.71	2.99	5.91	2.55	2.52	2.52	3.04	5.17
Prob. of default	bps	4.12	4.18	3.48	3.18	5.52	4.48	4.85	4.25	3.77	4.22
Liquidity category	1-6	3.43	3.44	3.27	3.26	3.91	3.31	3.27	3.05	3.07	3.42
Own-use	%	n.a.	n.a.	0.50	2.44	9.64	n.a.	n.a.	0.46	1.61	7.54
Financial health											
Equity ratio	%	6.45	5.72	5.34	4.78	4.58	6.47	5.82	5.31	4.94	4.42
Write-offs & prov.	%	0.42	0.47	0.48	0.44	0.49	0.44	0.49	0.51	0.46	0.33
ROA	%	0.01	0.01	0.15	0.01	-0.02	0.05	0.03	0.18	0.09	0.08
Deposit flow, normalized											
Banks, by assets	%	0.29	0.09	0.15	0.06	-0.12	0.10	0.09	0.13	0.09	0.11
Non-banks, by assets	%	0.29	0.33	0.35	0.24	0.04	0.28	0.29	0.32	0.26	0.13
Banks, by res. req.	%	39.12	-41.64	-281.44	761.10	-34.77	9.28	-35.89	-6.26	968.29	90.15
Non-banks, by res. req.	%	23.82	24.19	11.56	-22.19	-30.32	30.53	21.83	3.26	53.01	33.24
Concentration											
HHI collateral class	%	73.81	67.39	62.02	52.64	39.60	75.78	69.37	64.29	55.71	40.20
HHI issuer group	%	83.08	80.42	80.42	75.72	50.21	85.58	83.35	83.24	78.66	54.23
Number of banks		326	336	334	325	14	340	340	340	326	14

*not covering September 10 – November 11, 2008

Table 5

Tobit panel regressions of normalized credit on size, collateral quality, financial health, deposit flow, and concentration.

Panel A represents separate regressions carried out on the population of bank-maintenance period observations for the "Pre-Crisis", the "Early Crisis", the "Full Allotment", and the total period, respectively. Each regression includes bank sector and maintenance period fixed effects (not reported). Bank sectors are "private banks", "savings banks", "cooperatives", "foreign banks", "landesbanks", "cooperative central banks", "private loan banks", and "special purpose banks". We report tobit coefficients. In Panel B we decompose the tobit coefficients into the effects of a one unit change in the independent variable on (1) the change in *probability of* taking *credit*, "PoC", and (2) the unit change in normalized *credit conditional on* a bank taking *credit*, "CCoC". We calculate average marginal effects with observed values on the other independent variables.

The dependent variable is normalized credit (in percent; normalized by total assets taken from the end-of-month preceding each maintenance period). For variables subscripted by $m-1$ and $y-1$, values are taken from the end-of-month and the end-of-year preceding each maintenance period, respectively. Ln(assets) measures bank size. Haircut measures collateral quality. Financial health is measured by equity ratio, write-offs & provisions, and ROA. Deposit flows are contemporaneous, normalized in the same manner as credit is normalized, and separated into flows of banks and flows of non-banks. The Herfindahl index (HHI) for issuer group measures concentration of a bank's collateral pool. For the period labelled "Total," note that observations in the period September 10 to November 11, 2008, are dropped.

Underneath the coefficients in Panel A (marginal effects in Panel B) we report, in parentheses, t-statistics (z-statistics) with standard errors clustered on the banks. a, b, and c denote significance (two-tailed) at 1%, 5%, and 10% level with, first, standard errors clustered on the banks and, second, Huber-White corrected standard errors (in square brackets).

	Panel A: Tobit coefficients				***Panel B: Average marginal effects***				
	Pre-Crisis	***Early Crisis***	***Full Allot.***	***Total***	***Change***	***Pre-Crisis***	***Early Crisis***	***Full Allot.***	***Total***
	18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10		18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10
ln(assets)$_{m-1}$ [ln(Eur)]	$1.166^{a,[a]}$	$0.991^{a,[a]}$	$0.112^{\cdot,[a]}$	$0.486^{a,[a]}$	PoC	$0.055^{a,[a]}$	$0.052^{a,[a]}$	$0.008^{\cdot,[a]}$	$0.032^{a,[a]}$
	(4.01)	(4.85)	(1.05)	(3.94)		(5.14)	(5.07)	(1.05)	(4.14)
					CCoC	$0.328^{a,[a]}$	$0.278^{a,[a]}$	$0.050^{\cdot,[a]}$	$0.178^{a,[a]}$
						(4.14)	(4.84)	(1.05)	(3.98)
Haircut [%]	$0.524^{a,[a]}$	$0.285^{a,[a]}$	$0.162^{a,[a]}$	$0.261^{a,[a]}$	PoC	$0.025^{a,[a]}$	$0.015^{a,[a]}$	$0.012^{a,[a]}$	$0.017^{a,[a]}$
	(3.95)	(2.78)	(3.15)	(5.25)		(3.62)	(2.68)	(3.15)	(5.41)
					CCoC	$0.147^{a,[a]}$	$0.080^{a,[a]}$	$0.073^{a,[a]}$	$0.095^{a,[a]}$
						(3.98)	(2.77)	(3.15)	(5.29)
Equity ratio$_{m-1}$ [%]	$-0.622^{c,[a]}$	$-0.286^{\cdot,[a]}$	$-0.387^{a,[a]}$	$-0.410^{a,[a]}$	PoC	$-0.025^{b,[a]}$	$-0.012^{\cdot,[a]}$	$-0.024^{a,[a]}$	$-0.023^{a,[a]}$
	(-1.94)	(-1.46)	(-3.60)	(-2.99)		(-2.05)	(-1.30)	(-3.58)	(-2.93)
					CCoC	$-0.149^{c,[a]}$	$-0.062^{\cdot,[a]}$	$-0.147^{a,[a]}$	$-0.126^{a,[a]}$
						(-1.89)	(-1.28)	(-3.54)	(-2.85)
Equity ratio$^2_{m-1}$	$0.009^{b,[a]}$	$0.006^{b,[a]}$	$0.006^{a,[a]}$	$0.006^{a,[a]}$			Not applicable		
	(2.12)	(2.42)	(2.93)	(3.39)					
Write-offs & prov$_{y-1}$ [%]	$-1.211^{c,[b]}$	$-1.373^{b,[a]}$	$0.902^{a,[a]}$	$-0.201^{\cdot,[a]}$	PoC	$-0.057^{c,[b]}$	$-0.071^{b,[a]}$	$0.068^{a,[a]}$	$-0.013^{\cdot,[a]}$
	(-1.70)	(-2.42)	(2.61)	(-0.90)		(-1.78)	(-2.51)	(2.66)	(-0.91)
					CCoC	$-0.340^{c,[b]}$	$-0.384^{b,[a]}$	$0.405^{a,[a]}$	$-0.074^{\cdot,[a]}$
						(-1.71)	(-2.42)	(2.61)	(-0.90)
ROA$_{y-1}$ [%]	-0.013	0.029	-0.004	0.005	PoC	-0.001	0.002	-0.000	0.000
	(-0.08)	(0.28)	(-0.04)	(0.06)		(-0.08)	(0.28)	(-0.04)	(0.06)
					CCoC	-0.004	0.008	-0.002	0.002
						(-0.08)	(0.28)	(-0.04)	(0.06)

Table 5 – *continued*

	Panel A: Tobit Coefficients			
	Pre-Crisis	***Early Crisis***	***Full Allot.***	***Total***
	18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10
Deposit flow banks [%]	0.034	0.093	-0.012	-0.002
	(0.84)	(1.31)	(-1.05)	(-0.16)
Deposit flow non-banks [%]	-0.065	-0.115$^{b,[b]}$	0.017	-0.004
	(-1.28)	(-2.41)	(0.91)	(-0.28)
HHI issuer group [%]	-0.094$^{a,[a]}$	-0.055$^{a,[a]}$	-0.017$^{a,[a]}$	-0.040$^{a,[a]}$
	(-5.20)	(-4.52)	(-3.41)	(-6.14)
Constant	-17.646$^{a,[a]}$	-16.935$^{a,[a]}$	1.799$^{\cdot,[b]}$	-6.939$^{b,[a]}$
	(-2.91)	(-3.33)	(0.68)	(-2.31)
Sigma constant	6.791$^{a,[a]}$	6.143$^{a,[a]}$	4.545$^{a,[a]}$	5.300$^{a,[a]}$
	(9.20)	(14.62)	(27.62)	(18.89)
Banksector fixed effects	yes	yes	yes	yes
Maintenance period fixed effects	yes	yes	yes	yes
# of maintenance periods	19	13	24	56
# of observations	14,886	9,453	29,494	53,833
Pseudo R-squared	0.051	0.055	0.040	0.052

	Panel B: Average marginal effects				
	Change	***Pre-Crisis***	***Early Crisis***	***Full Allot.***	***Total***
		18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10
Deposit flow banks [%]	PoC	0.002	0.005	-0.001	-0.000
		(0.85)	(1.31)	(-1.06)	(-0.16)
	CCoC	0.009	0.026	-0.006	-0.001
		(0.84)	(1.31)	(-1.06)	(-0.16)
Deposit flow non-banks [%]	PoC	-0.003	-0.006$^{b,[b]}$	0.001	-0.000
		(-1.33)	(-2.45)	(0.91)	(-0.28)
	CCoC	-0.018	-0.032$^{b,[b]}$	0.008	-0.002
		(-1.28)	(-2.41)	(0.91)	(-0.28)
HHI issuer group [%]	PoC	-0.004$^{a,[a]}$	-0.003$^{a,[a]}$	-0.001$^{a,[a]}$	-0.003$^{a,[a]}$
		(-8.37)	(-5.16)	(-3.42)	(-7.06)
	CCoC	-0.027$^{a,[a]}$	-0.015$^{a,[a]}$	-0.008$^{a,[a]}$	-0.015$^{a,[a]}$
		(-5.34)	(-4.54)	(-3.42)	(-6.30)
Constant	Not applicable				
Sigma constant	Not applicable				
Banksector fixed effects, Maintenance period fixed effects, # of maintenance periods, # of observations	As in Panel A				
Pseudo R-squared	Not applicable				

Table 6

Decomposition of haircut – correlations between indicated variables and regressions of haircut on them.

The population is bank-maintenance period observations. Panel A shows correlations between indicated variables (haircut ingredients), which are duration, probability of default, and liquidity category of collateral. The correlations are shown for the "Pre-Crisis", the "Early Crisis", the "Full Allotment", and the total period. For the period labelled "Total," note that observations in the period September 10 to November 11, 2008, are dropped.

In Panel B, each column represents a separate panel regression of haircut (in percent) on indicated variables for the same sub-periods and the total period. Each regression includes maintenance period fixed effects. Standard errors are Huber-White corrected. t-statistics are in brackets underneath the coefficients. a, b, and c denote significance (two-tailed) at 1%, 5%, and 10% level, respectively.

Panel A: Correlations of indicated variables per sub period and the full period

		Duration	Prob. of default	Liquidity category	Duration	Prob. of default	Liquidity category
		Pre-Crisis			***Early Crisis***		
Duration	year	1			1		
Prob. of default	bps	-0.273	1		-0.058	1	
Liquidity category	1-6	-0.035	-0.175	1	0.026	0.512	1
		Full Allotment			***Total***		
Duration	year	1			1		
Prob. of default	bps	-0.072	1		-0.137	1	
Liquidity category	1-6	-0.045	0.527	1	-0.025	0.285	1

Panel B: Panel with maintenance period fixed effects of haircut on ingredients

		Pre-Crisis	***Early Crisis***	***Full Allotment***	***Total***
		18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10
Duration	year	0.293^a	0.228^a	0.256^a	0.264^a
		(48.21)	(15.72)	(21.72)	(34.96)
Prob. of default	bps	-0.003^a	0.052^a	0.151^a	0.034^a
		(-3.54)	(6.23)	(33.36)	(34.10)
Liquidity category	1-6	0.628^a	1.001^a	2.397^a	1.812^a
		(16.58)	(18.18)	(114.45)	(99.88)
Constant		-0.172^c	-0.964^a	-3.458^a	-2.155^a
		(-1.65)	(-6.21)	(-44.66)	(-34.79)
# of maintenance periods		19	13	24	56
# of observations		14,886	9,453	29,494	53,833
Adj. R-squared		0.320	0.236	0.673	0.696

Table 7

Tobit panel regressions of normalized credit on size, haircut decomposing collateral quality measures, financial health, deposit flow, and concentration.

Panel A represents separate regressions carried out on the population of bank-maintenance period observations for the "Pre-Crisis", the "Early Crisis", the "Full Allotment", and the total period, respectively. Each regression includes bank sector and maintenance period fixed effects (not reported). Bank sectors are "private banks", "savings banks", "cooperatives", "foreign banks", "landesbanks", "cooperative central banks", "private loan banks", and "special purpose banks". We report tobit coefficients. In Panel B we decompose the tobit coefficients into the effects of a one unit change in the independent variable on (1) the change in *probability of* taking *credit*, "PoC", and (2) the unit change in normalized *credit conditional on* a bank taking *credit*, "CCoC". We calculate average marginal effects with observed values on the other independent variables.

The dependent variable is normalized credit (in percent; normalized by total assets taken from the end-of-month preceding each maintenance period). For variables subscripted by $m-1$ and $y-1$, values are taken from the end-of-month and the end-of-year preceding each maintenance period, respectively. Ln(assets) measures bank size. Collateral quality is measured by the haircut composition measures (liquidity category, probability of default, and duration), the residual of an OLS regression of haircut on the haircut composition measures (per maintenance period), and the fraction of own-use collateral. Financial health is measured by equity ratio, write-offs & provisions, and ROA. Deposit flows are contemporaneous, normalized in the same manner as credit is normalized, and separated into flows of banks and flows of non-banks. The Herfindahl index (HHI) for issuer group measures concentration of a bank's collateral pool. For the period labelled "Total," note that observations in the period September 10 to November 11, 2008, are dropped.

Underneath the coefficients in Panel A (marginal effects in Panel B) we report, in parentheses, t-statistics (z-statistics) with standard errors clustered on the banks. a, b, and c denote significance (two-tailed) at 1%, 5%, and 10% level with, first, standard errors clustered on the banks and, second, Huber-White corrected standard errors (in square brackets).

	Panel A: Tobit coefficients				*Panel B: Average marginal effects*				
	Pre-Crisis	***Early Crisis***	***Full Allot.***	***Total***	***Change***	***Pre-Crisis***	***Early Crisis***	***Full Allot.***	***Total***
	18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10		18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10
$\ln(\text{assets})_{m-1}$ [ln(Eur)]	$0.934^{a,[a]}$	$0.869^{a,[a]}$	$0.100^{\cdot,[a]}$	$0.401^{a,[a]}$	PoC	$0.044^{a,[a]}$	$0.045^{a,[a]}$	$0.008^{\cdot,[a]}$	$0.026^{a,[a]}$
	(3.46)	(4.35)	(0.93)	(3.31)		(4.11)	(4.47)	(0.93)	(3.43)
					CCoC	$0.263^{a,[a]}$	$0.244^{a,[a]}$	$0.045^{\cdot,[a]}$	$0.148^{a,[a]}$
						(3.54)	(4.34)	(0.93)	(3.33)
Liquidity category [1-6]	$2.868^{a,[a]}$	$1.691^{a,[a]}$	$0.963^{a,[a]}$	$1.840^{a,[a]}$	PoC	$0.136^{a,[a]}$	$0.088^{a,[a]}$	$0.072^{a,[a]}$	$0.121^{a,[a]}$
	(5.20)	(4.63)	(4.10)	(7.48)		(6.40)	(5.14)	(4.12)	(8.81)
					CCoC	$0.809^{a,[a]}$	$0.476^{a,[a]}$	$0.435^{a,[a]}$	$0.677^{a,[a]}$
						(5.30)	(4.59)	(4.10)	(7.65)
Prob. of default [bps]	$0.069^{a,[a]}$	$0.229^{a,[a]}$	$0.145^{b,[a]}$	$0.025^{\cdot,[a]}$	PoC	$0.003^{a,[a]}$	$0.012^{a,[a]}$	$0.011^{b,[a]}$	$0.002^{\cdot,[a]}$
	(2.66)	(3.45)	(2.24)	(1.37)		(2.89)	(3.56)	(2.27)	(1.37)
					CCoC	$0.020^{a,[a]}$	$0.064^{a,[a]}$	$0.065^{b,[a]}$	$0.009^{\cdot,[a]}$
						(2.68)	(3.43)	(2.24)	(1.37)
Duration [year]	$0.531^{a,[a]}$	$0.218^{\cdot,[a]}$	$-0.212^{a,[a]}$	-0.001	PoC	$0.025^{a,[a]}$	$0.011^{\cdot,[a]}$	$-0.016^{a,[a]}$	-0.000
	(3.89)	(1.60)	(-3.73)	(-0.01)		(4.61)	(1.61)	(-3.78)	(-0.01)
					CCoC	$0.150^{a,[a]}$	$0.061^{\cdot,[a]}$	$-0.096^{a,[a]}$	-0.000
						(3.98)	(1.60)	(-3.73)	(-0.01)
OLS resid. (per cross-sect.)	$-0.149^{\cdot,[b]}$	$-0.154^{\cdot,[a]}$	$-0.155^{c,[a]}$	$-0.183^{b,[a]}$	PoC	$-0.007^{\cdot,[a]}$	$-0.008^{\cdot,[a]}$	$-0.012^{c,[a]}$	$-0.012^{b,[a]}$
	(-0.86)	(-1.16)	(-1.84)	(-2.13)		(-0.91)	(-1.19)	(-1.86)	(-2.22)
					CCoC	$-0.042^{\cdot,[b]}$	$-0.043^{\cdot,[a]}$	$-0.070^{c,[a]}$	$-0.067^{b,[a]}$
						(-0.86)	(-1.16)	(-1.84)	(-2.15)
Own use [%]	-0.011	-0.009	$0.049^{c,[a]}$	$0.018^{\cdot,[a]}$	PoC	-0.001	-0.000	$0.004^{c,[a]}$	$0.001^{\cdot,[a]}$
	(-0.34)	(-0.39)	(1.87)	(0.67)		(-0.34)	(-0.39)	(1.86)	(0.67)
					CCoC	-0.003	-0.003	$0.022^{c,[a]}$	$0.007^{\cdot,[a]}$
						(-0.34)	(-0.39)	(1.87)	(0.67)

Table 7 – *continued*

	Panel A: Tobit coefficients				Panel B: Average marginal effects				
	Pre-Crisis	***Early Crisis***	***Full Allot.***	***Total***	***Change***	***Pre-Crisis***	***Early Crisis***	***Full Allot.***	***Total***
	18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10		18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10
Equity ratio$_{m-1}$ [%]	-0.598$^{c,[a]}$	-0.214$^{\cdot,[a]}$	-0.413$^{a,[a]}$	-0.412$^{a,[a]}$	PoC	-0.024$^{c,[a]}$	-0.008$^{\cdot,[a]}$	-0.026$^{a,[a]}$	-0.023$^{a,[a]}$
	(-1.77)	(-1.04)	(-3.84)	(-2.81)		(-1.81)	(-0.87)	(-3.78)	(-2.69)
					CCoC	-0.142$^{c,[a]}$	-0.045$^{\cdot,[a]}$	-0.157$^{a,[a]}$	-0.126$^{a,[a]}$
						(-1.70)	(-0.87)	(-3.74)	(-2.63)
Equity ratio$^2_{m-1}$	0.009$^{b,[a]}$	0.005$^{b,[a]}$	0.006$^{a,[a]}$	0.007$^{a,[a]}$			Not applicable		
	(2.12)	(2.07)	(3.16)	(3.49)					
Write-offs & prov$_{y-1}$ [%]	-0.922$^{\cdot,[c]}$	-1.268$^{b,[a]}$	0.815$^{a,[a]}$	-0.161$^{\cdot,[b]}$	PoC	-0.044$^{\cdot,[c]}$	-0.066$^{b,[a]}$	0.061$^{a,[a]}$	-0.011$^{\cdot,[b]}$
	(-1.34)	(-2.37)	(2.58)	(-0.77)		(-1.38)	(-2.44)	(2.63)	(-0.78)
					CCoC	-0.260$^{\cdot,[c]}$	-0.357$^{b,[a]}$	0.368$^{a,[a]}$	-0.059$^{\cdot,[b]}$
						(-1.34)	(-2.37)	(2.59)	(-0.78)
ROA$_{y-1}$ [%]	0.034	0.057	-0.003	0.009	PoC	0.002	0.003	-0.000	0.001$^{a,[\cdot]}$
	(0.19)	(0.43)	(-0.03)	(0.10)		(0.19)	(0.43)	(-0.03)	(0.10)
					CCoC	0.010	0.016	-0.002	0.003
						(0.19)	(0.43)	(-0.03)	(0.10)
Deposit flow banks [%]	0.045	0.085	-0.006	-0.005	PoC	0.002	0.004	-0.000	-0.000
	(1.18)	(1.27)	(-0.57)	(-0.31)		(1.19)	(1.26)	(-0.57)	(-0.31)
					CCoC	0.013	0.024	-0.003	-0.002
						(1.18)	(1.27)	(-0.57)	(-0.31)
Deposit flow non-banks [%]	-0.068	-0.111$^{b,[b]}$	0.016	-0.001	PoC	-0.003	-0.006$^{b,[b]}$	0.001	-0.000
	(-1.45)	(-2.23)	(0.94)	(-0.06)		(-1.52)	(-2.26)	(0.94)	(-0.06)
					CCoC	-0.019	-0.031$^{b,[b]}$	0.007	-0.000
						(-1.45)	(-2.24)	(0.94)	(-0.06)
HHI issuer group [%]	-0.104$^{a,[a]}$	-0.060$^{a,[a]}$	-0.031$^{a,[a]}$	-0.056$^{a,[a]}$	PoC	-0.005$^{a,[a]}$	-0.003$^{a,[a]}$	-0.002$^{a,[a]}$	-0.004$^{\cdot,[a]}$
	(-5.54)	(-4.77)	(-5.61)	(-7.70)		(-8.82)	(-5.45)	(-5.70)	(-9.51)
					CCoC	-0.029$^{a,[a]}$	-0.017$^{a,[a]}$	-0.014$^{a,[a]}$	-0.021$^{a,[a]}$
						(-5.69)	(-4.79)	(-5.64)	(-7.98)
Constant	-20.482$^{a,[a]}$	-19.745$^{a,[a]}$	0.579	-8.309$^{a,[a]}$			Not applicable		
	(-3.41)	(-4.01)	(0.21)	(-2.82)					
Sigma constant	6.601$^{a,[a]}$	5.965$^{a,[a]}$	4.469$^{a,[a]}$	5.220$^{a,[a]}$			Not applicable		
	(9.39)	(15.41)	(28.12)	(19.29)					
Banksector fixed effects	yes	yes	yes	yes			As in Panel A		
Maintenance period fixed effects	yes	yes	yes	yes					
# of maintenance periods	19	13	24	56					
# of observations	14,886	9,453	29,494	53,833					
Pseudo R-squared	0.063	0.067	0.047	0.058			Not applicable		

Table 8

Heckman selection regressions of collateral quality measures on size and financial health.

In each Panel the four columns represent separate regressions carried out on the population of bank-maintenance period observations for the "Pre-Crisis", the "Early Crisis", the "Full Allotment", and the total period, respectively. The selection equation controls for banks having positive liquidity uptake. The dependent variables in the main regressions are the haircut (Panel A, in percent) and its components (Panel B: probability of default, in bps; Panel C: liquidity category, 1 – 6; Panel D: duration, in years). For variables subscripted by $m-1$ and $y-1$, values are taken from the end-of-month and the end-of-year preceding each maintenance period, respectively. Subscript $j-1$ refers to the previous maintenance period. Ln(assets) measures bank size. Financial health is measured by equity ratio, write-offs & provisions, and ROA. All regressions (main and selection) include bank sector (private banks, savings banks, cooperatives, foreign banks, landesbanks, cooperative central banks, private loan banks, special purpose banks) and maintenance period fixed effects (not reported). z-statistics, based on bank-clustered standard errors, are in parentheses underneath the coefficients. a, b, and c denote significance (two-tailed) at 1%, 5%, and 10% levels. Significance levels based on Huber-White corrected standard errors are in square brackets. For the period labelled "Total," observations in the period September 10 to November 11, 2008, are dropped.

		Panel A: Haircut				***Panel B: Probability of default***			
		Pre-Crisis	***Early Crisis***	***Full Allot.***	***Total***	***Pre-Crisis***	***Early Crisis***	***Full Allot.***	***Total***
		18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10	18.01.06-07.08.07	08.08.07-09.09.08	12.11.08-09.11.10	18.01.06-09.11.10
Main equation									
ln(assets)$_{m-1}$	ln(Eur)	0.008	0.107$^{\cdot,[a]}$	-0.184$^{b,[a]}$	-0.098$^{\cdot,[a]}$	-0.487$^{b,[a]}$	-0.231$^{a,[a]}$	-0.311$^{a,[a]}$	-0.328$^{a,[a]}$
		(0.12)	(0.95)	(-2.28)	(-1.37)	(-2.31)	(-3.10)	(-5.27)	(-5.27)
Equity ratio$_{m-1}$	%	-0.033$^{b,[a]}$	-0.019$^{\cdot,[a]}$	-0.038$^{\cdot,[a]}$	-0.035$^{\cdot,[a]}$	-0.118$^{b,[a]}$	-0.054$^{a,[a]}$	0.004	-0.038$^{\cdot,[a]}$
		(-2.56)	(-0.96)	(-0.98)	(-1.56)	(-2.28)	(-2.87)	(0.11)	(-1.19)
Write-offs & prov$_{y-1}$	%	0.313$^{c,[a]}$	0.184	0.220$^{\cdot,[a]}$	0.188$^{\cdot,[a]}$	-0.072	0.059	0.451$^{b,[a]}$	0.514$^{a,[a]}$
		(1.66)	(0.51)	(1.55)	(1.48)	(-0.10)	(0.21)	(2.45)	(2.76)
ROA$_{y-1}$	%	-0.030	-0.031$^{\cdot,[b]}$	0.049$^{\cdot,[c]}$	0.038$^{\cdot,[c]}$	0.057	0.088$^{a,[a]}$	0.098$^{\cdot,[a]}$	0.066$^{\cdot,[b]}$
		(-0.18)	(-0.96)	(1.03)	(1.14)	(0.12)	(3.55)	(1.58)	(1.12)
Constant		3.189$^{b,[a]}$	1.005	7.023$^{a,[a]}$	4.939$^{a,[a]}$	17.749$^{a,[a]}$	9.681$^{a,[a]}$	10.878$^{a,[a]}$	14.581$^{a,[a]}$
		(2.04)	(0.44)	(4.45)	(3.55)	(3.65)	(5.62)	(7.65)	(9.75)
Selection equation: bank has positive liquidity uptake in maintenance period j									
Positive liquidity uptake$_{j-1}$		2.829$^{a,[a]}$	2.378$^{a,[a]}$	2.988$^{a,[a]}$	2.824$^{a,[a]}$	2.829$^{a,[a]}$	2.378$^{a,[a]}$	2.990$^{a,[a]}$	2.825$^{a,[a]}$
		(47.79)	(42.20)	(68.37)	(81.79)	(47.77)	(42.22)	(68.40)	(81.75)
ln(assets)$_{m-1}$	ln(Eur)	0.125$^{a,[a]}$	0.133$^{a,[a]}$	0.037$^{b,[a]}$	0.077$^{a,[a]}$	0.125$^{a,[a]}$	0.134$^{a,[a]}$	0.037$^{b,[a]}$	0.076$^{a,[a]}$
		(7.09)	(7.39)	(2.54)	(6.77)	(7.10)	(7.42)	(2.55)	(6.73)
Equity ratio$_{m-1}$	%	-0.004	0.001	-0.008	-0.004	-0.004	0.001	-0.007	-0.004
		(-0.52)	(0.21)	(-1.16)	(-0.74)	(-0.52)	(0.21)	(-1.05)	(-0.77)
Write-offs & prov$_{y-1}$	%	-0.115$^{b,[a]}$	-0.128$^{b,[b]}$	0.019	-0.056$^{b,[a]}$	-0.114$^{b,[a]}$	-0.128$^{b,[b]}$	0.019	-0.055$^{b,[a]}$
		(-2.48)	(-2.42)	(0.48)	(-2.09)	(-2.48)	(-2.42)	(0.48)	(-2.07)
ROA$_{y-1}$	%	-0.003	-0.010	-0.014	-0.009	-0.003	-0.010	-0.013	-0.008
		(-0.26)	(-1.00)	(-1.10)	(-1.12)	(-0.25)	(-1.02)	(-1.10)	(-1.09)
Constant		-4.907$^{a,[a]}$	-4.008$^{a,[a]}$	-2.083$^{a,[a]}$	-3.881$^{a,[a]}$	-4.905$^{a,[a]}$	-4.003$^{a,[a]}$	-2.086$^{a,[a]}$	-3.862$^{a,[a]}$
		(-11.90)	(-9.92)	(-6.10)	(-14.24)	(-11.93)	(-9.96)	(-6.17)	(-14.25)
atanh ρ		-0.064$^{a,[a]}$	-0.066$^{c,[b]}$	-0.031	-0.055$^{a,[a]}$	0.016	-0.117$^{a,[a]}$	-0.088$^{a,[a]}$	-0.022$^{\cdot,[c]}$
		(-2.70)	(-1.92)	(-0.98)	(-2.79)	(0.43)	(-3.24)	(-3.74)	(-1.29)
ln(σ)		0.348$^{a,[a]}$	0.806$^{a,[a]}$	0.700$^{a,[a]}$	0.681$^{a,[a]}$	1.768$^{a,[a]}$	0.606$^{a,[a]}$	0.723$^{a,[a]}$	1.144$^{a,[a]}$
		(3.27)	(7.01)	(14.50)	(12.30)	(18.25)	(14.04)	(22.19)	(17.33)
# maintenance periods		18	13	23	54	18	13	23	54
# of observations		14,038	9,453	28,393	51,884	14,038	9,453	28,393	51,884
λ		-0.091	-0.148	-0.062	-0.108	0.091	-0.214	-0.180	-0.070
σ		1.417	2.239	2.013	1.975	5.861	1.832	2.060	3.139
ρ		-0.064	-0.066	-0.031	-0.055	0.016	-0.117	-0.087	-0.022

Table 8 – *continued*

		Panel C: Liquidity category				***Panel D: Duration***			
		Pre-Crisis	***Early Crisis***	***Full Allot.***	***Total***	***Pre-Crisis***	***Early Crisis***	***Full Allot.***	***Total***
Main equation									
ln(assets)$_{m-1}$	ln(Eur)	0.001	$0.020^{\cdot,[b]}$	$-0.033^{c,[a]}$	$-0.019^{\cdot,[a]}$	$0.222^{c,[a]}$	$0.301^{b,[a]}$	$0.160^{a,[a]}$	$0.191^{a,[a]}$
		(0.05)	(0.69)	(-1.94)	(-1.20)	(1.95)	(2.23)	(2.67)	(2.99)
Equity ratio$_{m-1}$	%	$-0.032^{a,[a]}$	$-0.021^{c,[a]}$	$-0.010^{\cdot,[a]}$	$-0.019^{\cdot,[a]}$	$-0.021^{\cdot,[a]}$	$-0.031^{c,[a]}$	$-0.012^{\cdot,[c]}$	$-0.021^{\cdot,[a]}$
		(-5.13)	(-1.91)	(-0.69)	(-1.53)	(-1.03)	(-1.77)	(-0.63)	(-1.31)
Write-offs & prov$_{y-1}$	%	$-0.047^{\cdot,[c]}$	0.017	$0.035^{\cdot,[a]}$	0.007	0.046	$-0.283^{\cdot,[b]}$	$0.074^{\cdot,[c]}$	-0.007
		(-0.62)	(0.19)	(0.85)	(0.20)	(0.14)	(-0.83)	(0.49)	(-0.05)
ROA$_{y-1}$	%	$-0.087^{c,[a]}$	0.002	0.005	0.001	$-0.363^{b,[a]}$	$-0.114^{b,[a]}$	$-0.029^{\cdot,[a]}$	$-0.049^{b,[a]}$
		(-1.75)	(0.10)	(0.30)	(0.05)	(-2.28)	(-2.14)	(-1.17)	(-2.24)
Constant		$3.030^{a,[a]}$	$2.508^{a,[a]}$	$4.037^{a,[a]}$	$3.209^{a,[a]}$	-0.587	$-1.632^{\cdot,[c]}$	-0.115	0.016
		(4.72)	(3.82)	(10.77)	(9.25)	(-0.22)	(-0.54)	(-0.10)	(0.01)
Selection equation: bank has positive liquidity uptake in maintenance period j									
Positive liquidity uptake$_{j-1}$		$2.829^{a,[a]}$	$2.378^{a,[a]}$	$2.988^{a,[a]}$	$2.824^{a,[a]}$	$2.829^{a,[a]}$	$2.378^{a,[a]}$	$2.989^{a,[a]}$	$2.824^{a,[a]}$
		(47.76)	(42.20)	(68.35)	(81.80)	(47.81)	(42.16)	(68.43)	(81.77)
ln(assets)$_{m-1}$	ln(Eur)	$0.126^{a,[a]}$	$0.133^{a,[a]}$	$0.038^{a,[a]}$	$0.077^{a,[a]}$	$0.123^{a,[a]}$	$0.133^{a,[a]}$	$0.037^{b,[a]}$	$0.076^{a,[a]}$
		(7.12)	(7.42)	(2.58)	(6.84)	(7.05)	(7.36)	(2.50)	(6.73)
Equity ratio$_{m-1}$	%	-0.004	0.001	-0.008	-0.004	-0.004	0.001	-0.008	-0.004
		(-0.51)	(0.26)	(-1.11)	(-0.69)	(-0.53)	(0.24)	(-1.15)	(-0.77)
Write-offs & prov$_{y-1}$	%	$-0.112^{b,[a]}$	$-0.127^{b,[b]}$	0.017	$-0.056^{b,[a]}$	$-0.115^{b,[a]}$	$-0.129^{b,[b]}$	0.019	$-0.055^{b,[a]}$
		(-2.45)	(-2.40)	(0.44)	(-2.07)	(-2.48)	(-2.44)	(0.48)	(-2.08)
ROA$_{y-1}$	%	-0.003	-0.010	-0.013	-0.009	-0.003	-0.010	-0.013	-0.009
		(-0.29)	(-0.97)	(-1.06)	(-1.08)	(-0.23)	(-0.95)	(-1.04)	(-1.08)
Constant		$-4.925^{a,[a]}$	$-3.996^{a,[a]}$	$-2.095^{a,[a]}$	$-3.888^{a,[a]}$	$-4.873^{a,[a]}$	$-3.995^{a,[a]}$	$-2.065^{a,[a]}$	$-3.858^{a,[a]}$
		(-11.95)	(-9.97)	(-6.16)	(-14.34)	(-11.90)	(-9.91)	(-6.09)	(-14.25)
atanh ρ		$-0.110^{a,[a]}$	$-0.104^{b,[a]}$	$-0.072^{b,[a]}$	$-0.104^{a,[a]}$	$-0.066^{b,[a]}$	$-0.072^{b,[a]}$	$0.058^{c,[b]}$	$-0.029^{\cdot,[b]}$
		(-3.00)	(-2.57)	(-2.26)	(-4.45)	(-2.31)	(-2.11)	(1.79)	(-1.53)
ln(σ)		$-0.678^{a,[a]}$	$-0.479^{a,[a]}$	$-0.635^{a,[a]}$	$-0.613^{a,[a]}$	$0.634^{a,[a]}$	$0.744^{a,[a]}$	$0.377^{a,[a]}$	$0.498^{a,[a]}$
		(-16.29)	(-9.26)	(-25.50)	(-24.89)	(5.74)	(5.72)	(9.20)	(8.50)
# maintenance periods		18	13	23	54	18	13	23	54
# of observations		14,038	9,453	28,393	51,884	14,038	9,453	28,393	51,884
λ		-0.056	-0.064	-0.038	-0.056	-0.124	-0.151	0.085	-0.047
σ		0.508	0.619	0.530	0.542	1.885	2.104	1.458	1.645
ρ		-0.110	-0.104	-0.072	-0.104	-0.066	-0.072	0.058	-0.029